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Research Paper

Regional Survey for Fresh Water Aquifer Determination Zones in Parts of the Niger Delta Region of Nigeria using Vertical Electrical Sounding Techniques

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ABSTRACT:*This regional survey describes the resistivity measurements made in some selected Communities in parts of the Niger Delta area comprising mainly Rivers, Delta and Bayelsa States. The purpose of the survey is to evaluate the effectiveness of the method in locating portable groundwater aquifer as well as in delineating the entire area into different groundwater potential zones. The sounding results is based on DC method using the Vertical Electrical Sounding in 69 locations. The field data acquisition was carried out using the Abem terrameter. The data reduction, filtering and analysis were achieved using field computers and Schlumberger Automatic Inversion Program (SLINV) to produce the equivalent layering model and n-layers model of each sounding location. The model was used to construct the subsurface resistivity and to map out the zones of fresh water potentials using the Iso-paach and Iso-resistivity techniques. The geoelectric section represents the hydro stratigraphy and lithostratigraphy of the entire study area. The interpretations of the data revealed fresh water aquifer in most of the explored locations which is recharged from the water circulated from the Delta. The results of the interpretation reveal mainly six distinct geoelectric layers. On the basis of the resistivity data, it is possible to map out zones of groundwater potential. This was basically found to consist of fine grained – medium – coarse sands with high resistivity values (> 100Ωm) enough for prolific aquifer yield. The unaccepted low resistivity values experience in some parts of the areas is as a result of high iron content and manganese contamination prevalent in the area according to local geologic information.*
KEYWORDS: *Aquifer, Vertical Electrical Sounding, groundwater potential, Resistivity, Geoelectric*

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I. INTRODUCTION

Over ninety percent of fresh water available, at any given moment on the earth lies beneath the land surface as underground water[1]. In the Niger Delta area, quite a lot of work have been done on groundwater studies by some researchers[2-5]. Indeed, groundwater resources, although replenishable, is not inexhaustible. The increasing demand placed on it has stimulated this investigation oriented towards quantification of the resources which is basic to formulation of plans for its exploitation, management and conservation. However, subsurface structural conditions and the various controls which determine the presence and movement of water within geologic formation, is the key to the understanding of groundwater as a natural resource[6]. The source of subsurface water is rain and snow that fall to the ground. The infiltration continues until a zone of saturation is attained.

However, formations or strata within the saturated zone from which ground water can be obtained for beneficial use are called aquifers[7]. The aquifer therefore stores and transmits water to wells or springs as a practical sources of water supply. Aquifers are highly saturated since they contain pores or open spaces, which are filled with water and these openings, must be large enough to permit water to move through them. Water in the zone of saturation is the only part of all subsurface water which is properly referred to as groundwater. The saturated zone may be viewed as a huge natural reservoir or system of reservoirs, whose capacity is the total volume of the pores or openings in the rocks that are filled with water[8]. Different kinds of aquifer systems exist within the subsurface of the Niger Delta Region, with some containing mineralized water, saline water and fresh water[9-11].

In this work, the earth resistively method is employed to explore and map the aquiferous zones in parts of the Niger Delta Region of Nigeria. Sixty-nine (69) vertical electrical soundings were conducted in parts Bayelsa and Delta States. The method involves the direct introduction of low frequency alternating current by means of two electrodes connected to the terminals of a portable source of electromotive force. This method provides indirect evidence of subsurface formation that indicates whether the formation may possibly be aquifer [12]. The method does not directly measure types of rocks, porosity, permeability or density of any formation but it measures some other properties of the material that vary with the factors which determine whether a formation may be sufficiently porous and permeable to serve as an aquifer[13]. The interpretation of the VES points were carried out with the appropriate chanting software. Measurements of electrical resistivity show values that vary with certain aquifer characteristics. For instance, clean sand saturated with fresh water show relatively high resistivity whereas dirty sand containing clay show low resistivity[14]. It is then known that dirty sand has low permeability than clean sand. This implies that various types of earth materials generally exhibit characteristic values of resistivity. Strata of differing materials can be identified, that is, high resistive sands, gravel and sand stones may be differentiated from low resistive materials such as clay and shale[15].

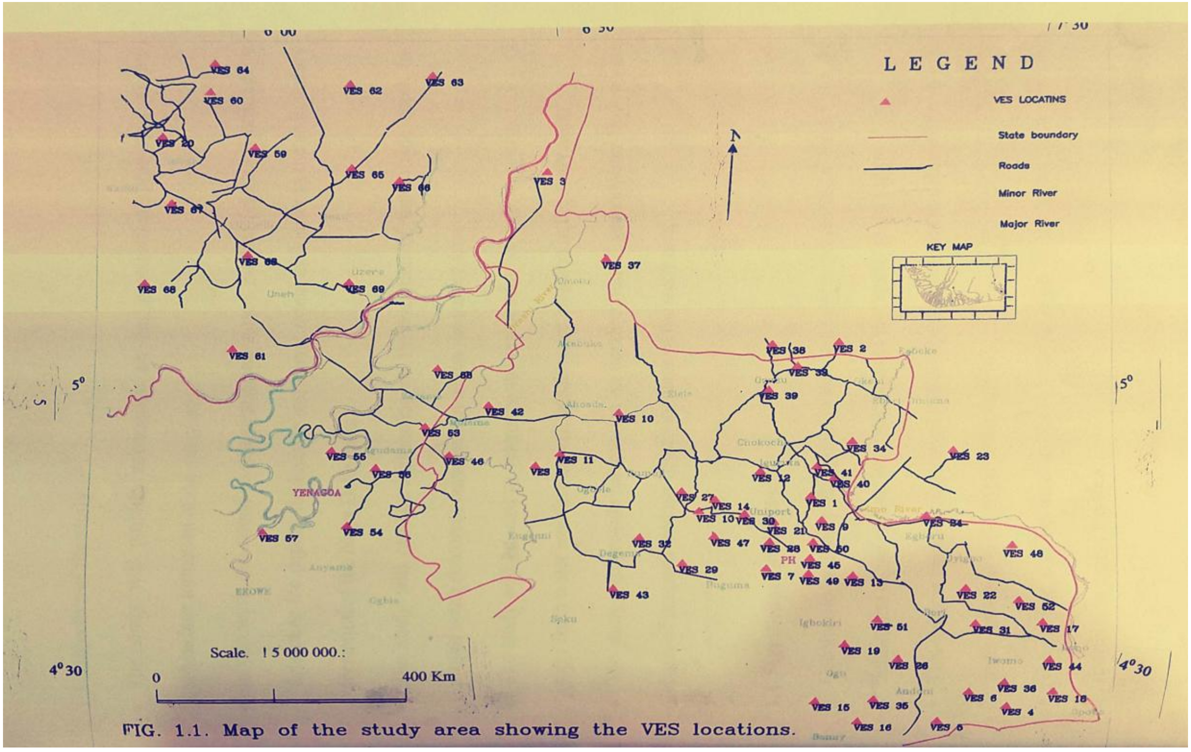

Figure 1: Map of Study Area Showing VES Locations

II. SITE DESCRIPTION AND LOCAL GEOLOGY

The study area covers parts of Bayelsa States and the southwest corner of Delta State. The area is enclosed by latitudes 5^o and 4^o 15' and longitudes 5^{o}30' and 7^{o}30'. It consists of a broad riverine area through which the River Niger enters the Atlantic Ocean dividing into numerous rivulets, which fan out into the sea. It also includes a number of tidal creeks separating Small Islands. Basically, the area consists of medium coarse to coarse unconsolidated sands with groundwater at the water table atmospheric pressure. The top sediments are aerated unconsolidated and highly variable thickness throughout the area[16, 17]. The subsurface geology of the Niger Delta consists of three lithostratigraphic units (Benin, Agbada and Akata Formations) which are in turn overlain by quaternary sediments. The Benin formation is about 2100m thick and is made up of over 90% massive, porous and coarse sands[18].

The high permeability of Benin formation, the overlying lateritic red sand and weathered top of the formation provide the hydrologic condition favoring aquifer formation in the area[19]. Groundwater potentials are very high due to the high permeability, high recharge potential and considerable aquifer thickness. The water in most of the area has high iron content and water table varying between 1.0m to 15.0m inland[17, 20].

Generally, the sediments in the Niger Delta range in age from Paleocene to recent. Due to the more prolific character of Benin formation, their aquifers are expected to discharge more copiously than the Deltaic sediments[21]. Moreover, with little run-off and other loses, much of the water will go into storage.

Nevertheless, the aquifers at shallow depths (10m) are unconfined while the deeper aquifers are confined and isolated from the ground surface. The water expected from the shallow layers are generally of low PH value (acidic) and high carbon dioxide. These waters are highly corrosive and soft. Besides, these waters contain high dissolved iron and needs treatment. The upper unconfined aquifer depths vary from 15m to nearly 100m[22]. The middle semi- confined aquifer consists of medium to coarse grained sands with clay lenses and fine clayey sands. This section ranges between 100m to 200m[23]. The confined aquifer extends from 200m to 300m depths and consists of coarse-grained sands and grained with some clay intercalates[24]. Generally fresh water is expected from this aquifer.

The islands are lined with sandy ridges. There are good network of roads and tracks crisscrossing the study area accessible, (Figure 1) Most of the sounding points were carried out at roads adjoining the Towns and Communities.

III. CLIMATE AND VEGETATION OF THE STUDY AREA

The climate of the study area is tropical and dominated by two main seasons: the dry and rainy seasons. Average mean annual rainfall is over 2400 mm and according to hydro-geological studies over 40% of this infiltrate and recharge groundwater [25]. The soil profile is remarkably uniform throughout the area. Approximately, the whole areas consist of deeply weathered and intensely leached soil. The heavy rainfall coupled with the drainage nature of the sub soil is conducive for the high infiltration of rainwater.

The proximity of Nigeria to the equator is responsible for the general high temperature. A mean annual temperature of 27^oC is recorded in part of the Niger Delta Region. Minimum 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 80% to 100% at dawn and 70 to 80% in early afternoon at maximum temperature[26].

The vegetation cover is thick mangrove in a very swampy environment implying significant evapo-transpiration effect. Run–off is limited following the thick vegetation; hence ground water recharge and storage is plentiful in this area. However, the water table is deep (>3m), hence chances of groundwater ex-filtration and evaporation is low. Generally speaking, the topography of the Benin formation is flat lying with the greatest height not exceeding 180m above sea level. The ground level however, slopes gently towards the Niger River flood plains, being directed mainly by the River systems. The vegetation is typically tropical rain forest.

IV. MATERIALS AND METHOD

4.1 Materials

The survey equipment for resistivity measurement is quite simple comprising an Abem Terrameter SAS 300/log SAS 200, a – 12 V battery, four stainless steel electrodes, and calibrated tapes, four reels of high resistance cable, clips and hammers. This equipment is rugged and built to adapt to any field work manipulation. They are equally portable, accessible and can be moved about with ease. The resistivity meter, Abem SAS 300/log SAS 200B can be used for both surface (VES) and down-hole log. It is powered by a 12V rechargeable battery which supplies the external power source by means of a cable in – built in the instrument. This transmits the power source to the ground through the electrode by means of the reels of cables spread to a distance varying between 700m to 1000m.

4.2 Methodology

The vertical electrical sounding (VES) survey using Schlumberger configuration was conducted at sixty-nine (69) sites distributed along different traverse locations (see figure 1) of the study area. With the Schlumberger array, the potential (MN) electrodes separation is kept constant while the current electrodes AB/2 (as used in this project) spacing is increased in steps. A maximum current electrode separation AB/2 of 700m – 1000m was marked out in this work. In each measurement, the digital averaging instrument (Abem SAS 300) displays the apparent resistivity directly. The readings are made possible as the four electrodes driven into the ground are connected to potential and current measuring terminals of the meter through the reels of cables. This procedure is repeated for each location along the marked profile as the depth of penetration of current into the ground (1/3 – 1/5) is increased with increase in the electrode separation. The electrode spread is observed to range from $3MN << L$ to $5MN << L$.

The value of the resistance (Ω) corresponding to the electrodes separation at each sounding points was recorded in the field data sheet. With these results, the apparent resistivity was calculated using the geometric factor for Schlumberger array. A 1-D inversion program was used for the final data interpretations. The detailed Sounding locations, no of layers, layer resistivities, layer thicknesses as well as elevation from surface is summarized in Table 1. Isopach and iso resistivity maps were constructed to properly define zones of freshwater potentials in the study area.

Table 1: Summary of resistivity measures in the study area

VES No.	No. of Layers	Resisitivity of Layers (Ω-m)							Thickness of Layers (m)						Elevation of Layers from Surface						
		ρ_1	ρ_2	ρ_3	ρ_4	ρ_5	ρ_6	ρ_7	t_1	t_2	t_3	t_4	t_5	t_5	h_1	h_2	h_3	h_4	h_5	h_6	h_7
1	5	329.0	560.0	4540.0	950.0	60.4	-	-	0.8	3.5	11.6	98.9	-	-	0.0	-0.8	-4.3	-15.9	-114.8	-	-
2	5	627.0	6340.0	1970.0	2240.0	1050.0	-	-	0.8	3.5	11.6	98.9	-	-	0.0	-0.8	-10.8	-74.9	-181.2	-	-
3	4	149.0	21.6	830.0	542.0	-	-	-	1.9	10.7	74.6	-	-	-	0.0	-1.9	-12.6	-87.2	-	-	-
4	6	122.0	1670.0	111.0	19.6	110.0	1460.0	-	0.6	3.1	12.3	59.6	101.0	-	0.0	-0.6	-3.7	-16.0	-75.6	-126.6	-
5	5	1970.0	2.8	270.0	458.0	74.1	-	-	5.0	15.0	39.3	102.0	-	-	0.0	-5.0	-20.0	-59.1	-161.3	-	-
6	6	251.0	19.0	54.8	21.8	10.2	8.8	-	8.5	26.2	51.1	78.0	121.0	-	0.0	-8.5	-34.7	-85.9	-163.3	284.5	-
7	6	95.0	23.5	51.3	117.0	405.0	152.0	-	1.0	2.6	6.0	40.3	178.0	-	0.0	-1.0	-3.6	-9.6	-49.9	227.9	-
8	6	747.0	2630.0	1140.0	339.0	640.0	-	-	0.5	16.5	65.6	148.0	-	-	0.0	-0.5	-17.0	-82.6	-220.6	-	-
9	6	820.0	3300.0	2510.0	177.0	397.0	-	-	0.3	22.4	77.6	158.0	-	-	0.0	-0.3	-22.7	-100.3	-258.3	-	-
10	5	1560.0	910.0	2900.0	615.0	3270.0	-	-	4.8	22.3	84.2	219.0	-	-	0.0	-4.8	-27.1	-111.3	-330.3	-	-
11	5	663.0	1300.0	247.0	96.0	3060.0	-	-	0.8	2.2	16.4	87.8	-	-	0.0	-0.8	-3.0	-19.4	-107.2	-	-
12	5	527.0	480.0	1700.0	303.0	2010.0	-	-	1.4	10.8	31.1	181.1	-	-	0.0	-1.4	.12.2	-43.3	-224.3	-	-
13	5	132.0	407.0	970.0	178.0	2440.0	-	-	0.4	4.6	91.5	222.0	-	-	0.0	-0.4	-5.0	-96.5	-318.5	-	-
14	6	820.0	810.0	1700.0	1270.0	317.0	59.6	-	4.4	12.7	27.0	74.4	178.0	-	0.0	-4.4	-17.1	-44.1	-118.0		-
15	6	141.0	91.0	16.0	2.5	47.6	2150.0	-	1.5	4.9	21.6	50.1	73.2	-	0.0	-1.5	-6.4	-28.0	-78.1	-151.0	-
16	6	312.0	27.7	134.0	17.1	57.9	1790.0	-	3.0	7.4	94.5	100.0	121.0	-	0.0	-3.0	-10.4	-104.9	-205.0	-326.0	-
17	6	14.9	3.9	3.8	13.8	47.1	1820.0	-	0.4	13.2	63.7	70.4	95.1	-	0.0	-0.4	-13.6	-77.3	-147.7	-242.8	-
18	6	94.0	59.8	7.7	2.0	23.4	37.5	-	1.0	1.9	12.7	43.2	127.0	-	0.0	-1.0	3.9	-15.6	-55.9	-182.9	-
19	6	306.0	623.0	705.0	800.0	121.0	6210.0	-	0.5	1.7	10.8	42.1	89.8	-	0.0	-0.5	-2.2	-13.0	-55.1	-144.9	-
20	5	980.0	6640.0	960.0	560.0	6460.0	-	-	0.9	2.6	4.6	9.4	-	-	0.0	-0.9	-3.5	-8.1	-17.5	-	-
21	4	1800.0	82.0	2460.0	1730.0	-	-	-	2.3	5.6	10.3	-	-	-	0.0	-2.3	-7.9	-18.2	-	-	-
22	6	230.0	393.0	336.0	860.0	193.0	30.7	-	0.7	1.6	40.2	79.4	116.0	-	0.0	-0.7	-2.3	-42.2	-121.9	-237.9	-
23	6	37.6	16.2	520.0	99.0	138.0	424.0	-	0.7	2.4	15.6	84.3	231.0	-	0.0	-0.7	-3.1	-18.7	-103.0	-334.0	-
24	6	99.0	980.0	513.0	960.0	172.0	26.3	-	0.5	3.5	32.5	98.6	149.0	-	0.0	-0.5	-4.0	-36.5	-135.1	-284.1	-
25	6	1040.0	1590.0	310.0	1570.0	114.0	1980.0	-	1.6	4.3	13.1	33.6	88.8	-	0.0	-1.6	-6.1	-19.2	-52.8	-141.6	-
26	5	447.0	448.0	870.0	453.0	1.1	-	-	0.9	3.5	12.8	68.8	-	-	0.0	-0.9	-4.4	-17.2	-86.0	-	-
27	6	32.1	31.0	109.0	762.0	820.0	49.4	-	1.0	3.5	27.5	57.7	118.0	-	0.0	-1.0	-6.3	-33.8	-91.5	-210.0	-
28	5	538.0	1750.0	1530.0	412.0	1700.0	-	-	0.4	1.3	90.0	188.0	-	-	0.0	-0.4	-1.7	-91.7	-27.7	-	-
29	6	52.9	544.0	166.0	150.0	1010.0	27.7	-	0.4	2.3	8.4	30.4	90.3	-	0.0	-0.4	-2.7	-11.1	-41.5	-131.8	-
30	5	1550.0	2610.0	1960.0	820.0	1820.0	2610.0	-	0.5	1.3	57.1	145.0	-	-	0.0	-0.5	-1.8	-58.9	-203.9	-	-
31	6	121.0	11750.0	910.0	2300.0	4980.0	519.0	-	0.5	6.9	57.1	70.9	180.0	-	0.0	-0.5	-7.4	-53.3	-124.2	-304.2	-
32	6	694.0	138.0	32.6	19.4	1270.0	21400.0	-	1.0	3.9	7.5	17.4	36.6	-	0.0	-1.0	-4.9	-12.4	-29.8	-66.4	-
33	6	567.0	1300.0	4630.0	1740.0	704.0	3420.0	-	1.2	4.6	11.2	22.5	50.4	-	0.0	-1.2	-5.8	-17.0	-39.5	-89.9	-
34	6	1930.0	1290.0	6710.0	2300.0	572.0	5800.0	-	0.9	3.3	12.5	38.3	101.1	-	0.0	-0.9	-4.2	-161.0	-550.0	-156.0	-
35	6	197.0	144.0	12.7	1.3	9.8	63.0	-	0.9	5.2	24.3	60.0	104.0	-	0.0	-0.9	-6.1	-30.4	-90.4	-194.0	-
36	6	384.0	980.0	11.9	41.6	111.0	2000.0	-	0.6	1.4	5.2	15.9	53.2	-	0.0	-0.6	-2.0	-7.2	-23.1	-76.3	-
37	6	37.8	860.0	615.0	21.4	9.1	2060.0	-	0.4	0.9	1.7	20.6	47.7	-	0.0	-0.4	-3.8	-3.0	-23.1	-71.3	-
38	6	1740.0	5290.0	1400.0	2230.0	8100.0	1140.0	-	0.8	2.0	5.8	14.5	54.4	-	0.0	-0.9	-3.8	-8.6	-85.8	-77.5	-
39	5	58.1	1690.0	880.0	2830.0	2750.0	-	-	0.4	3.6	15.3	66.5	110.0	-	0.0	-0.6	-2.1	-19.3	-41.8	-	-
40	6	576.0	1120.0	4740.0	11300.0	1070.0	304.0	-	0.9	2.9	9.8	28.2	110.0	-	0.0	-1.0	-3.9	-13.6	-49.3	-151.0	-
41	7	1880.0	5830.0	950.0	2410.0	2400.0	1900.0	289.0	0.6	1.5	4.0	6.8	19.0	38.0	0.0	-0.5	-2.1	-6.1	-12.9	-31.9	-69.9
42	6	143.0	478.0	1090.0	284.0	50.7	170.0	-	1.0	2.9	8.3	37.1	131.0	-	0.0	-0.8	-6.9	-12.2	-50.8	-180.0	-
43	7	144.0	830.0	207.0	840.0	73.6	10.1	20.3	0.5	1.7	5.6	14.5	28.8	132.0	0.0	0.1	-4.0	-7.8	-72.8	-51.1	-183.0
44	6	1880.0	197.0	39.3	179.0	771.0	34300.0	-	0.8	6.1	18.7	25.2	35.2	-	0.0	-0.4	-1.5	-25.6	-17.6	-86.0	-
45	7	2120.0	1660.0	772.0	3010.0	800.0	890.0	1980.0	1.0	3.0	14.7	44.8	135.0	285.0	0.0	-1.0	-34.2	-28.7	-290.0	-60.8	-493.0
46	7	1030.0	43.9	52.2	85.0	66.6	295.0	192.0	0.4	1.1	3.3	12.8	43.2	167.0	0.0	-0.9	-2.6	-4.8	-46.3	-60.8	-227.0
47	5	4120.0	4230.0	10600.0	3500.0	2640.0	-	-	1.0	33.2	88.1	168.0	-	-	0.0	-0.7	-2.5	-122.0	-61.1	-	-
48	6	33.3	207.0	1670.0	45.2	305.0	45.6	-	0.9	1.7	6.9	36.8	117.0	-	0.0	-1.7	-10.5	-9.5	-113.0	-163.0	-
49	6	55.1	25.3	358.0	91.0	146.0	254.0	-	0.7	1.8	7.7	50.9	136.0	-	0.0	-0.7	-2.5	-10.2	-61.1	-197.0	-
50	6	73.1	740.0	490.0	1210.0	391.0	150.0	-	1.7	8.8	25.5	76.9	117.0	-	0.0	-0.4	-3.3	-38.0	-36.1	-230.0	-
51	7	840.0	311.0	23.2	81.0	67.2	379.5	5300.0	1.2	4.8	9.1	80.1	117.0	158.0	0.0	-0.5	-2.2	-15.1	-95.2	-212.0	-373.0
52	7	90.0	4820.0	120.0	2270.0	142.0	33.6	2660.0	0.4	2.9	8.1	24.7	37.9	85.0	0.0	-0.4	-3.3	-11.4	-36.1	-74.0	-159.0
53	7	53.6	234.0	67.8	605.0	377.0	250.0	167.0	0.5	1.7	19.7	53.0	89.1	180.0	0.0	-0.5	-2.2	-21.9	-74.0	-164.0	-344.0
54	7	26.6	562.0	34.6	52.5	240.0	29.0	733.0	0.4	1.4	6.4	19.3	47.4	121.0	0.0	-0.4	-0.8	-7.2	-26.5	-73.9	-195.0
55	7	49.8	252.0	556.0	67.5	395.0	361.0	47.0	0.7	5.8	12.7	30.5	78.7	173.0	0.0	-0.7	-6.5	-19.2	-49.7	-128.0	-301.0
56	6	16.9	130.0	613.0	99.0	121.0	88.0	-	1.5	4.7	30.7	97.5	194.0	-	0.0	-1.5	-6.2	-36.9	-84.4	-278.0	-
57	6	18.2	5.4	273.0	626.0	31.1	-	-	2.3	21.6	45.3	245.0	-	-	0.0	-2.3	-23.9	-78.2	-323.0	-	-
58	6	58.9	1140.0	907.0	8800.0	4720.0	-	-	0.6	2.9	39.0	194.0	-	-	0.0	-0.6	-3.5	-42.5	-237.0	-323.0	-
59	6	187.0	691.0	5290.0	1610.0	623.0	1540.0	-	0.8	9.7	46.8	63.7	117.0	-	0.0	-0.8	-10.5	-57.3	-121.0	-238.0	-
60	6	236.0	398.0	94.0	4780.0	2470.0	4760.0	-	0.8	3.8	9.5	53.0	171.0	-	0.0	-0.8	-4.6	-14.1	-67.1	-238.0	-
61	7	234.0	1940.0	138.0	820.0	5590.0	1140.0	408.0	1.1	3.4	10.0	32.1	58.9	109.0	0.0	-1.1	-4.5	-14.5	-46.6	-106.0	-
62	7	227.0	1100.0	274.0	688.0	657.0	407.0	1820.0	2.5	5.6	12.0	36.4	62.4	150.0	0.0	-2.5	-8.1	-20.1	-56.5	-119.0	-268.9
63	7	128.0	1850.0	1480.0	1910.0	2160.0	1420.0	632.0	2.1	16.7	51.9	89.4	180.0	228.0	0.0	-2.1	-18.8	-70.7	-160.0	-340.0	-558.1
64	7	258.0	587.0	5770.0	8000.0	1530.0	411.0	145.0	2.7	12.9	22.8	44.4	60.0	154.0	0.0	-2.7	-25.6	-58.4	-102.0	-164.0	-317.0
65	5	489.0	578.0	97.0	46.1	1480.0	-	-	1.2	16.8	27.4	32.8	-	-	0.0	-1.2	-18.0	-45.4	-78.2	-	-
66	6	100.0	3150.0	214.0	3700.0	293.0	149.0	-	0.5	3.6	14.4	47.0	113.0	-	0.0	-0.5	-4.1	-18.5	-65.5	-179.0	-
67	5	603.0	2160.0	329.0	3050.0	635.0	-	-	3.2	16.7	51.7	165.0	-	-	0.0	-3.2	-19.9	-71.6	-236.0	-	-
68	7	193.0	6930.0	1600.0	234.0	870.0	2950.0	8000.0	0.4	2.5	5.4	18.6	29.0	42.0	0.0	-0.4	-2.9	-8.3	-26.9	-55.9	-98.4
69	7	423.0	172.0	737.0	90.0	430.0	820.0	167.0	1.3	2.4	5.9	11.7	37.7	124.0	0.0	-1.3	-3.7	-9.6	-21.3	-59.0	-183.0

V. RESULTS/INTERPRETATION

5.1 Iso-Pach Contour Map of the Overburden

To assess the actual groundwater potential of a location, it is necessary to have knowledge of thickness of the geologic soil profile of the sedimentary basin. A study of the contour map below (Figure2) gives comprehensive geohydrological information about the area, namely the variation of the alluvial thickness. It is observed that almost all the aquiferous zone appear thick enough for drilling productive boreholes over the entire area. The iso pach map constructed are divided in general into five profiles consisting Profile I – South Eastern zone (Bonny, Opobo, Andoni and part of Khana LGA), Profile II – Port Harcourt and Environs, Profile III – Old Ahoada LGA, part of Degema and Buguma, Profile IV – South Western part of Bayelsa State and Western Delta State.

However, the depth to the fresh/saline water sedimentary basin (overburden thickness) beneath the sounding stations is as plotted and contoured in Figures 2 and 3 below. The overburden is assumed to include the topsoil, the lateritic horizon and the weathered sediments. The values vary from 0.2 to 230m. The iso-pach map reveals areas with thick overburden which corresponds to sedimentary depression of the area. Generally, areas with thick overburden and low percentage of clay in which the inter-granular flow is either dominant or important are known to have high groundwater potential.

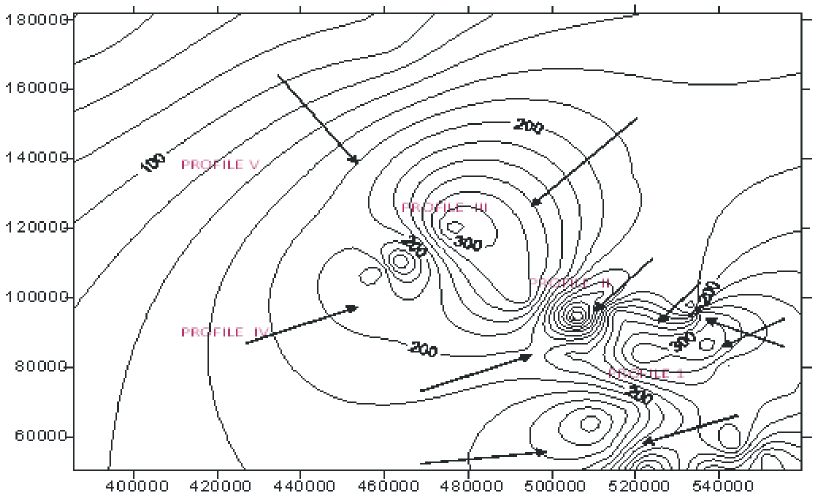

Figure 2: Iso-pach contour map of the study area

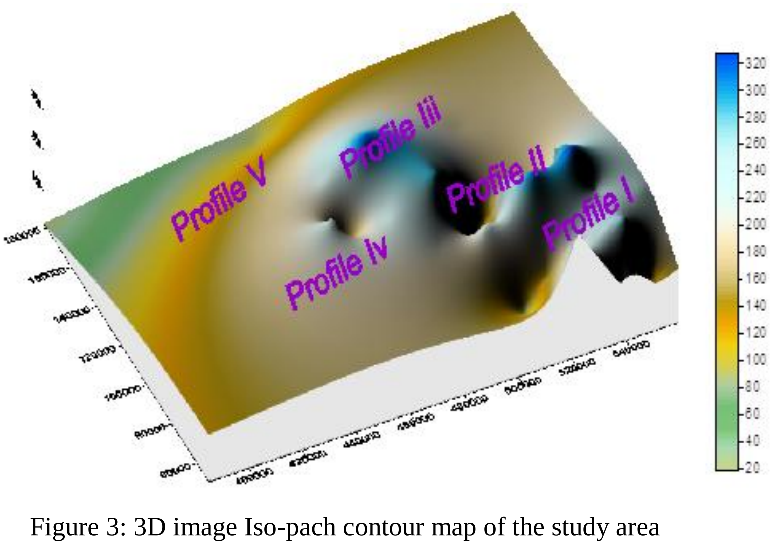

Figure 3: 3D image Iso-pach contour map of the study area

5.2 Iso - Resistivity Maps

To study the subsurface resistivity distribution of the area, Iso resistivity maps at different elevations (relative to sea level) are presented in the figures below. Zones of different resistivity values are grouped in terms of magnitude as high (> 2000Ωm), moderately high (500 – 1000Ωm), moderately low (100 -500) Ωm and very low < 10Ωm. To make a meaningful interpretation of conditions pertaining to the resistivity characteristics of the area, which is a very important factor in determining aquifer characteristics; high resistivity below low resistivity formation is also delineated and indicated with special attribute to the iso resistivity maps. 3D image maps are also constructed to show the topography of the VES locations shown below.

At AB/2 = 100m, Figure 4, which is 25m depth of penetration indicated high resistivity values across the study area. The resistivity values in this zone ranges from (100 – 4100)Ωm, except the areas covering VES 4, 6, 15, 17, 18, 35, 37, 43 and 57 whose resistivity values fall as low as 3.3 Ωm to 51.2 Ωm, an indication of clay, brackish and saline water zones. The variations in the resistivity values can possibly be traced to the variation in topography, geology or water quality and degree of saturation. However, the iso resistivity map is a qualitative interpretational tool which shows possible values in resistivity at the given electrode spacing and does not give the true resistivity of a definite geoelectric layer[3]. The image map, Figure 5, gives a clear picture of the land topography at the depth under review.

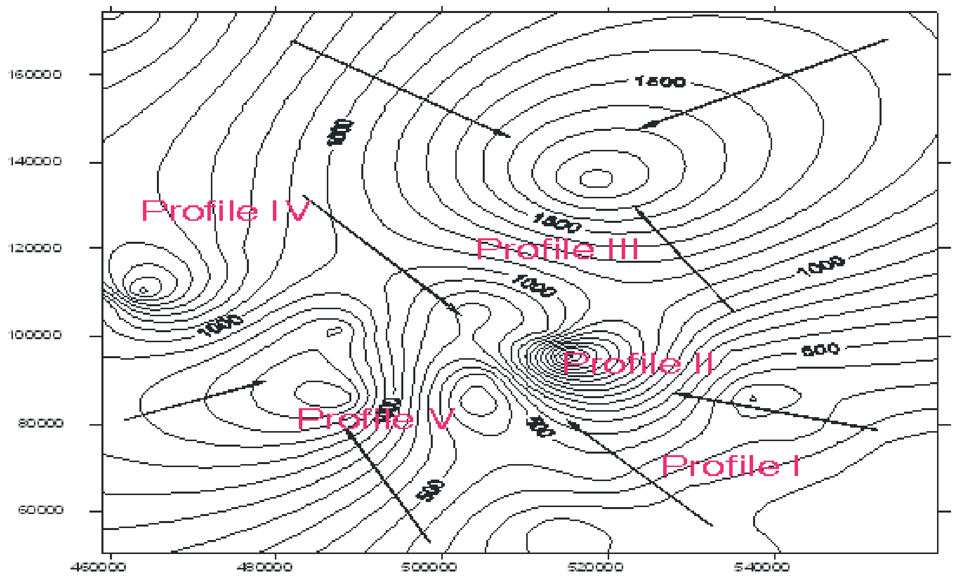

Figure 4: Iso Resistivity Contour Map at AB/2 = 100 m of VES locations in the study area.

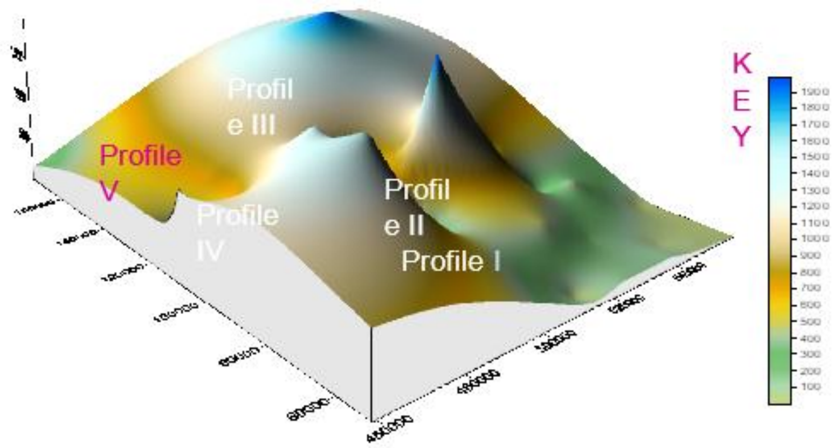

Figure 5: 3D Image Iso Resistivity Map at AB2 = 100m of VES locations in the study area

5.3 Subsurface Sequence / Geoelectric Section

In order to have a clear picture the resistivity with depth, five resistivity cross section profiles were taken and illustrated below. Most of the VES field data interpreted here using the Schlumberger Automatic Program indicated five/six geoelectric layers as delineated from the study area. These include mainly the topsoil, the lateritic sand, and fresh water weathered sediments.

The topsoil varies in composition from clay, sandy clay to sand and has layer resistivity varying from 14.9Ωm (in the core mangrove zones) to 1,500Ωm (at the extreme northern parts) of the survey area. The thickness of the topsoil ranges from 0.3m to 4.8m. The lateritic sands have resistivity values ranging from 0.9m to 33.2m. The low resistivity encountered in this layer is as result of inter-fingering clayey sands and brackish water zone in some cases. These are illustrated in (Figures6 – 10) below.

The fractured/weathered sand and medium to coarse sands constitutes the major component of the aquifer in the study area based on their thick overburden and relatively high resistivity values. Their permeability and porosity are well sorted for groundwater evaluation.

The resistivity in the subsurface sequence changes only with depth but does not change in the horizontal. (Loke 1999). Indeed, the geoelectric sections show the vertical distribution of resistivities within a given volume of rock. From the subsurface horizontal geoelectric sections, it can be further observed that the resistivity values at different depths reveal some interesting information about the subsurface lithology. It is clear that the northern part of the surveyed area is characterized by high resistivity values indicating the surface of water – bearing formation. Extreme high resistivity values may indicate an equivalent gravel – rich formation in the bedrock of the water – bearing section. In the southern part of the area under study, the resistivity values decrease showing probably increase in clay intercalations and saline water filled zone of saturation.

5.3.1 Profile I

This profile covers the extreme South Eastern part of the study area with orientation S900E comprising Bonny, Opobo, Andoni and part of Khana and Ogu/Bolo LGAs of Rivers State. This area basically falls within the mangrove vegetation of the Niger Delta. The resistivity cross section along this profile is presented in Figure 6, with VES 44, 6, 15, 16, 5, 25 and 36, as can be seen, most part of the section are marked by a high resistivity top layer (> 1000 Ωm) with thickness in the range of 0.5 – 5m. The next layer is a resistivity structure with a reduced magnitude except at VES 25 whose second layer resistivity is 1590Ωm. This low resistivity continued vertically to a greater depth to the third, fourth and fifth layers across the profile. These low resistivity values are attributed to the usual clay and /or saline water zone characteristics of the formation of the area. The sixth layer is generally a high resistivity structure beneath the low resistivity layer. It consists of different resistivity values between 1700 and more than 2000 Ωm.

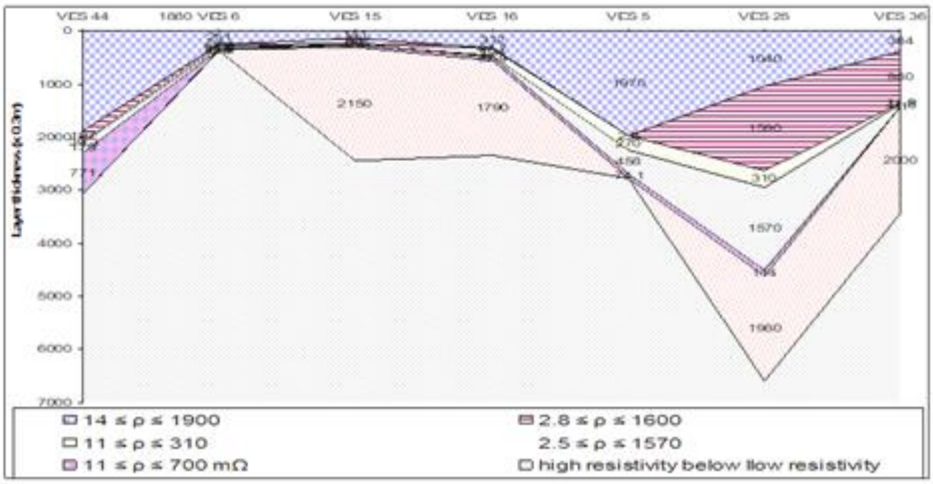

Figure 6: Interpretive Resistivity cross Section across Profile I

5.3.2 Profile II

Profile II is located in Port Harcourt and its environs with VES 45, 49, 7, 21, 50, 47, 13 and 30 of the survey area. The entire formation within this profile indicated high resistivity throughout the section. The resistivity values range from 100Ωm to more than 4000 Ωm with thickness as much as 250m and above, the aquifer in this zone are often very prolific for a sustainable pumpage. The resistivity cross section is presented in figure 7.

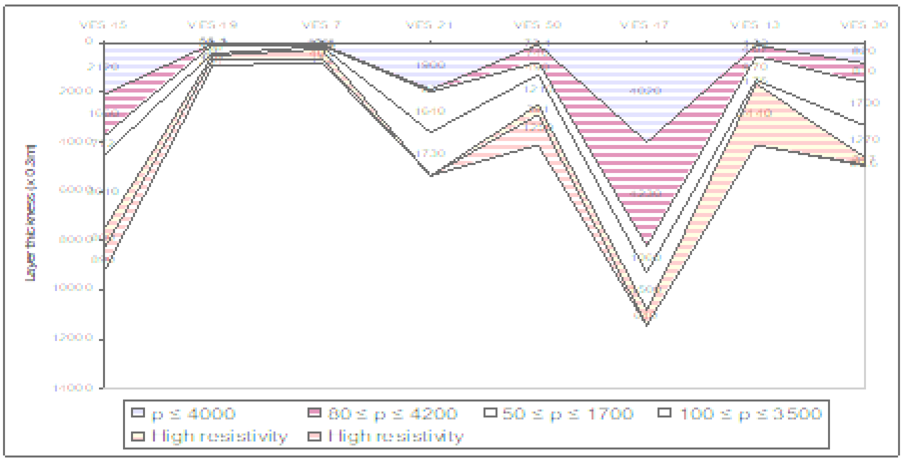

Figure 7: Resistivity cross section across Profile II

5.3.3 Profile III

This profile covers the old Ahoada local Government area, part of Degema and Buguma consisting of VES 40, 11, 53, 8, 46, 43 and 10. The resistivity cross section of profile 111 is presented in Figure 8 below. The resistivity structure in the profile is marked by high resistivity top layer having values > 14 Ωm and thickness in the range of 0.5 – 4.8m in most part of the line. This high resistivity values trends out throughout the entire profile, a clear indication of portable and high yielding aquifers in the area. It is obvious that the water – bearing formation is mainly medium to coarse sands which contain prolific aquifer in the area. However, low resistivity values (<10 Ωm) were observed at VES 43 – Buguma at the fifth through the seventh layer. This is probably as a result of clay/saline water intrusion prevalent in the area.

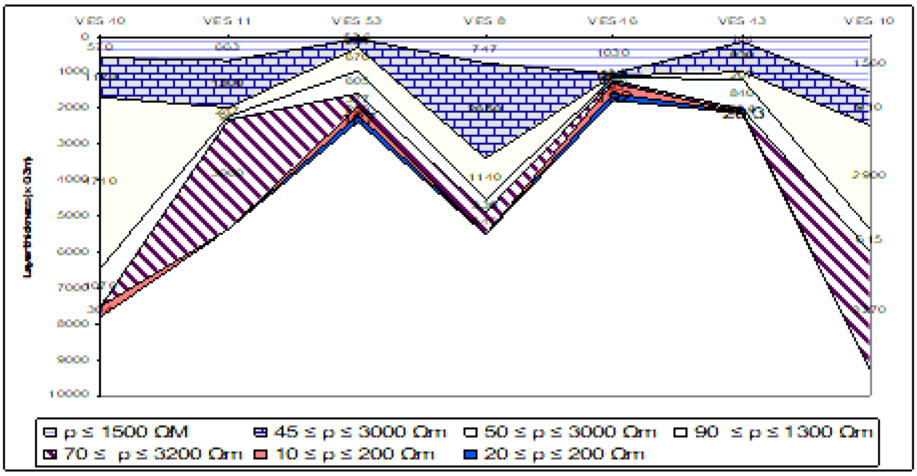

Figure 8: Resistivity cross section across Profile III

5.3.4 Profile IV

The geoelectric section (profile IV) covers the South Western part of Bayelsa State consisting of VES 54, 51, 55, 56, 46, 53, 42 and 58 as presented in Figure 9 below. The VES results show that the aquifer in the area is highly variable in thickness and resistivity; the thickness being thinner in the vicinity of VES 43 and 46. The resistivity values of this zone are relatively thick enough for drilling productive groundwater boreholes over the entire area. However, available records of water quality of boreholes drilled in the area (Old Rivers State – DFRRI water Project Records, 1994) indicated high level iron content in the entire zone. These showed the probable drop in the resistivity values as clay and or salt water was least suspected in the surveyed area.

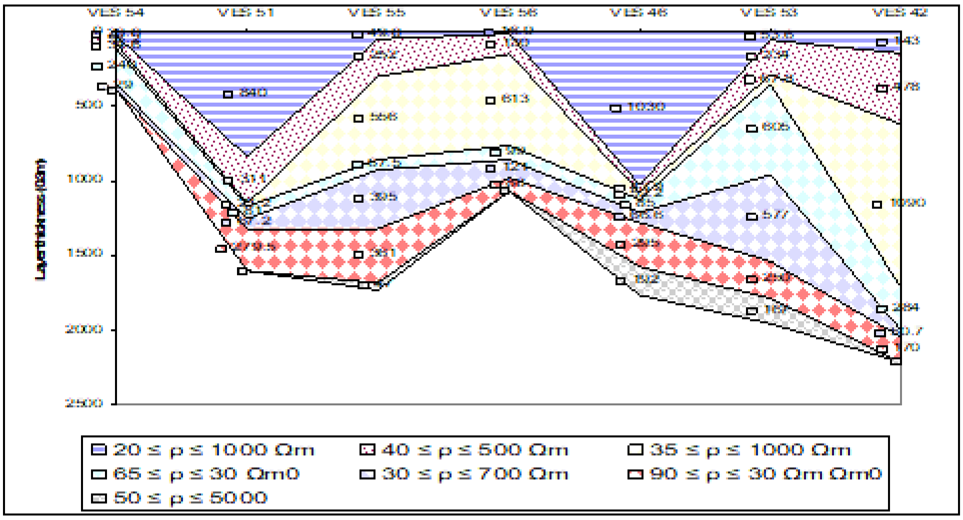

Figure 9: Resistivity cross section across Profile IV

5.3.5 Profile V

The geoelectric section of Profile V is as presented in Figure 10, consisting of VES 61, 69, 68, 87, 59, 20, 64, and 60 covering mainly part of Western Delta and part of Bayelsa States. The resistivity values are quite high with thick thickness enough to sustain productive groundwater extraction. The resistivity values range from 90 - 8000Ωm which is quite enough to indicate gravel-rich formation. Borehole yield in this area is expected to be very high in the zone.

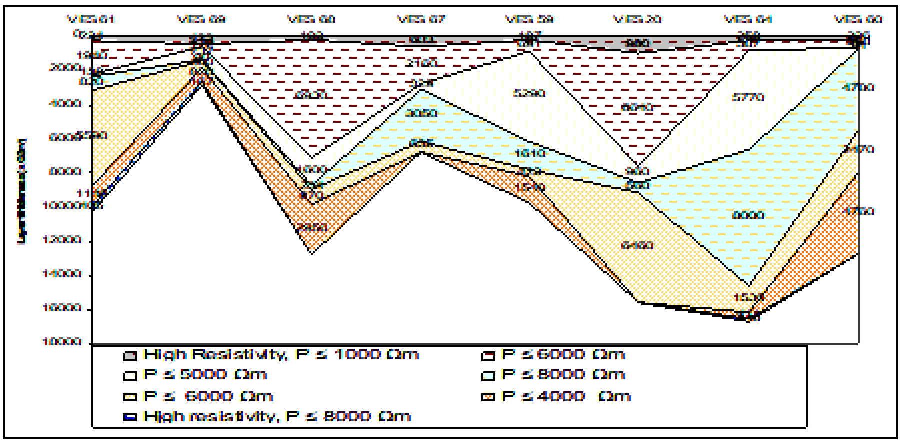

Figure 10: Resistivity cross section across Profile V

VI. CONCLUSION

Rivers, Bayelsa and Delta States form part of the Niger Delta region where these surveys were conducted. In the study of aquifer potential in parts of the Niger Delta area, sixty-nine (69) Schlumberger soundings were carried out in some selected Towns and communities of the area. The data are presented using one – dimensional Schlumberger Automatic program (SLINV.). The data are presented as Iso pach and Iso resistivity maps and resistivity cross sections using the VES data set.

The iso pach map of the overburden and water distribution revealed the depth to the freshwater aquifer of the area. Boreholes located within sedimentary depression zones with relatively thick overburden, will give relatively high yield. Such area with thick overburden materials are porous formations for possible groundwater development most especially when the clay content is low. Indeed, this work has helped to delineate precisely aquiferous zones within the study area. The depth to aquiferous zones under each survey locations were found. Geoelectric sections which are related to the lithostratigraphic sections for the area has been constructed.

REFERENCES

[1] Younger, P.L., *Groundwater in the environment: an introduction*. 2009: John Wiley & Sons.

[2] Mbipom, E. and J. Archibong, *Vertical Electric Sounding of Coastal Aquifers near Qua-Iboe Estuary.* Nigerian Journal of Mining and Geology, 1989. **25**(2): p. 151-154.

[3] Mbonu, P., et al., *Geoelectric sounding for the determination of aquifer characteristics in parts of the Umuahia area of Nigeria.* Geophysics, 1991. **56**(2): p. 284-291.

[4] Nwankwoala, H. and S. Ngah, *Groundwater resources of the Niger Delta: Quality implications and management considerations.* International Journal of Water Resources and Environmental Engineering, 2014. **6**(5): p. 155-163.

[5] Ophori, D.U., *A simulation of large-scale groundwater flow in the Niger Delta, Nigeria.* Environmental Geosciences, 2007. **14**(4): p. 181-195.

[6] Nag, S. and P. Ghosh, *Delineation of groundwater potential zone in Chhatna Block, Bankura District, West Bengal, India using remote sensing and GIS techniques.* Environmental Earth Sciences, 2013. **70**(5): p. 2115-2127.

[7] Ahmed, S., et al., *Viewing sub-surface for an effective managed aquifer recharge from a geophysical perspective.* Natural Water Treatment Systems for Safe Sustainable Water Supply in the Indian Context: Saph Pani, 2016: p. 301.

[8] Todd, D.K. and L.W. Mays, *Groundwater hydrology*. 2004: John Wiley & Sons.

[9] Amechi, B.U., I. Tamunobereton-ari, and E.N. Womuru, *Application of Earth resistivity measurement in the North Eastern Rivers State (A Geoelectric based study).* Journal of Scientific and Engineering Research, 2018. **5**(2): p. 18-24.

[10] Etu-Efeotor, J. and E. Akpokodje, *Aquifer systems of the Niger Delta.* Journal of Mining and Geology, 1990. **26**(2): p. 279-284.

[11] Amajor, L., *Aquifers in the benin formation (miocene—recent), eastern Niger delta, Nigeria: Lithostratigraphy, hydraulics, and water quality.* Environmental Geology and Water Sciences, 1991. **17**(2): p. 85-101.

[12] Amechi, B.U., J. Amonieah, and O.I. Horsfall, *Delineation of Groundwater Potentials and Overburden Layers Using Vertical Electrical Sounding (VES) Techniques in Parts of Etche LGA, Rivers State. Nigeria.* Journal of Scientific and Engineering Research, 2017. **4**: p. 258-264.

[13] Huntley, D., *Relations between permeability and electrical resistivity in granular aquifers.* Groundwater, 1986. **24**(4): p. 466-474.

[14] Vacquier, V., et al., *Prospecting for ground water by induced electrical polarization.* Geophysics, 1957. **22**(3): p. 660-687.

[15] Kirsch, R., *Groundwater geophysics: a tool for hydrogeology*. 2006: Springer.

[16] Onuoha, K.M. and F. Mbazi, *Aquifer transmissivity from electrical sounding data: The case of Ajali sandstone aquifers, southeast of Enugu, Nigeria.* Groundwater and Mineral Resources of Nigeria, 1988. **51**: p. 17-30.

[17] Amechi, B.U. and O.I. Horsfall, *Well design, construction and downhole logs for fresh water aquifer.* World, 2015. **7**(2): p. 185-190.

[18] Egai, A.O. and R.K. Douglas, *Aspects of Geophysical Survey Using Vertical Electrical Sounding (VES) for Groundwater Exploration in Parts of Ahoada West LGA of Rivers State, Southern Nigeria.* Geosciences, 2015. **5**(1): p. 31-38.

[19] Short, K. and A. Stauble, *Outline of geology of Niger Delta.* AAPG bulletin, 1967. **51**(5): p. 761-779.

[20] Paschal, C.C., et al., *Hydrogeochemical Assessment of Groundwater Quality in Parts of Ohaji Egbema Eastern Niger Delta, Nigeria.* Universal Journal of Environmental Research and Technology, 2014. **4**(6): p. 307-316.

[21] Bhattacharya, A.K., *An Analysis of Saline Water Intrusion Into Coastal Nigeria*, in *Wastewater Reuse and Watershed Management*. 2019, Apple Academic Press. p. 319-330.

[22] Hassan, I., et al., *Hydrostratigraphy and hydraulic characterisation of shallow coastal aquifers, niger delta basin: A strategy for groundwater resource management.* Geosciences, 2019. **9**(11): p. 470.

[23] Adelana, S., et al., *An overview of the geology and hydrogeology of Nigeria.* Applied Groundwater Studies in Africa, 2008. **1**: p. 181-208.

[24] Shahin, M., *Groundwater resources of Africa*. Hydrology and Water Resources of Africa, 2002. **41**: p. 509-563.

[25] Nwankwoala, H. and A. Amadi, *Hydro-geochemical Attributes and Quality Status of Groundwater in Port Harcourt, Eastern Niger Delta.* World Journal of Science and Technology Research, 2013. **1**(2): p. 151-167.

[26] Uko, E., J. Emudianughe, and C. Eze, *Comparison of the Characteristics of Low Velocity Layer (LVL) in the Mangrove Swamp and in the Upper Flood Plain Environments in the Niger Delta, using Seismic Refraction Methods.* Journal of Geology & Geophysics, 2016. **5**(4): p. 248.