Subsurface Geophysical Estimation of Sand Volume in Ogudu Sandfilled area of Lagos, Lagos, Nigeria.

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Abstract
Surface geophysical survey was carried out using Electrical resistivity and induced polarization methods to estimate volume of sand deposits for the purpose of development/exploitation via dredging in Agboyi area of Lagos State .The study area was divided into square, rectangular, triangular and trapezoidal cells before conducting the geophysical survey. A total of 125 Vertical electrical sounding (VES) data were collected using Schlumberger electrode configuration with an electrode spacing varying between 100 and 400m. Five wells were also drilled for the collection of soil samples with a view to mapping the litho-logical variations of the subsurface strata. The combination of Vertical electrical sounding (VES) data, Induced Polarization (IP) data and well log data were used in inferring the litho-logical units of each geo-electric layer within the study area. The geo-electric sections delineate three to five subsurface layers, which include sand, sandy clay/ clayed sand, and clay. The 2-D and 3-D Isopach maps show the distribution of sand with thickness ranging between 0.5m and 7.0m.The volume of sand within each cell was calculated and the results were summed to give a total volume of 165596.5712m^3 of sand as against 1.5million m^3 projected. Hence, the analysis shows that the study area is devoid of enough sands for the purpose of development/exploitation via dredging. [Journal of American Science 2010;6(7):68-77]. (ISSN: 1545-1003).

Keywords: Vertical Electrical sounding (VES); Geoelectric Section; Lithological

1.0. Introduction

Lagos state is one of the heartbeats of economic activities in Nigeria because of the presence of many industries, ports (air and sea), etc. The population of the state is now becoming explosive that many people could not afford decent accommodation while those that could afford pay exorbitantly. Thus, congestion makes suitable sites to become very scarce in urban areas. This now informed the study of some abundant areas in coastal part via geophysical methods in order to quantify the volume of sand for reclamation purposes.

Geophysical methods are often used in site investigation to determine the overburden thicknesses and map subsurface conditions prior to excavation and construction. Electrical resistivity and seismic exploration methods are the most common techniques used for this purpose (Kurthenecker 1934; Moore 1952; Drake 1962; Early and Dyer 1964; Burton 1976; kearey and Brooks 1984; Olorunfemi and Meshida 1987). There are many methods of electrical surveying, some make of naturally occurring fields within the Earth while others require the introduction of artificially generated currents into ground. These comprise the spontaneous of self-potential (SP) method, induced polarization (IP) method and electrical resistivity methods. Although more labour intensive, the electrical resistivity method is more viable for deep subsurface investigation (Reynolds, 1997). Electrical resistivity method is routinely used in engineering and hydrogeological investigations to investigate the shallow subsurface geology.

The study was carried out at Agboyi village which is considered to be one of the Islands in the coastal part of Lagos. About 1.5million m^3 of sand was envisaged for reclaiming part of the area by the proponents. The Electrical resistivity and induced polarization methods were employed because VES gives low resistivity values for both saline sand and clay but in contrast, induced polarization method differentiate both i.e, saline sand typifies low induced polarization (poor chargeability) while clay depicts high induced polarization (medium to high chargeability). In view of the nature of the geology of the study area, the combination of both methods in delineating the subsurface could not be overemphasized.

2.0. Materials and Methods

2.1. Site and Geology

The area of study (Figure 1**)** is an Island with a swampy terrain having daily rising and falling of tides. It is accessible by road from Oworonsoki-Ojota axis expressway and from Ojota via the overhead bridge. A canoe is required to get to the site because of a canal which traverses the area and empties into the lagoon. Some of the visible activities include fishing, sand dredging and transportation via canoe. The geology of the study area can be described broadly as a sedimentary basin, which thickens from North to South (Down dip) and from East to West. The littoral and lagoon deposits of recent sediments underlie the study area. The area shares the geologic characteristics of coastal environments in Nigeria which include the presence of clays, shale deposits, sandstones and pebbles. Hence, the study area is characterized by unconsolidated sands, clays and mud with a varying proportion of vegetable matter, along the coastal areas while the alluvial consist of the coarse, clayey, unsorted sands with clay lenses and occasional beds.

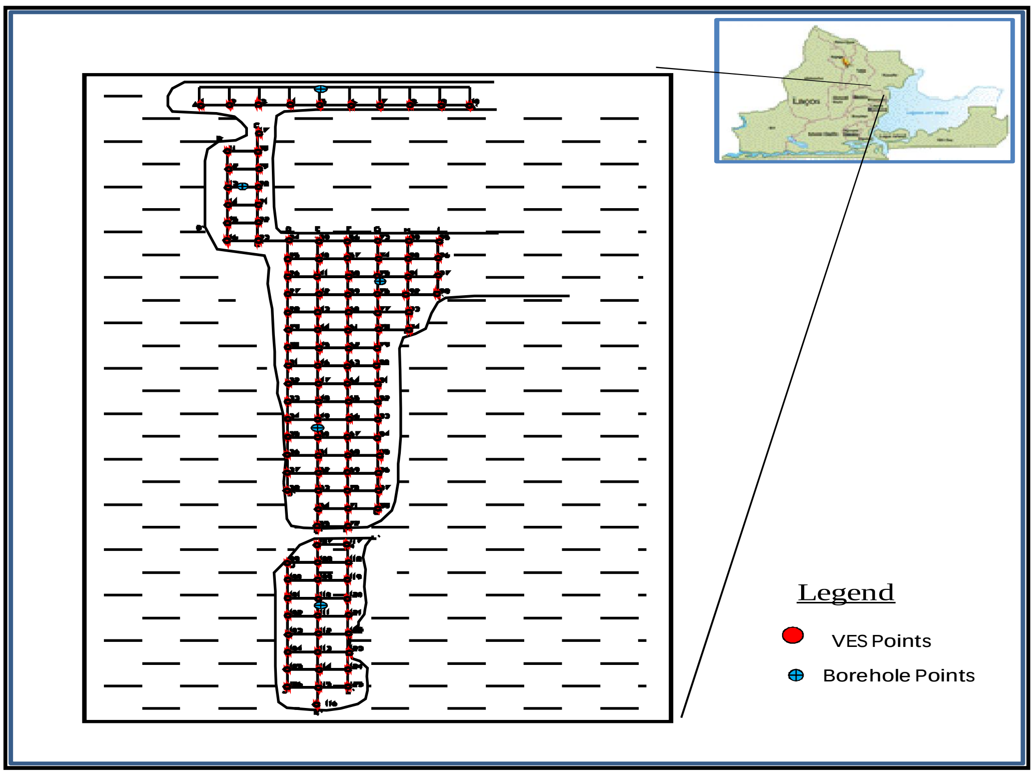


Figure 1: Base Map of Study Area

2.2. Data Acquisition

The study area was divided into square, rectangular, triangular and trapezoidal cells and geo referenced by Garmin Etrex model Global Positioning System (GPS) handset with a view to determining the longitude, latitude and elevation of the VES locations (figure 1). ABEM Terrameter SAS 1000 and PASI Tarrameter were used for the data acquisition. A total of 125 Vertical electrical sounding (VES) data were collected using the Schlumberger electrode array with electrode spread (AB) varying from 2.0m to a maximum of 400m. The electrical chargeability and resistivity measurements were taken simultaneously. The essential idea behind the vertical sounding used in this study area assume conductivity variation with depth only, is such that as the resistance between the current and potential electrode is increased, the current filament passing across the potential electrode carries a current fraction that has returned to the surface after reaching increasing deeper depth (Telford et. al., 1976). Five wells were also drilled for the purpose of correlation with sounding results.

3.0. Results

Sounding curves were interpreted qualitatively and quantitatively. The qualitative interpretation involved evaluation of curves for estimation of volume of sand deposit in the studied area. Quantitative interpretation of the curves involves partial curve matching using two layer Schlumberger master curves and the auxiliary K, Q, A and H curves. Outputs were modelled using computer iterations. WinGLink software was utilized for the iterations. The results of qualitative interpretation of 125 VES data are characterized by HA, QHA, QH and KH curves. The results of the cuttings from the five wells drilled revealed the subsurface strata as sand, clay, clayed sand and sandy clay at various depths (Table 2).

Samples of the resistivity and IP curves are respectively shown in Figures 2 & 3. One of geoelectric sections beneath the VES is shown in Figures 4**.** Summary of some of the interpreted VES data is presented in Table 1. 2-D Isopach Map (Figure 5), 3-D Isopach Map in South-Eastern View **(**Figure 6), and Isopach Map in North-Western View (Figure 7) are presented. The estimated volume of sand within each cell is shown Table 3.

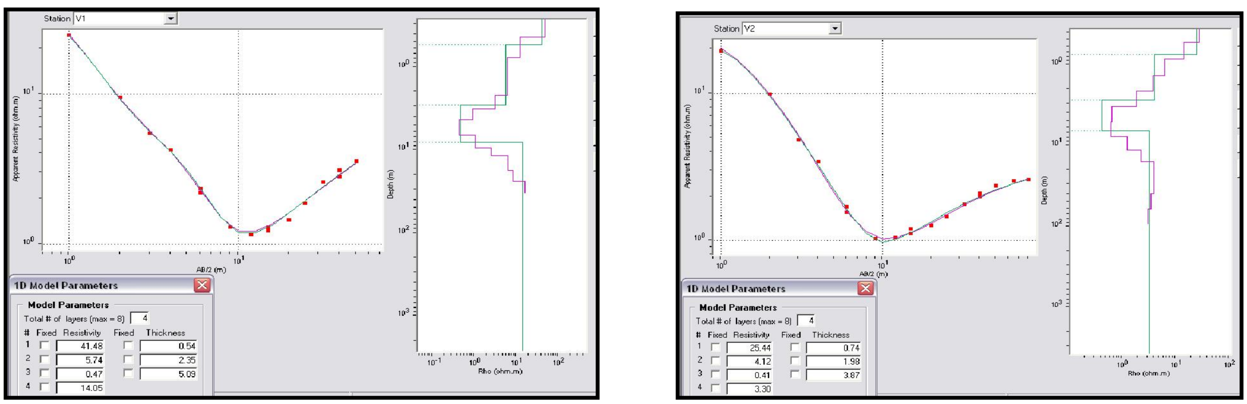


Figure: 2 Sample of resistivity field curves

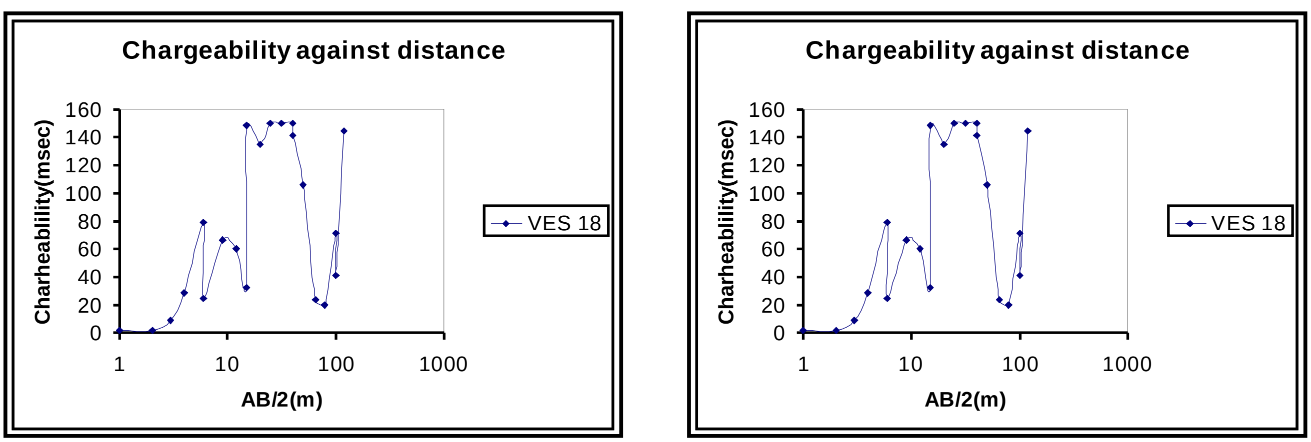
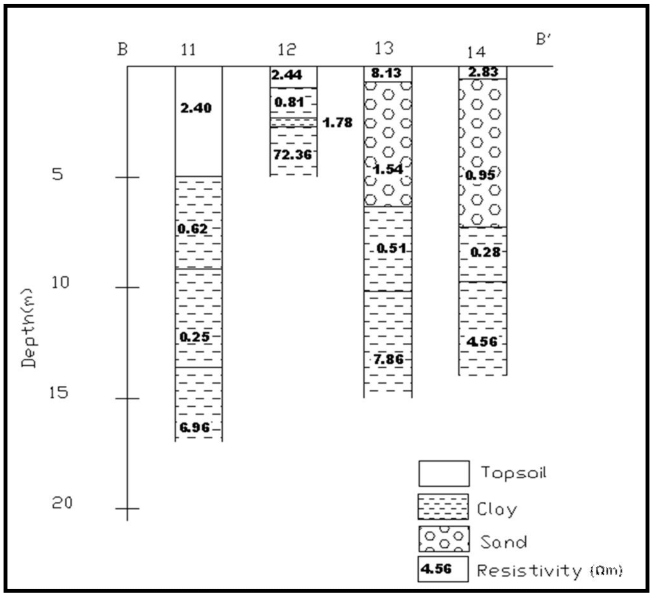


Figure 3: Sample of Induced Polarization curves



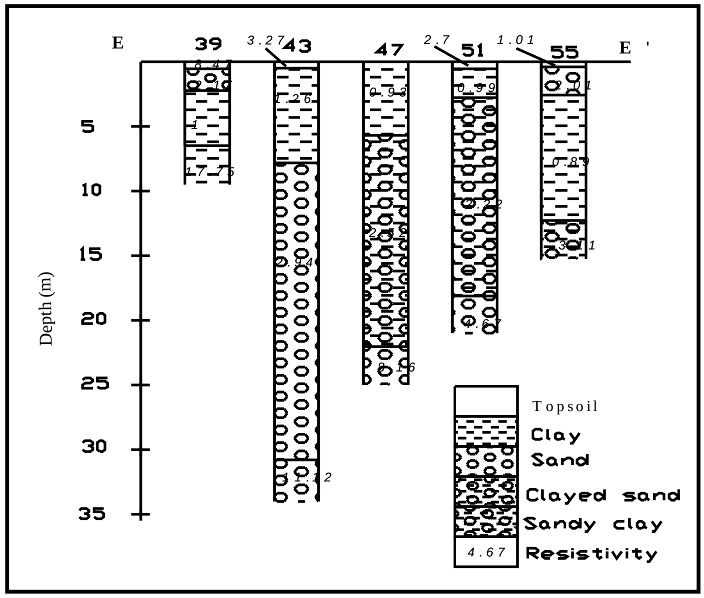


Figure 4: Sample of Geo-electric sections Along traverses BB' and EE'

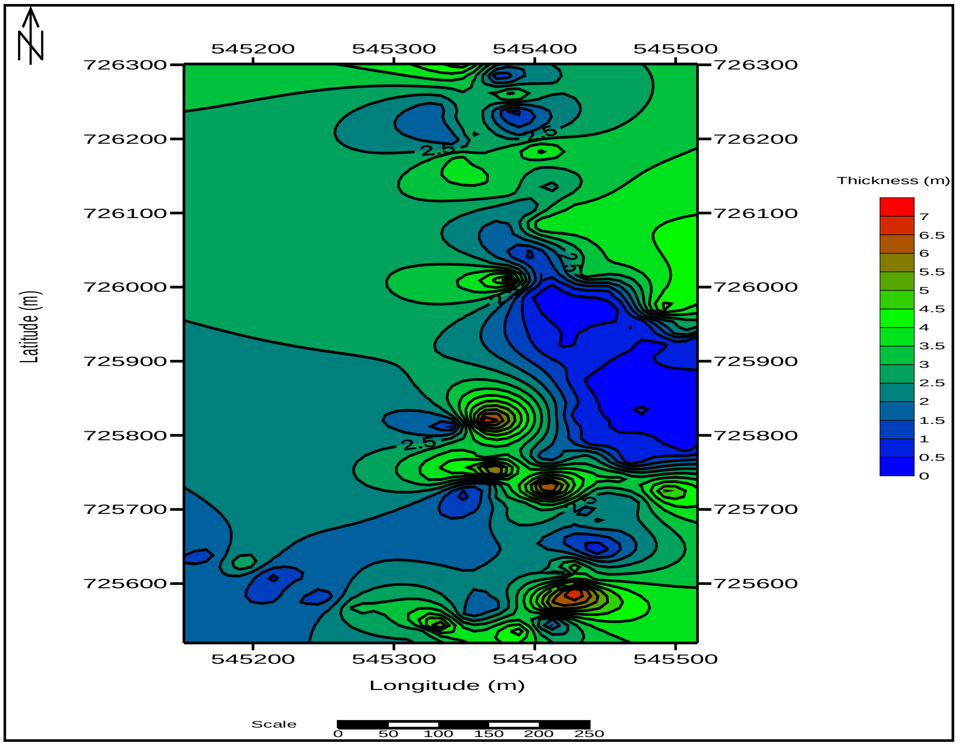


Figure 5: 2D Isopach Map of Agboyi-Ogudu, Lagos State

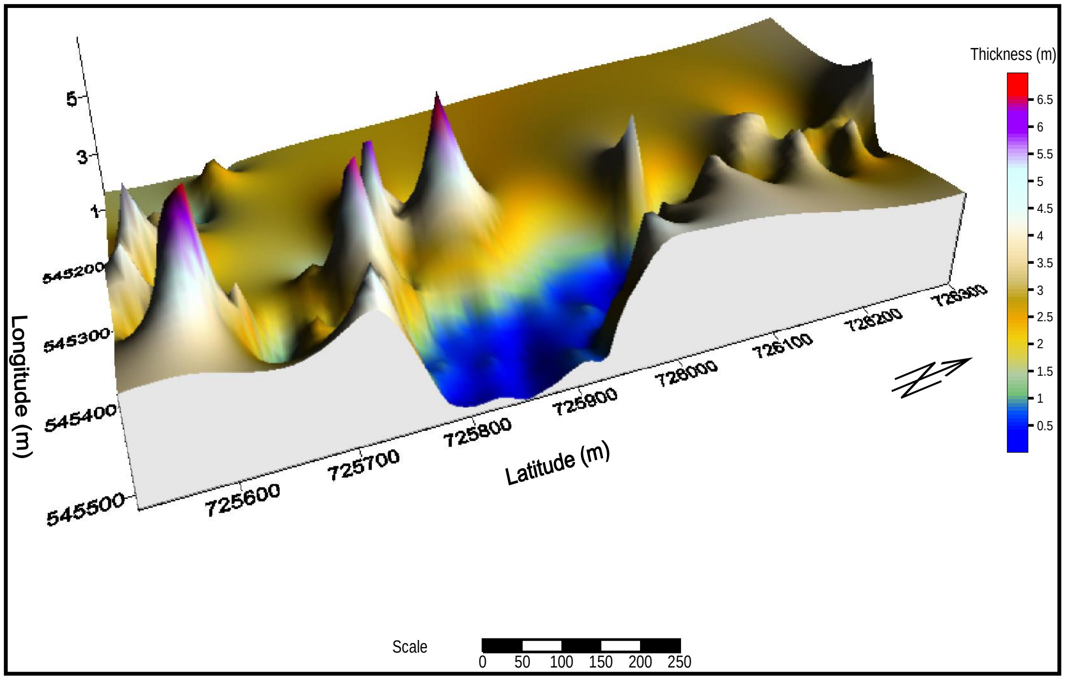


Figure 6: 3D Isopach Map (South-Eastern View) of Agboyi-Ogudu, Lagos State.

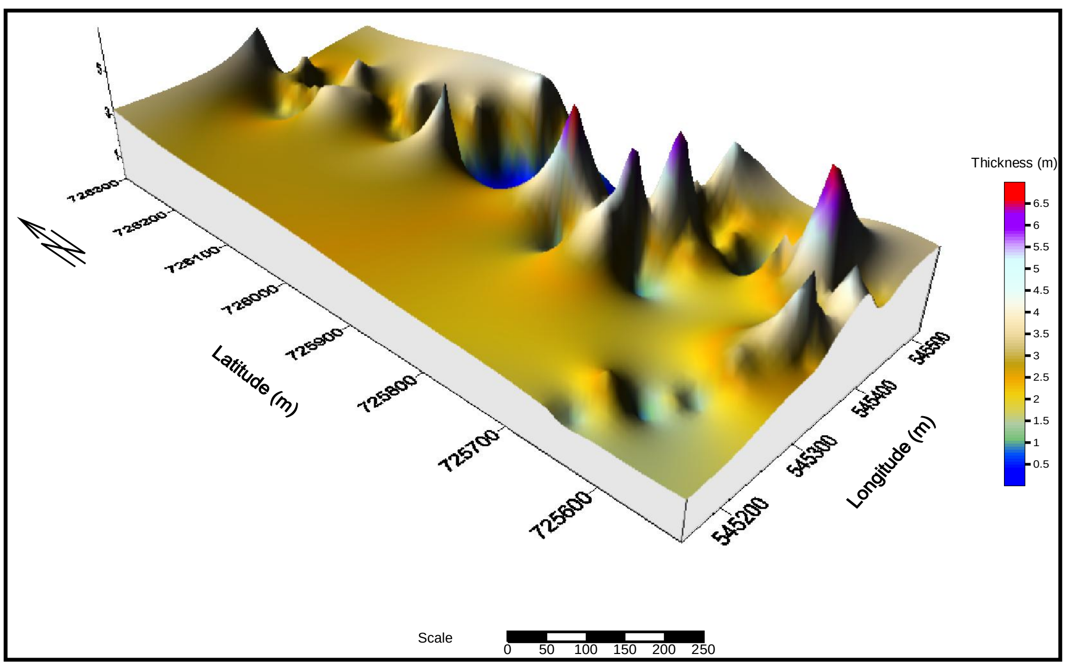


Figure 7: Isopach Map (North-Western View) of Agboyi-Ogudu, Lagos State.

Table 1. True Resistivity and Horizon Depths.

VES Number	Number of Layers	Resistivity(Ωm)	Thickness(m)	Depth(m)	Lithology
1	1	36.16	0.54	0.54	Topsoil (Sand)
	2	7.85	2.55	3.09	Sand
	3	0.16	5.09	8.18	Clay
	4	5.63	---	---	Clay
2	1	25.44	0.74	0.74	Topsoil (Sand)
	2	4.12	1.98	2.73	Sand
	3	0.41	3.87	6.59	Clay
	4	3.30	---	---	Clay
3	1	41.48	0.62	0.62	Topsoil (Sand)
	2	5.74	2.19	2.81	Sand
	3	0.47	14.75	17.56	Clay
	4	14.05	---	---	Clay
4	1	204.54	0.47	0.47	Topsoil (Sand)
	2	5.15	2.79	3.26	Sand
	3	0.88	14.37	17.63	Clay
	4	29.16	---	---	Clay
5	1	95.83	0.57	0.57	Topsoil (Sand)
	2	3.63	0.53	1.10	Sand
	3	1.46	18.52	19.62	Clay
	4	4.10	---	---	Clay
6	1	74.37	0.47	0.47	Topsoil (Sand)
	2	5.02	1.39	1.86	Sand
	3	1.26	3.76	5.62	Clay
	4	8.35	---	---	Clay
7	1	190.9	0.43	0.43	Topsoil (Sand)
	2	84.81	0.29	0.72	Sand
	3	4.95	2.97	3.69	Sand
	4	9.53	14.20	17.89	Clay
	5	5.20	---	---	Clay
8	1	28.04	0.58	0.58	Topsoil (Sand)
	2	3.36	2.54	3.12	Sand
	3	1.19	11.22	14.34	Clay
	4	9.69			Clay
9	1	5.73	1.26	1.26	Topsoil (Sand)
	2	0.91	3.24	4.50	Sand
	3	1.52	15.94	20.44	Clay
	4	2.16	---	---	Clay

Table 2: Borehole log

Sample	Depth(m)	Lithology
1	0 – 0.15	Brownish Clay (with plant roots)
2	0.15 – 1.50	Brownish- grey clay
3	2.25 - 3.0	Medium to coarse grained sand(light grey)
4	3.50 – 4.25	Fine sandy clay (light grey)
5	4.50 – 5.25	Fine - medium sandy clay (compacted)
6	5.25 – 6.0	Dark grey clay
7	6.0 – 6.75	Dark grey clay
8	6.75 – 7.5	Dark grey clay
9	7.50 – 8.25	Dark grey clay
10	8.25 – 9.00	Dark grey clay
11	9.0 – 9.75	Dark grey clay (compact)
12	9.75 – 10.25	Dark grey clay (compact)
13	10.25 – 11.00	Dark grey clay (compact)
14	11.00 – 11.75	Dark grey clay (compact)
15	12.00 – 12.55	Dark grey clay (compact)
16	12.55 – 13.25	Dark grey clay (compact)
17	13.50 – 14.25	Dark grey clay (compact)

4.0. Discussion

4.1. Geo-electric Sections

The well log data of the borehole drilled, induced polarization and VES data were used to infer geoelectric layers. These were later used to draw the geoelectric sections AA’, BB’, CC’, DD’, EE’, FF’, GG’, HH’, II’, JJ’, KK’ and LL’. The layer resistivities and thicknesses indicate four to five subsurface layers. The topsoil is made up of sand, clay and clayed sand. The sand has resistivity values which vary from 0.53 to 90.60 ohm-m with layer thickness 0.2-7.25m. The clay shows resistivity contrast 0.93-9.13ohm-m with layer thickness between 0.23m and 6.00m while clayey sand has thickness and resistivity value of 1.59m and 2.16 ohm-m respectively.

Sand, clay and sandy clay constitute the second geoelectric layer. The sand has layer thickness and resistivities values that vary from 0.34-5.67m and 0.98-120.34 ohm-m respectively. The clay has resistivity values that range from 0.6-1130ohm-m and thickness values that vary between 0.73-7.89m. The resistivities in sandy clay vary from 0.35 to 1.55ohm-m with earth thickness 0.74-6.99m.

The third horizon is symptomatic of clay, sandy clay, and sand. The clay has resistivity values between 0.16 and 28.73ohm-m while its thickness varies from 0.15 to 17.43m. In some of the VES data, thickness could not be determined because the current terminated within this layer. Clayeysand/sandy clay region have 1.71-21.30m layer thickness with resistivity values ranging from 0.71ohm-m to certained because the current terminated within this region. The sand exhibits resistivity values 0.59-96.44ohm-m and its thickness falls between 3.89 and 3.19m.

Table 3: Estimation of volume of sand within each cell

VES Points	Average Thickness(m	Area(m^2)	Volume(m^3)
1,2,3,4,5	2.5560	3283.2428	8391.9686
6,7,8,9,10	1.7440	4530.8750	7901.8460
1,2,17	2.9000	1025.3820	2973.6078
11,12,18,19	2.3450	2060.8662	4832.7312
12,13,19,20	2.8225	1333.5017	3763.8085
13,14,20,21	4.7775	1333.5017	6370.8044
14,15,21,22	4.5225	1333.5017	6030.7614
15,16,22,23	2.6225	1575.9565	4132.9459
24,25,39,40	1.9300	947.0893	1827.8823
25,26,40,41	2.2100	694.5321	1534.9159
26,27,41,42	3.3900	694.5321	2354.4638
27,28,42,43	3.0025	694.5321	2085.3326
28,29,43,44	1.0525	694.5321	730.9950
29,30,44,45	0.4650	694.5321	322.9574
30,31,45,46	0.3950	694.5321	274.3402
31,32,46,47	0.2450	694.5321	170.1604
32,33,47,48	0.1625	694.5321	112.8615
33,34,48,49	0.5775	694.5321	401.0923
34,35,49,50	0.6375	694.5321	442.7642
35,36,50,51	1.0650	694.5321	739.6767
36,37,51,52	1.5525	694.5321	1078.2611
37,38,52,53	2.1575	694.5321	1498.4530
38,53,54,55	2.9550	719.7827	2126.9579
39,40,56,57	2.4000	947.0893	2273.0143
40,41,57,58	3.4800	625.0000	2175.0000
41,42,58,59	4.1825	625.0000	2614.0625
42,43,59,60	2.5575	625.0000	1598.4375
43,44,60,61	1.1050	625.0000	690.6250
44,45,61,62	0.6050	625.0000	378.1250
45,46,62,63	0.4950	625.0000	309.3750
46,47,63,64	0.2450	625.0000	153.1250
47,48,64,65	0.1800	625.0000	112.5000
48,49,65,66	0.5150	625.0000	321.8750
49,50,66,67	0.6375	625.0000	398.4375
50,51,67,68	0.5125	625.0000	320.3125
51,52,68,69	0.3850	625.0000	240.6250
52,53,69,70	0.5100	625.0000	318.7500
53,54,70,71	1.2875	625.0000	804.6875
54,55,71,72	1.8400	625.0000	1150.0000
56,57,73,74	2.5150	947.0893	2381.9296
57,58,74,75	4.0450	625.0000	2528.1250
58,59,75,76	3.8700	625.0000	2418.7500
59,60,76,77	2.3300	625.0000	1456.2500
60,61,77,78	1.5575	625.0000	973.4375
61,62,78,79	0.7250	1055.6889	765.3745
62,63,79,80	0.7000	1055.6889	738.9822
63,64,80,81	0.5350	1055.6889	564.7936
64,65,81,82	0.4500	1055.6889	475.0600
65,66,82,83	0.5600	1055.6889	591.1858

VES Points	Average Thickness(m)	Area(m^2)	Volume(m^3)
66,67,83,84	0.6225	1055.6889	657.1663
67,68,84,85	0.5625	1055.6889	593.8250
68,69,85,86	0.4325	1055.6889	456.5854
69,70,86,87	1.7150	1055.6889	1810.5065
70,71,87,88	2.3375	1055.6889	2467.6728
71,72,88	1.3833	544.4569	753.1654
73,74,89,90	1.6425	947.0893	1555.5942
74,75,90,91	3.6725	625.0000	2295.3125
75,76,91,92	3.7175	625.0000	2323.4375
76,77,92,93	2.5175	625.0000	1573.4375
77,78,93,94	3.5475	625.0000	2217.1875
89,90,95,96	2.5425	1414.3200	3595.9086
90,91,96,97	4.0475	889.0011	3598.2320
91,92,97,98	3.5600	889.0011	3164.8439
92,93,94,98	3.7325	1181.9269	4411.5422
99,107,108	3.1933	1212.2743	3871.1959
99,100,108,109	2.7375	889.0011	2433.6405
100,101,109,110	2.9750	889.0011	2644.7783
101,102,110,111	3.3950	889.0011	3018.1587
102,103,111,112	3.0100	889.0011	2675.8933
103,104,112,113	2.9725	889.0011	2642.5558
104,105,113,114	2.6750	889.0011	2378.0779
105,106,114,115	1.8950	889.0011	1684.6571
107,108,117,118	2.5425	1288.0414	3274.8453
108,109,118,119	2.7000	944.5637	2550.3220
109,110,119,120	3.4750	944.5637	3282.3589
110,111,120,121	3.4850	944.5637	3291.8045
111,112,121,122	2.8625	944.5637	2703.8136
112,113,122,123	2.3750	625.0000	1484.3750
113,114,123,124	2.3750	944.5637	2243.3388
114,115,124,125	2.6550	944.5637	2507.8166
106,115,125,116	2.9075	1575.9565	4582.0935
Total			**165596.5712**

The fourth substratum layer denotes clay, sandy clay/clayed sand and sand. The clay, sandy clay/clayedsand and sand have resistivity values that vary from 1.18-28.81ohm-m, 3.11-89.64ohm-m, and 2.13-31.30ohm-m respectively. The layer thicknesses could not be determined because the current terminated within those zones except in some parts of clay region where VES 8 and VES 20 have layer thicknesses of between 7.38 and 17.89m.

The fifth identified layer is diagnostic sections AA', CC', DD', and FF'. The resistivity values in clay vary from 0.11-25.64ohm-m while those in clayey sand/sandy clay ranging between 4.78 and 5.92ohm-m. Their earth thickness could not be determined because the current terminated within these horizons. 97.59ohm-m in some of the VES. Also, the earth thickness of some VES could not be as

4.2. Isopach Maps

The 2-D Isopach map in Figure 5 shows the distribution of the sand in the area investigated with thickness ranging from 0.5 to almost 7.0m. The 3-D Isopach map along South-Eastern view of the study area (Figure 6) shows the distribution of the trough and peak of the sand. The thickness of the sand ranges from 0.5m to almost7.0m. The 3-D Isopach map along the North-Western view of the area investigated shows the distribution of the trough and peak of the sand with thickness between 0.5m and almost 7.0m (Figure 7).

The analysis of both 2-D and 3-D Isopach maps show that the sand thickness varies from 0.5m to almost 7.0m.

4.3. Volume of sand

The study area was divided into square, rectangular, triangular and trapezoidal cells. The volume of sand within each cell was calculated as shown in Table 3. Hence, these results were summed to give a total volume of 165,596.5712m^3 of sand.

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