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Research Paper

Geoelectric Layering and Subsurface Mapping via Vertical Electrical Sounding: A Case Study of Owherhe-Uduere Community, Delta State Nigeria.

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***ABSTRACT**: Sand is an important resource for the construction industry. Due to rapid urban expansion and increasing standards of living, sand consumption has increased worldwide. The efficient and economic extraction of sand in a place requires a proper understanding of the location's ground model. In order to delineate and determine the extent of sand deposits, a piece of land in the Owherhe-Uduere community in the Niger Delta region was used for this study. This study carried out an integrated approach that consisted of electrical resistivity sounding (VES) and boreholes drilled in the piece of land to supplement the electrical resistivity data. The electrical resistivity data was processed using inversion techniques. The results show four geoelectric layers. The first exhibits thickness and the resistivity range between (0.4-1.6)m and (52-2721) Ωm, second range from (1.4 - 4.8) m and (147-3664) Ωm respectively indicating a sandy deposit predominantly, and with a higher value of 2000Ωm, indicating a likelihood of coarse sand. The sandy deposit correlates with the lithology from the drill test hole which also confirms the presence of silty sand. The thickness and resistivity of the third layer ranges from (2.0-9.8) m and (32-3590) Ωm, the low resistivity indicates clay or fine sand , while the high resistivity points to the presence of gravelly sand (coarser sand). The thickness and resistivity of the fourth layer range from (3.2-24.0) m and (75-2181)Ωm, and it suggests a continuous sand formation with the drill test hole showing that this contains sand with some intercalations of clay. The second and fourth layers consist of fine-medium and coarse sand that are dreadgeable sand. Thus, the application of geophysics to indicate sand and gravel prospecting, enhances considerable economic saving for the aggregate industry and it is also an environmental saving for society as it gives an indicator of what is in the subsurface, so indiscriminately dredging can be avoided.*

***KEYWORDS:** Electrical resistivity, Sand and gravel deposits, Owherhe-Uduere Community, Southern Nigeria.*

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I. INTRODUCTION

Sand is a loose granular material that is produced as a result of the disintegration of rocks and is an indispensable natural resource for any society. Sand and gravel deposits according to[1] are good groundwater and hydrocarbon reservoirs and is a key construction aggregate used in beach replenishment, coastal defences and in the reclamation of swampy lands[2]. Sand is used in a wide range of industries and products. It is a main component in various construction materials such as cement, mortar, tile, brick, glass, adhesives, ceramics. Aside, sand and gravel are used in the construction of major civil engineering works such as airports, bridges, roads, highways, residential and commercial buildings, power generating facilities, factories, water supply and waste treatment facilities. In fact, almost every house, dam, road, wine glass, and cellphone contain some type of sand-related material[3]. Vast quantities of frack sand are used to extract oil from shale in the fracking industry. Due to these multiple uses, sand consumption has increased worldwide, in part due to the growth of the world´s population, increasing standards of living, and rapid urban expansion [4]and [5].

Gravel and sand extractions are often carried out in environmentally valuable areas such as river channels and streams in the Niger Delta. In the Niger Delta, adventitious exploitation techniques such as artesian methods (example; hand tools) or dredger badges are used. Unfortunately, the increasing sand mining activities worldwide is having a serious negative impact on rivers, deltas, and coastal and marine ecosystems [3]and [6]. Among the more common effects of dredging[7] are lowering of river bed base-level, alteration of bathymetry of a river channel, changes in flow velocity, discharge and hydrodynamics of river cross sections, erosion leading to bed and bank instability, changes in sediment transport regime and associated turbidity profile, shifts or relocation in saline and freshwater interface, lowering of channel water levels, changes in river morphology and disruption, and, occasionally, disappearances of fish nursery and spawning grounds [7]and [8]. In most cases, the scope of these adverse effects extends from the local area to larger regions that are far away from the sites where sand is taken[4].

Owherhe-Uduere Community in Delta State in the Niger Delta region is a land locked community, and the distance to the river channel is fairly long. Besides, sand mining from the nearest river channel has reached a stage where natural sand deposits have become depleted, and thus the use of alternative source was considered. In this study, the focus for sand search was on a piece of land in Owherhe-Uduere Community.

Soil in the coastal area of the Niger Delta consists of sandy silt, brownish clayey/silty sand, and fine medium/coarse grained unconsolidated sands. The area is overlain by various types of quaternary alluvial deposit comprising mainly of Recent deltaic sand, silt and clay of varying thickness. These alluvial deposits occur in five major geomorphic units namely: Active and abandoned coastal beaches, Salt water /Mangrove swamp, Fresh water swamp, Deltaic plain with abundant fresh water swamps and dry flat land and plain overly sub-soils comprise distinct units or intercalations of sand, clay and some silt [9].

The aim was to determine the spatial distribution which might lead to possibly the volume of exploitable sand. The standard technique for assessing both the spatial distribution and quality of a reserve is to undertake a shallow drilling programme[7]. But such a procedure is limited by spatial sampling due to the number of boreholes to be drilled, besides this approach was considered to be invasive, extremely time consuming and expensive[7].

Thus, the approach of geophysical investigation using Electrical Resistivity method which would furnish the needed information with minimum test holes, was used. The electrical resistivity technique has been used to investigate a wide range of problems such as hydrogeological, geological, engineering and environmental problems [10]and [11]. The electrical resistivity method has also been used for hydrogeological investigations in the Niger Delta[12],[13]and [14]. In these studies, the electrical resistivity data displays good resistivity contrasts between the overburden, sand and gravel, and bedrock; a useful albeit qualitative indicator for the applicability of the electrical method. The electrical resistivity technique can delineate compositional variations in a rock layer in the subsurface, and can therefore be used to distinguish between different geological sequences for example, clean sand and gravel (high resistivity) and clay (low resistivity). If the fluid conductivity characterizing aggregate deposits using electrical resistivity method does not vary, the resistivity of unconsolidated sedimentary deposits generally increases with grain size [15]and[16]. Thus, the electrical resistivity method has the capability of providing a qualitative estimate of the grain size of a sand and gravel deposit[17]. It was considered therefore that the electrical resistivity technique will be effective in mapping the lithology and areal extent of aggregate deposits.

II. GEOLOGY OF THE STUDY AREA.

Owherhe-Uduere in Ughelli North Local Government Area of Delta State is situated on coordinates 5°33'N and 6°07'E (Figure 1). Generally, the Delta area is a wetland characterized by swamps, marshes and bogs. [18], [19], [20]and [21].

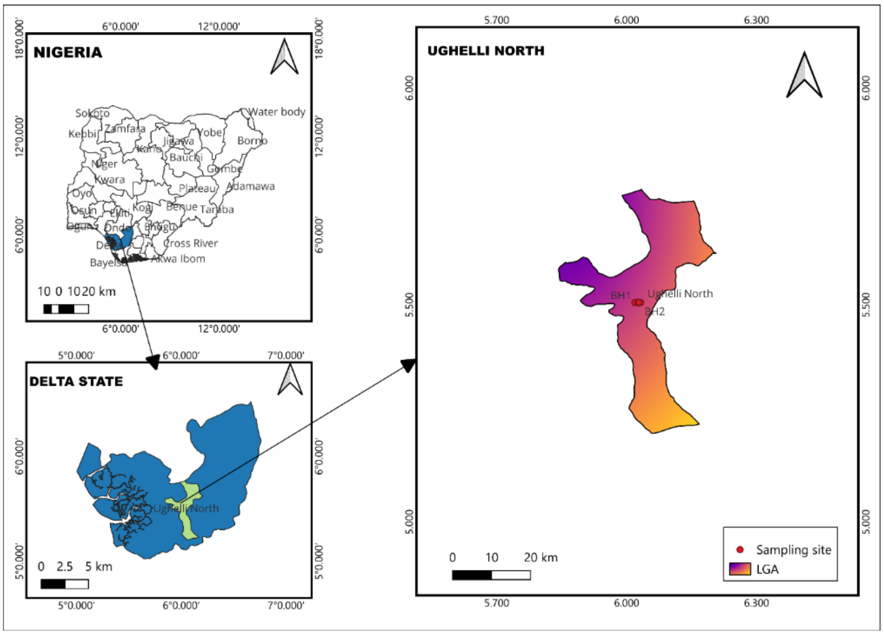

Figure 2.1: Map of Delta State Nigeria, Ughelli North showing the study area

This zone is characterized by considerable thickness of greyish silty-clay coastal plain sands of the Benin geologic Formation[22]and[23]. The Niger Delta basin which includes the study area has three major sedimentary subsurface stratigraphic units namely, the Benin, the Agbada and the Akata Formations [22]and [23]. The Benin Formation consists of loose and unconsolidated sands, and is about 1800m thick. The underlying Agbada Formation consists of sandstone and shales. It is up to 3000m thick and is underlain by the Akata Formation which consists of shales[24].

III. Materials and Method

a. Vertical Electrical Sounding (VES)

Thirty (30) vertical electrical soundings (VES) were acquired using Abem Terrameter SAS 1000 utilizing the Schlumberger electrode array (Figure 3.1). Current was applied to the ground through two electrodes (A and B) and then measuring the resultant potential difference (ΔV) between the potential electrodes (M and N). The centre point of the electrode array remains fixed but the spacings of the electrodes were increased so as to obtain information from successively greater depths. In this study, the separation AB/2 of the current electrodes was as follows: 1.0, 1.5, 2.0, 2.5, 3.2, 4.0, 5.0, 6.0, 7.0, 8.0, 10.0, 12.0, 15.0, 20.0, 25.0, 30.0, 40.0, 50.0, 60.0, 70.0, 80.0 and 100.0 m, while MN/2 of the potential electrodes is as follows: 0.3, 0.5, 1.5, 2.5, 5.0 and 7.5m. Apparent resistivity was calculated from Schlumberger array as follows:

$$\rho_a = \frac{\pi \cdot (AB^2 - MN^2)}{4 \cdot MN} \cdot \frac{V}{I} \qquad \text{Equation} \quad (3.1)$$

Where ρ = Apparent resistivity ohm-meter(Ω-m)

AB= Distance between the two outer current electrode (A and B) meter(m)

MN= Distance between the two inner potential electrode (M and N) meter(m)

V = Voltage difference measured between the potential electrode Volts (V)

I = Current injected into the ground through the current electrode (A and B) Amperes (A).

The values of the apparent resistivity at each sounding station were plotted against half-current electrode separation on a log-log paper generated the VES field curves. The interpretation process involves inputting the apparent resistivities and the corresponding AB/2 values at each station into a I-D inversion software (Interpex, USA, 2002). In this program, the operator introduces the number, thickness and resistivities of the subsurface layers. This starting model is adjusted until the difference in root mean square (RMS) error is less than 5 % between the field data curve and the synthetic curve. The interpretation was constrained using lithological data from drilled boreholes in the area.

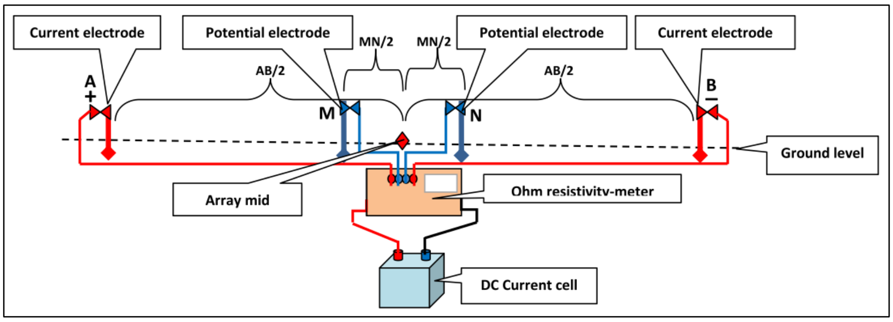

Figure 3.1: Schlumberger array schematic diagram

b. Borehole Drilling

Four boreholes were drilled in the site, using the hand percussion and reversed circulation technique[25] in order to calibrate the resistivity results and also to observe the geological sequences [26]. This was important because the calibration of the resistivity interpretation with known geological sequences or lithological information from borehole is vital for meaningful interpretation. During the drilling, disturbed sediment samples were collected in polythene bags (Figure 3), at 5ft. (1.5m) intervals and classified into various lithologies for each stratum, using Wentworth Scale [27]and[28]. The general description included colour, grain size, and texture. The depths of the boreholes were about 60ft. (18.3m). All samples recovered from the boring in the field were thoroughly examined and classified to produce lithological logs. Thereafter, they were taken to Civil laboratory where they were dried and analysed to get their percentile for fact finding the type of sand that are viable.

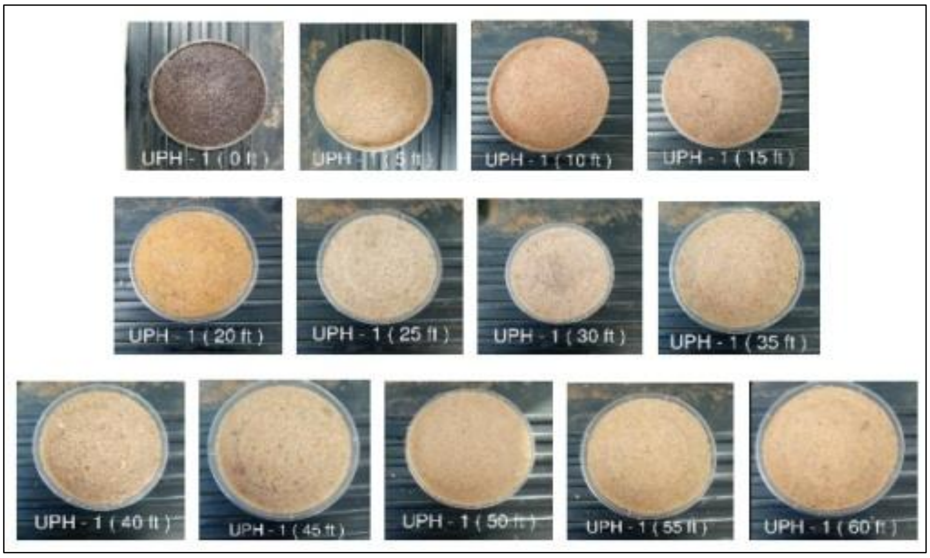

Figure 3.1: UH-01 Core Samples, Example

4.1 RESULTS AND DISCUSSION

The VES resistivity values, their corresponding thicknesses are presented in Table 1 - 30, while Figures (4.1 -4.5) show the VES curve types obtained in the study area. Vertical electrical sounding (VES) curve types obtained in the area are mainly K, H, KH and HK. Figure 4.8 shows the lithological information obtained from drilling boreholes. The 1D VES interpretation results with the lithological information shows that the stratigraphy of the area consists of four geoelectric layers (within the depth of investigation (0-24)m. The thicknesses of the layers observed in the drill test holes were used to constrain the 1D VES interpretation.

Table 4.1: Summary of model VES results

S/N	VES	Layer Thickness (m)				Layer Resistivity (Ohm-m)					RMS	Curve
	NO	1	2	3	4	1	2	3	4	5	Error (%)	Type
1	1	0.5	4,8	9.1	5.7	630	903	8470	1757	271	4.9736	K
2	2	0.5	4.3	2.0	20.0	2721	2379	2589	1839	576	3.131	HK
3	3	0.6	1.4	1.7	21.0	168	407	2832	277	5181	5.0661	KH
4	4	1.7	4.0	7.0	14.0	286	1552	246	489	3324	4.8874	H
5	5	1.0	1.7	6.0	12.0	290	367	3590	1650	150	3.8737	K
6	6	0.5	1.8	6.2	24.0	1083	3664	984	2181	529	2.445	HK
7	7	1.4	1.7	5.7	8.8	354	555	1021	184	799	2.1158	KH
8	8	1.6	1.8	5.6	14.8	354	621	891	347	347	2.3048	K
9	9	0.5	2.1	9.3	21.4	168	591	32	117	423	3.5379	H
10	10	0.6	1.7	5.3	11.5	66	399	84	279	490	3.1659	H
11	11	0.8	3.4	9.6	22.8	68	594	84	55	122	3.4213	H
12	12	0.4	1.6	7.4	20.4	52	333	99	347	78	2.7582	HK
13	13	1.1	3.8	5.5	10.0	84	436	267	75	91	4.7890	H
14	14	0.9	3.4	5.3	9.6	315	147	122	76	5893	7.5884	K
15	15	0.6	2.5	6.7	5.7	282	591	256	240	1519	4.7419	H

16	16	0.3	4.7	7.6	3.2	245	553	2000	725	281	1.6723	K
17	17	0.2	4.9	6.0	6.4	180	608	210	1361	210	2.0650	HK
18	18	0.4	2.2	6.2	8.5	103	289	180	120	462	3.8643	H
19	19	0.8	2.4	5.7	10.7	280	160	88	684	420	2.9856	H
20	20	1.2	1.9	4.8	16.2	94	240	682	422	248	1.4629	K
21	21	0.7	3.2	8.2	14.8	381	684	740	348	543	2.5438	KH

Table 4.1: Summary of model VES results continued

S/N	VES	Layer Thickness (m)				Layer Resistivity (Ohm-m)					RMS	Curve
	NO	1	2	3	4	1	2	3	4	5	Error (%)	Type
22	22	1.2	2.7	6.4	12.0	158	307	1832	277	4181	3.0761	KH
23	23	0.8	1.4	6.8	22.0	296	1252	244	409	1324	1.8374	H
24	24	1.6	1.9	7.7	6.8	260	467	2590	1250	250	2.5737	K
25	25	0.9	1.7	5.8	12.8	1093	2634	784	2080	429	2.0445	HK
26	26	0.6	2.4	9.8	10.4	254	455	1016	284	869	3.1558	KH
27	27	0.7	1.9	4.3	13.5	364	601	791	247	447	1.4068	KH
28	28	0.9	3.6	9.7	20.8	268	491	85	217	523	2.4379	H
29	29	0.5	2.6	6.4	14.2	266	399	184	280	496	3.2639	H
30	30	1.2	2.8	4.5	8.0	186	462	686	384	261	2.8651	K

4.2 RESISTIVITY CURVES

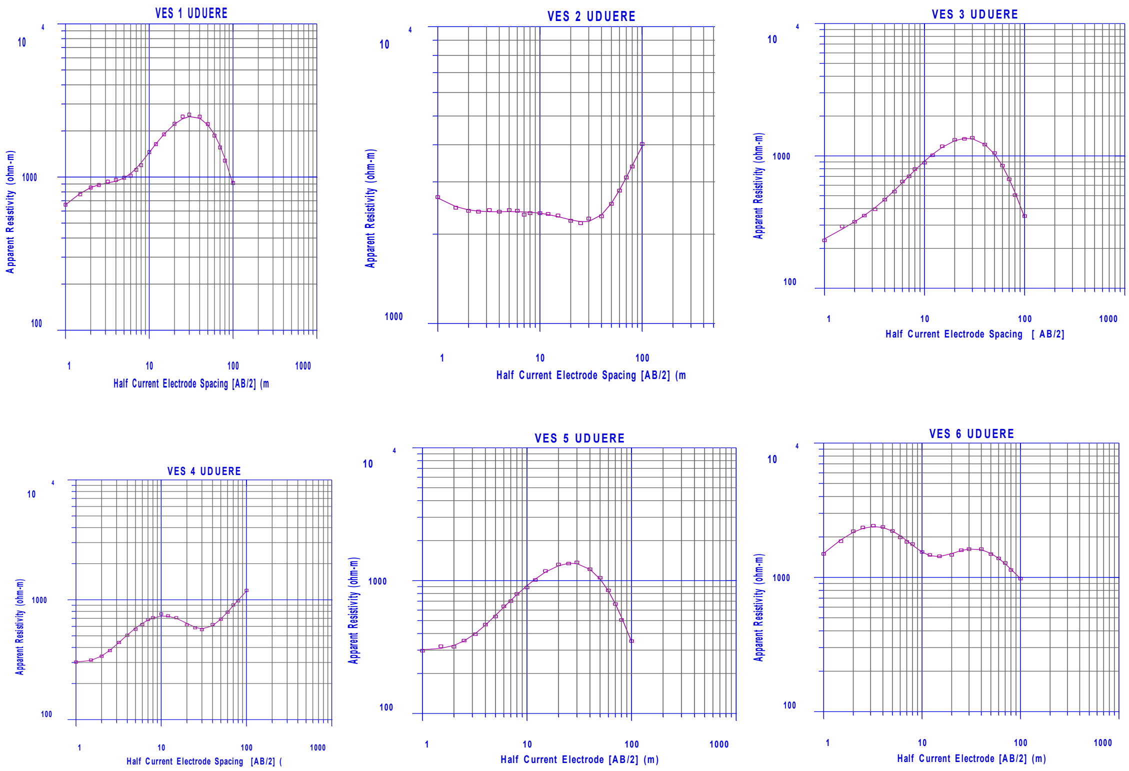

Figure 4.1 : VES_1 – VES_6

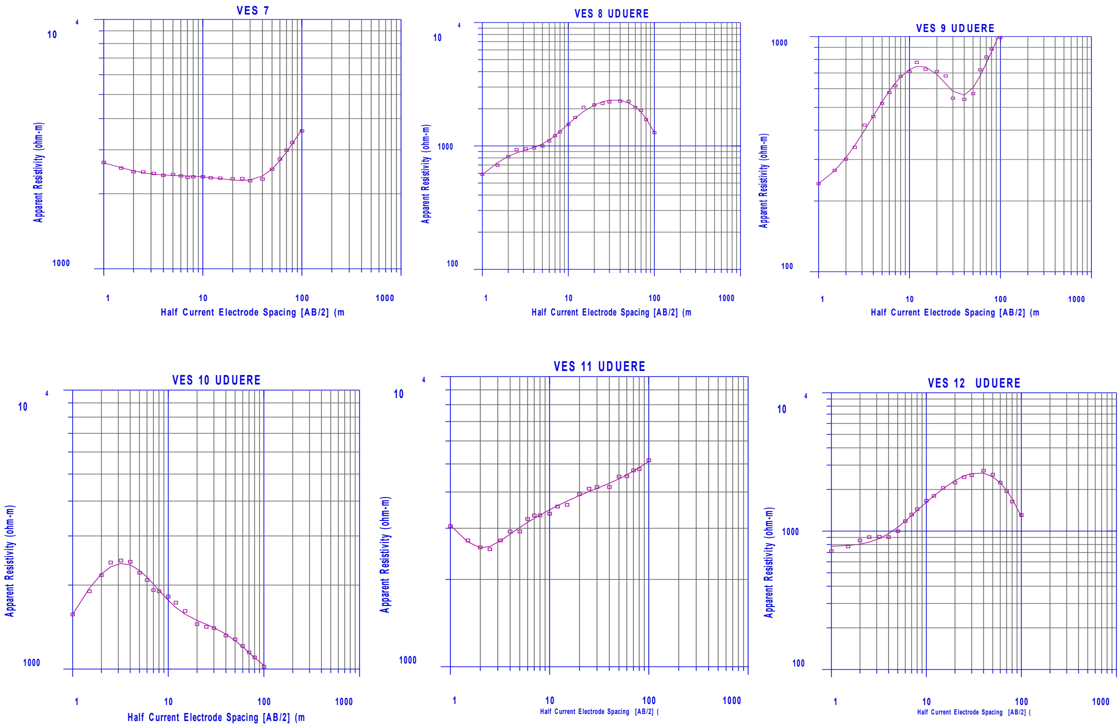

Figure 4.2: VES_7 - VES_12

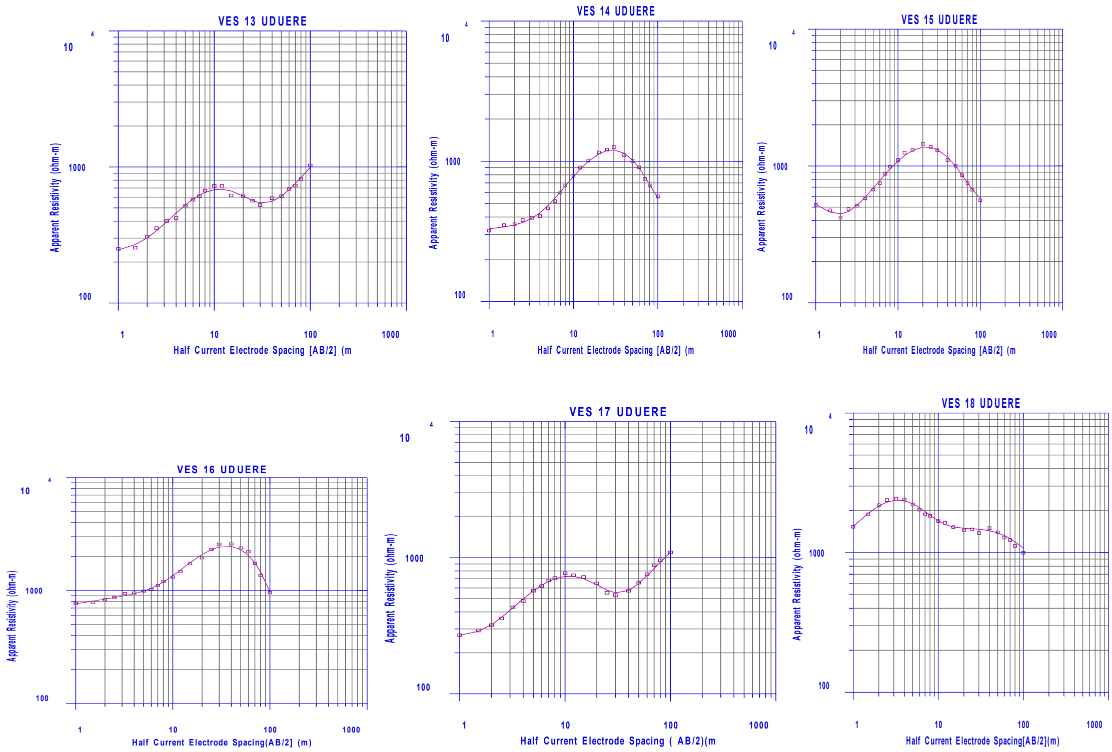

Figure 4.3: VES_13- VES_18

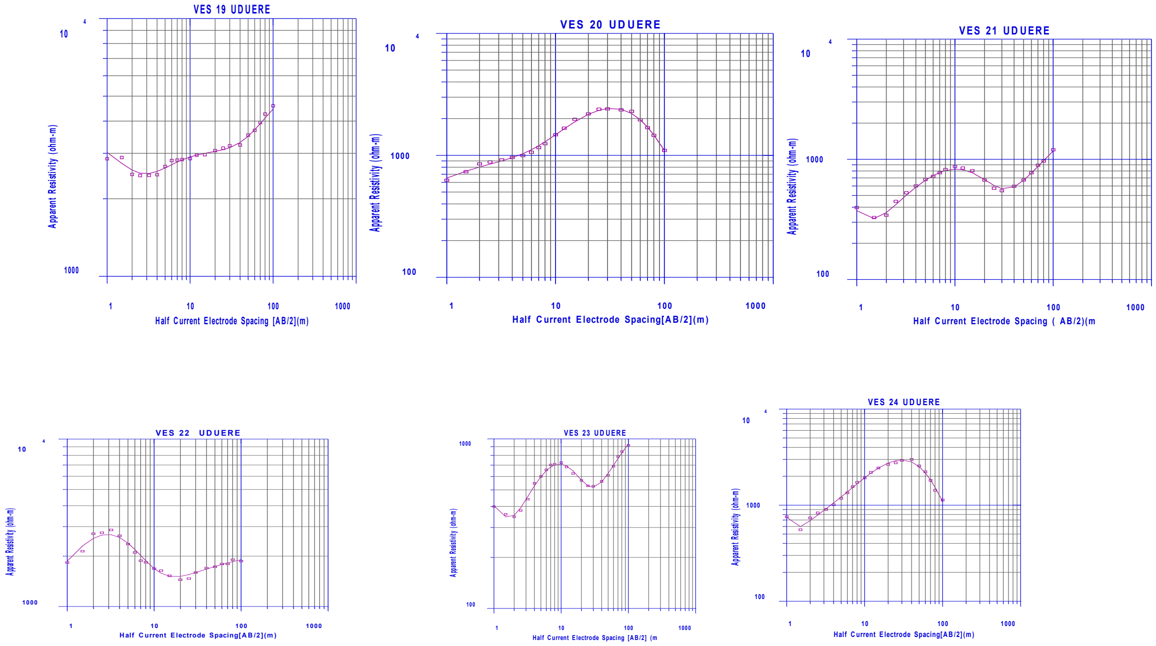

Figure4.4 VES_19 – VES_24

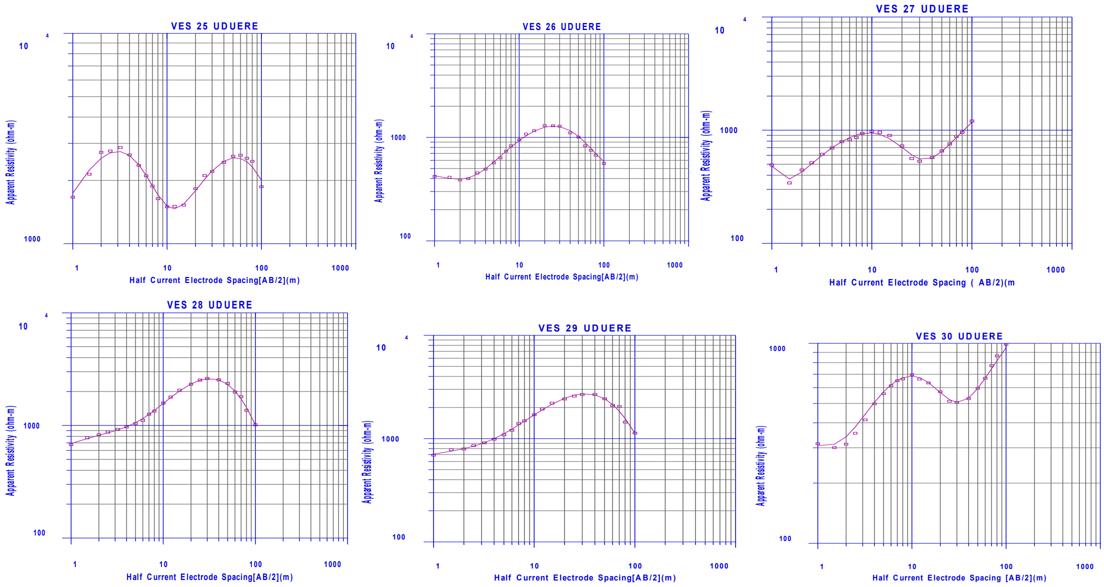

Figure 4.5 : VES_25- VES_30

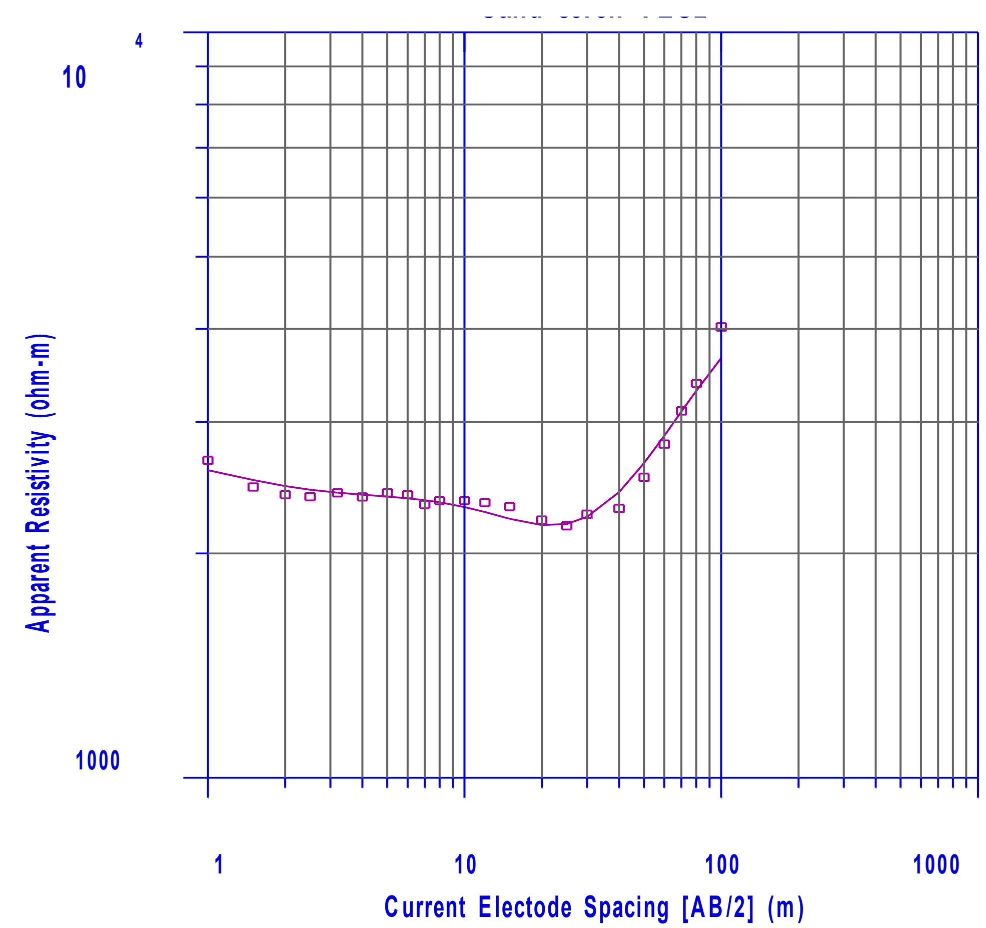

Figure 4.6: Vertical Electrical Sounding (VES) curve type H obtained in the study area.

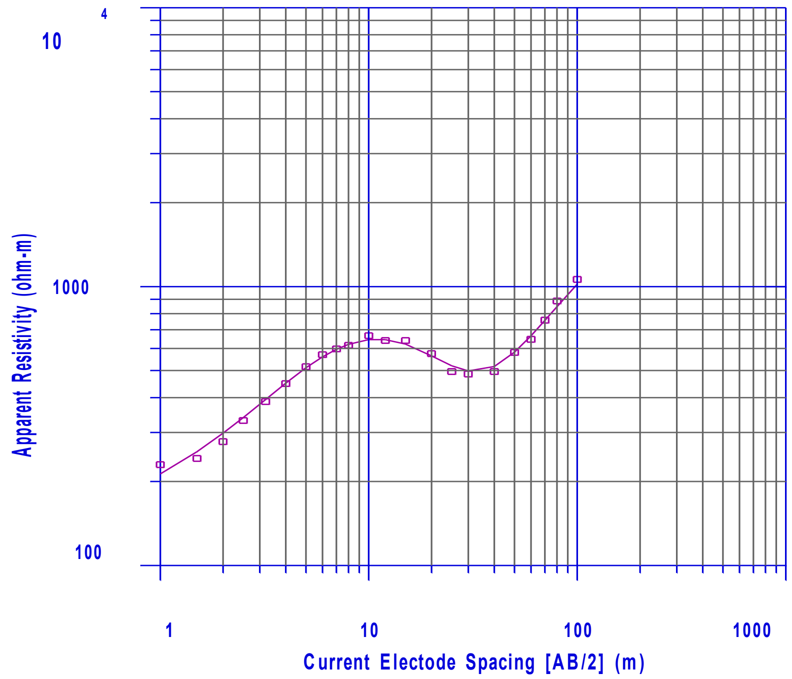

Figure 4.7: Vertical Electrical Sounding (VES) curve type KH obtained in the study area

In this study, the geophysical signal is not only used to decipher stratigraphy but also used to discriminate sand grains. Figure (4.1-4.5) show that the initial apparent resistivity value in each VES curve type . In a H type curve, the stratigraphy consists of topsoil/ sandy loam then a lesser resistivity that depict, silty sand, and then a higher resistivity of fine medium- coarse sand. In the KH curve type, the stratigraphy consists of top soil, silty sand, fine medium sand, silty sand and coarse sand.

Apparent resistivity values greater than 2000 Ωm is an indication of the presence of aggregate materials such as sand and gravel. [29]and[1]suggested that potential sand and gravel deposits are usually distinguished by their high resistivity values from their surrounding clay and silt, hence the high resistivity values with depth are an indication of major unit for sand and gravel production.

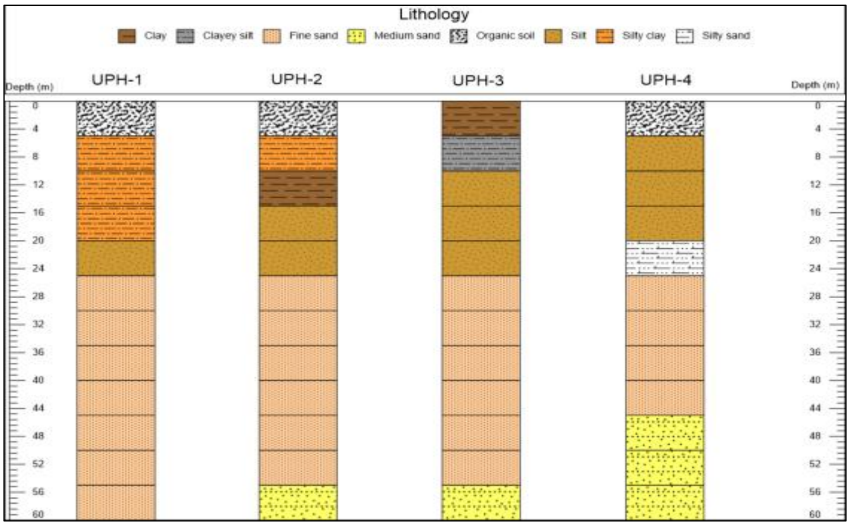

Figure 4.8 : Geological information obtained from the drill test holes in the study area.

geological information obtained from the drill test holes were used in constructing the stratigraphy and as well as constraining the VES interpretation.

The table 4.1 above ,shows that the thickness and the resistivity of the top soil range between (0.4-1.7)m and (52-2721) Ωm. This layer reflects mixed materials, such as lateritic soil, with occasional clay and weathered sand, however the higher resistivity suggests pockets of coarse grain near the surface. The thickness and resistivity of the second layer range from (1.4 - 4.8) m and (147-3664) Ωm respectively , indicating a sandy deposit predominantly, and with a higher value of 2000Ωm, there is likelihood of coarse sand. The sandy deposit correlates with the lithology from the drill test hole which, also confirms presence of silty sand . The thickness and resistivity of the third layer ranges from (1.7-9.8) m and (32-8470) Ω. In this layer, the low resistivity is an indication of clay or fine sand , while the very high resistivity points to the presence of gravelly sand (coarser sand). The drill test holes shows that this layer consists of fine-medium sand, alternating clay and coarse sand [30]. The thickness and resistivity of the fourth layer range from (3.2-24.0) m and (75-2181)Ωm, and it suggests a continuous sand formation, the drill test hole shows that this contains sand with some intercalations of clay .

V. CONCLUSION

This study carried out geoelectric sounding, VES, complemented by borehole drilling to map potential sand aggregate sources in Owherhe-Uduere community in Ughelli North Local Government Area of Delta State in the Niger Delta region. It was conducted in thirty locations across the study area consisting of thirty VES points . Due to the inherent challenge of equivalence in geoelectric sounding data, borehole data were used to constrain the interpretation. Between (0-1.7) m consists of top soil and silty sand. This is the strippable overburden which overlies the second layer that is a fine-medium sand and in some cases, coarse sand. This is also indicative in the fourth layer, thus mapping out the second and the fourth layers as layers that are more viable than the first .However, the third layer has some intercalations of sand deposit, the low resistivity indicates that there is more clay deposit.

In summary, using the VES approach at the stations exhibited high resistivity which is a possible indication of potential sand and very coarse deposit. The test drill holes also confirmed the presence of aggregate materials. Thus, the integration of Vertical electrical sounding (VES) and borehole investigation is a good tool for mapping sand , however conscious steps must be taken to minimize ecological and environmental effects if dredging is considered.

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