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EFFECT OF TOPOGRAPHIC AND GEOLOGIC HETEROGENEITIES ON THE DISTRIBUTION PATTERN OF AQUIFERS IN AKWA IBOM STATE, SOUTHEASTERN NIGERIA.

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ABSTRACT

Geologic heterogeneities and topographic variations in relation to aquifer distribution and occurrence in Akwa Ibom State have been assessed based on geologic and geophysical studies Sixty-six sounding points together with electric log responses of representative wells together with surface geologic data have been integrated and used in deciphering subsurface variations in hydrologic unit in the state. The results show that three aquiferous units, made up of medium to coarse grained whitish sands exist within a depth range of 72 to 98 metres and having resistivities less than 1500 ohm metres. These aquifers are clearly defined in those locations close to the coast and in the hinterlands whereas towards the northern parts of the state they appear to pinch-out or dip downward to much greater depths. Measurements of elevation across the study area show a drastic decrease in altitude tending toward the mean sea level within the hinterland and coastal regions, whereas towards the northern part, relatively higher elevations exist. The increase in altitude in addition to the occurrence of thick columns of compacted shales greatly account for the scarcity of aquiferous zones in this northern part of the study area contrary to the localities within and surrounding the coastal and central regions.

Key words: Heterogeneities, aquifer, topography, pinch-out, hydrologic.

INTRODUCTION

This paper outlines the effects of geologic heterogeneities and topographic variations on the distribution patterns of aquifers in parts of Akwa Ibom State, southern Nigeria (Figure 1). According to Esu et al (1999), the estimated areal extent of the state is about 6500km and it lies within longitudes 7°30' and 8°21' East and latitudes 4°30' and 5°30' North. The area belongs to the low-lying coastal/deltaic plains of Southern Nigeria (Masasan and Quinn-Young, 1977).

This paper considers in regional terms the aquifer delineation and distribution in parts of the area. The paper therefore attempts to adduce reasons for the uneven distribution of ground water in the area given the fact that the study area lies within the same geologic and geographic provinces. It is therefore not uncommon to document numerous failed water projects in some parts of the area whereas greater success records abound in some other parts. It is the intent of this paper to unravel the mysteries surrounding this observation and to proffer a more appropriate remedy for the water supply problems to the inhabitants of these hydrogeologically 'hostile' environments within the study area.

Significantly, the initial site appraisal vis-à-vis groundwater development schemes in the study area from this report is very possible. In this regard, it would be possible to pre-emp' and anticipate the perculiar condition(s) of the field remediation steps adopted to achieve success.

In carrying out this study, a two month intensive geological mapping, surface resistivity surveys as well as downhole borehole logging were done in 20 Local Government Areas of the state (table 1) which considered quite representative.

GENERAL GEOLOGY

The geology of Akaw Ibom has been extensively studied by many workers among whom are Amajor (1986), Petters (1989), Esu et al. (1999), Inyang (1995), Effanga and Chuku (1995). According to these authors, the area belongs to the southern pars of the Cretaceous to Teritary sedimentary basin of Southern Nigeria, including parts of the lower Benue Trough and the Niger delta (Figure 2). The area is underlain by Maastrichtian to Pleistocene sedimentary rocks dipping 6-10° southwest (Esu et al., 1999). According to these authors, the late Cretaceous and early Tertiary, comprising the Ajali and

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Table 1: Localities and documented data.

S/No	Locality Name	VES Date	Log Data	Elevation (M)	Sectoral Classification
1	Okon Ita	Available	Not available	26.2	C
2	Afaha Ufuat	..	..	24.7	C
3	Ikot Akpan Nya	..	..	24.1	C
4	Okopedi Use	..	..	20.4	C
5	Ikot Ekpeyak	..	..	18.2	T
6	Ikot Oku Akpan	..	Not available	32.3	T
7	Ikot Nya	..	Available	21.3	B
8	Afaha Abia	..	..	26.8	B
9	Ikot Akpabio	..	..	29.6	B
10	Ikot Unya	..	..	31.1	B
11	Ikot Ubo Akpan	..	Not available	18.9	B
12	Asunna	..	..	21.0	B
13	Ekom Iman	Not available	Available	17.1	B
14	Ikot Ekan	Available	..	19.5	B
15	Ndon Eyo	..	..	21.3	B
16	Mbat Ikot Abasi	..	Not available	39.0	A
17	Ikot Akpan Abia	..		47.5	A
18	Ikot Ekpene Prison	..	Available	46.9	A
19	Ikot Edibon	..	..	17.4	A
20	Ibakang	..	Available	15.8	A

Table 2: Half-Current electrode (AB/2) Spacing and corresponding VES date for Ikot Edibon, Nsit Ubium LGA.

S/No	AB/2	ρ_1(Ohm-m)	ρ_2(Ohm-m)	ρ_3(Ohm-m)
1	1	182	154	254
2	2	253	155	273
3	2	294	198	300
4	4	472	255	259
5	6	947	314	198
6	6	869	390	201
7	8	926	426	215
8	10	1074	506	233
9	10	940	536	248
10	15	961	785	263
11	20	1485	1061	279
12	20	2061	1028	400
13	30	1256	1313	474
14	40	1012	1412	565
15	40	1023	1946	600
16	50	916	1561	900
17	60	831	972	879
18	60	769	961	1099
19	80	628	1006	1233
20	100	609	940	2116
21	100	698	818	1578
22	150	620	801	1241
23	200	536	678	1915
24	200	368	612	1234
25	250	461	658	809
26	300	496	408	941
27	350	380	-	688
28	400	-	-	775

- Error 1 could not be resolved

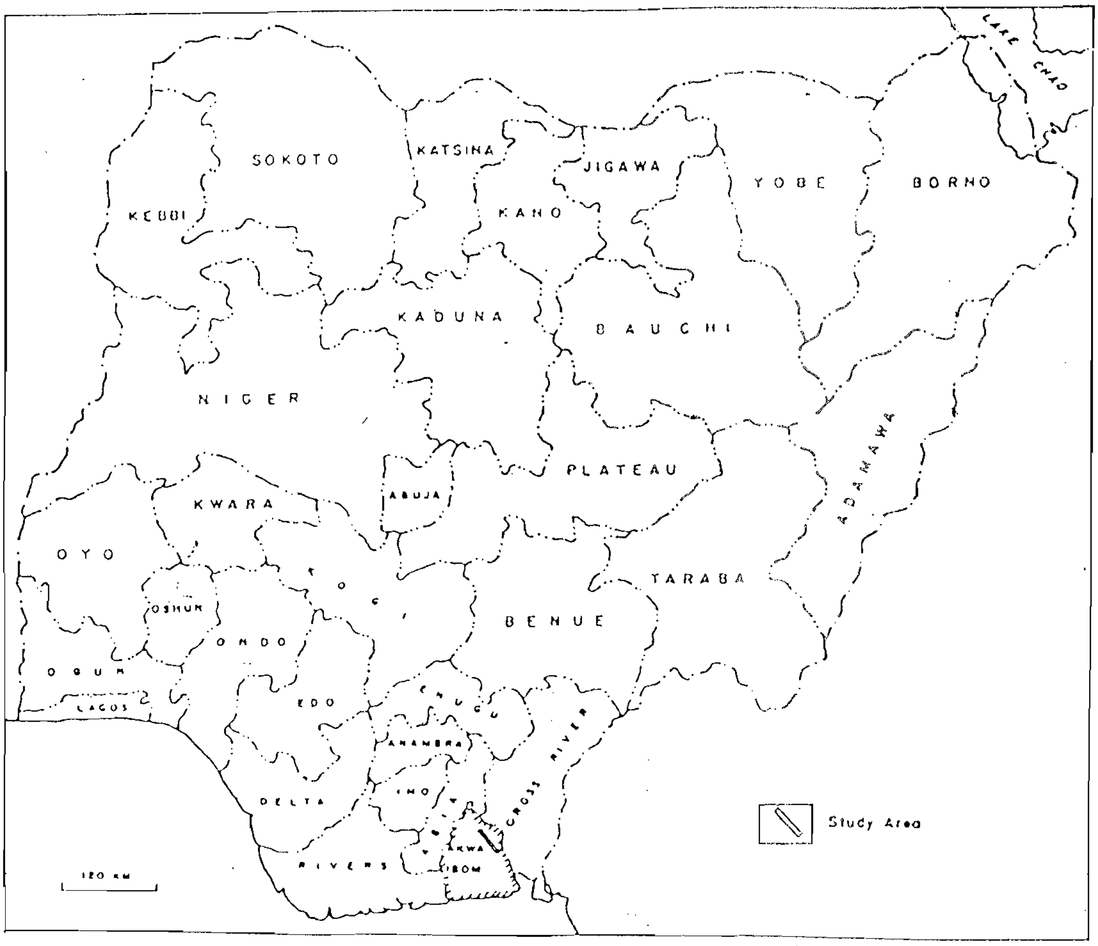

Figure 1 Map of Nigeria showing Akwa Ibom State with study Area

Nsukka Formations, the Imo shale and Ameki Groups underlie a strip, about 3 to 15km wide in the northeast, forming the northern part of the Calabar Flank (Figure 2). These strata are more extensively developed in the Anambra Basin further northwest of the present study area. It is also evident that more than 85% of the study area is underlain mainly by Neogene and Quaternary sediments of the Niger Delta which comprise the Ogwashi-Asaba and Benin Formations. As shown by Inyang 91995) and Esu et al (1999). The geological succession of the area consists mostly of shales, sandstones, sands and clays representing the transgression and regression episodes which characterized the development of southern Nigeria sedimentary basin. The shales generally thicken northwards whereas down to the coastal regions, sands of various sizes predominate.

METHODOLOGY

After a preliminary general geological mapping of the study area, sixty sounding points were made in selected localities (table 1). The maximum half current electrode spacing (AB/2m) was varied from 350 meters to 500 meters depending on the complexities in geology and availability of space. For each location, 3 soundings, using Schlumberger electrode array were made on the basis of which Government boreholes drilled by the Cross River State Basin and Rural Development Authority were sited. All the interpreted curves with distinctive similarities were selected and grouped in accordance with the three sub-classified zones (Figure 3) made for the entire area. A representative curve from amongst the three (Figures 3-6) (a-c respectively) so selected from the respective zones A,B,C and an unclassified transitional zone (Fig 6a-c respectively) were then displayed and interpreted.

Drilled cuttings from the boreholes drilled during this project period were collected and the electrical logging of the wells (where applicable) was made. The combination of lithofacies characteristics and electric log responses coupled

Table 3: Half-current elecrode (AB/2) spacing and corresponding VES data for Asunan, Etinan

S/N0	AB/2 (M)	ρ_1(Ohm-m)	ρ_2(Ohm-m)	ρ_3(Ohm-m)
1	1	168	171	248
2	2	162	179	196
3	4	290	172	465
4	6	291	223	526
5	8	117	320	578
6	10	370	304	516
7	15	789	384	641
8	20	1781	497	807
9	20	763	586	1318
10	40	2084	717	816
11	40	1734	627	650
12	50	3837	607	925
13	60	4806	802	722
14	60	2508	810	781
15	80	4470	939	786
16	100	6021	1295	622
17	100	3910	1011	767
18	150	9432	1023	682
19	200	6723	1830	654
20	200	1292	663	361
21	250	1576	568	466
22	300	1522	333	425
23	300	1798	-	-
24	350	2733	-	-
25	400	3640	-	-
26	500	3862	-	-

Table 4: Half-currrent electrode (AB/2) spacing and corresponding VES data for Ikot Obio Okon, Ibiono LGA

S/N0	AB/2 (m)	Mn/2 (m)	ρ_1(Ohm-m)	ρ_2(Ohm-m)	ρ_3(Ohm-m)
1	1	0.25	463.2	552	491
2	2	0.5	696.3	647	505
3	2	0.5	511.3	604	464
4	4	0.5	510.8	561	446
5	6	1.0	238	352	423
6	6	1.0	440	477	387
7	8	1.0	426.7	489	514
8	10	2.0	1471	723	635
9	10	2.0	477.7	646	671
10	15	2.0	732.5	706	664
11	20	4.0	616.1	594	542
12	20	4.0	666.5	631	749
13	30	4.0	770.6	729	703
14	40	8.0	667.4	916	822
15	40	8.0	1064.6	1129	936
16	50	8.0	1162.3	1181	1057
17	60	12.0	2749	1646	1238
18	60	12.0	1230.5	1504	1361
19	80	12.0	1402	1467	1618
20	100	20	4167	1527	1672
21	100	20	1.172	1606	1785
22	150	20	2657.1	1518	1923
23	200	30	811	1326	1700
24	200	30	3480	1663	1958
25	250	30	3451	1729	1896
26	300	40	7096	2017	1995
27	300	40	3565	-	-
28	350	40	2948	-	-

Table 5: Half-current electrode (AB/2) spacing and corresponding VES data for Afaha Utuat, Ibiono Ibom LGA.

S/N0	AB/2(m)	$_1$(ohm-m)	$_2$(ohm-m)	$_3$(0hm-m)
1	1	69	66	338
2	2	74	51	439
3	2	66	62	380
4	4	73	50	351
5	6	89	49	206
6	8	87	47	222
7	10	88	54	154
9	20	105	91	101
10	30	97	83	25
11	40	94	98	12
12	50	142	107	14
13	60	69	152	10
14	60	80	133	32
15	80	57	126	36
16	100	20	126	45
17	100	61	210	57
18	150	35	182	52
19	200	32	156	55
20	200	36	195	86
21	250	17	95	25
22	300	32	73	52
23	300	27	64	63
24	350	5	28	60.5
25	400	4	17.2	43
26	400	28	19	-
27	500	23	-	-

Table 6: Selected representatives VES Data from each of zones A, B, and C

Locality		VES 1	VES2	VES 3
		Layer Resistivity and thickness		
Mbat Ikot Abase (Zone A)	Layer 1 Layer 2 Layer 3 Layer 4	1523Ωm.(2.3m) 323Ωm, (31.7m) 1350Ωm, (62.0m) 689Ωm, -	2479Ωm, (1.9m) 1438Ωm, (11.1m) 2872Ωm, (76.5m) 868Ωm, -	1460Ωm, (1.5m) 831Ωm, (13.1m) 1585Ωm, (84.4m) 732Ωm,
Asunan (Zone B)	Layer 1 Layer 2 Layer 3 Layer 4	24Ωm, (14.0m) 377Ωm, (16.0m.) 1952Ωm, (55.0m) 689Ωm, -	56Ωm, (3.m) 116Ωm, (26.0m) 558, -	133Ωm, (2.9m) 432Ωm, (10.1m) 307Ωm, -
Afaha Ufuat (Zone C)	Layer 1 Layer 2 Layer 3 Layer 4	1754Ωm, (32.0m) 278Ωm, (70.0m) 34Ωm, - - -	480Ωm, (5.0m) 153Ωm, (62.0m) 20Ωm, - - -	1835Ωm, (3.2m) 340Ωm, (12.5m) 44Ωm, - - -
Ikot Obio Okon (Transitionary Zone)	Layer 1 Layer 2 Layer 3 Layer 4	178Ωm, (6.0m) 628Ωm, (42.0m) 3400Ωm, (44.2m) 6835Ωm, -	640Ωm, (2.1m) 1163Ωm, (39.3m) 2124Ωm, (54.6m) 3277Ωm, -	701Ωm, (3.2m) 1004Ωm, (28.2m) 2989Ωm, (61.6m) 1850Ωm, -

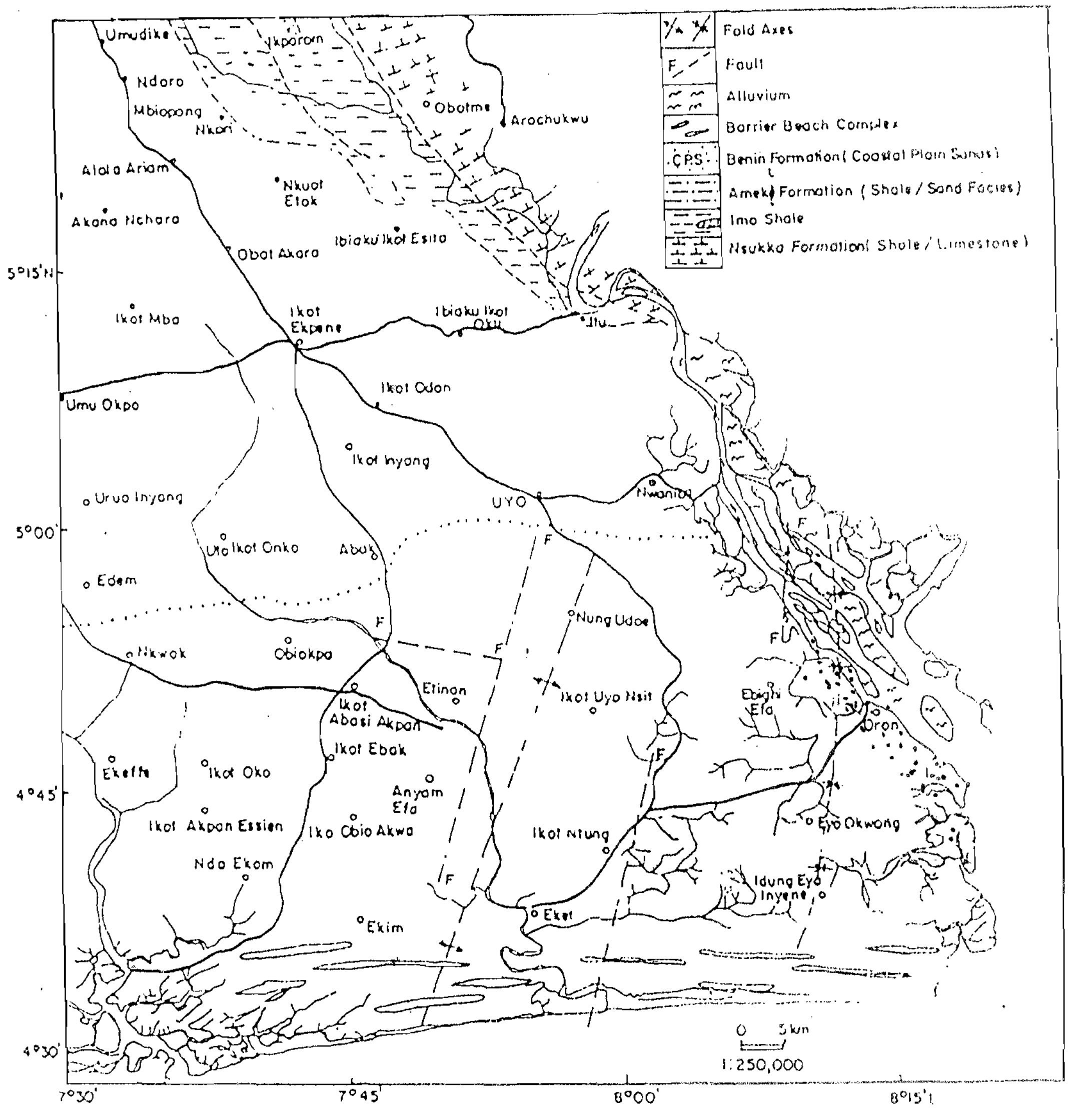

Figure 2 Geological Map of Akwa Ibom State (Modified from Petters, 1989)

with the surface geophysical and geological interpretation provided adequate information on the groundwater potentials of the study area. Variations in elevation were documented for each location with the help of a ground positioning system (GPS). Computer modeling programme (Zoddy) was used for the interpretation of the VES data for proper delineation of the various aquiferous units existing in the study area. Delineated aquifers were then correlated along strike in terms of both thickness and depth of occurrence in all the localities in a similar manner in which the well cuttings and electric log responses (from wells that were available for logging) were done.

DISCUSSION OF RESULTS

Figure 3-6 (a-c respectively) are the representative curves and selected from the stack of Nine sounding points from each of the sectional zones of extreme south (coastal region), central and the northern axis. Table 3 gives the interpretation made from the curves. Also, figure 7 is a typical (representative) log display for one of the representative wells from sector B.

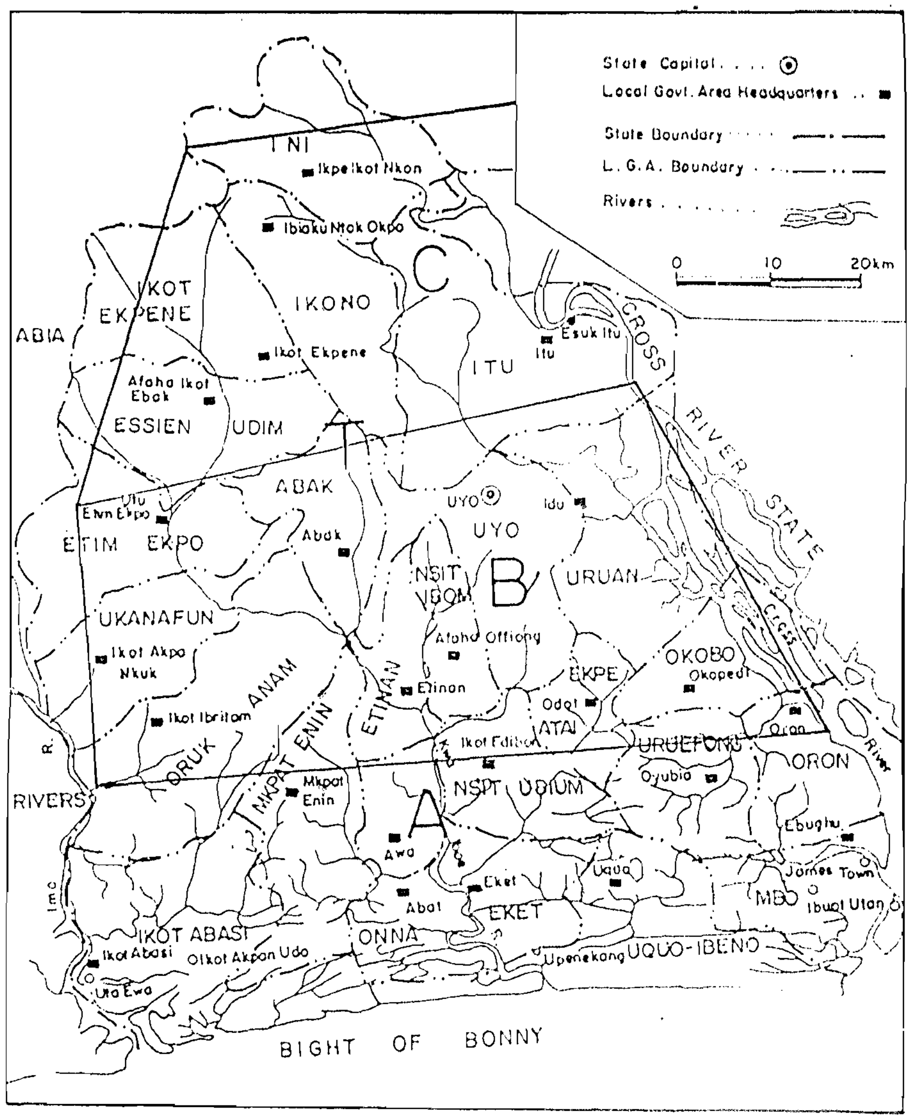

Figure 2b Map of Akwa Ibom State showing the Local Government Areas sectional subdivisions. (Modified from Petters, 1989)

Interpretation made on the basis of figures 3-11 have revealed the existence of 3 resistive earth layers in all three sectors. Results show that layers 2 and 3 in the localities within sectors A and B (figure 3) with resistivities of 377 and 1952 ohm meters, 323 and 1350 ohm meters respectively in section make up the main aquiferous units. These aquifers exist between 52 and 76 meters depth with insignificant variations in their depth of occurrences within the sector where unconsolidated sands with minor clays form the main lithologic units. The mean elevation value is no more than 20.7m. In section B, these aquifers occurs between 65 and 92 meters depth. Here the thickness of clay units and their abundance appear quite significant. On the basis of this, all the wells drilled within sector B were terminated between 100 and 110 metes whereas those of sector A were terminated between 82 and 87 meters. The apparent variations in the depths of occurrence of these aquifers show clearly that there is a slight dip variation in the formations of the area. This element of dip had earlier been reported and estimated to between 6

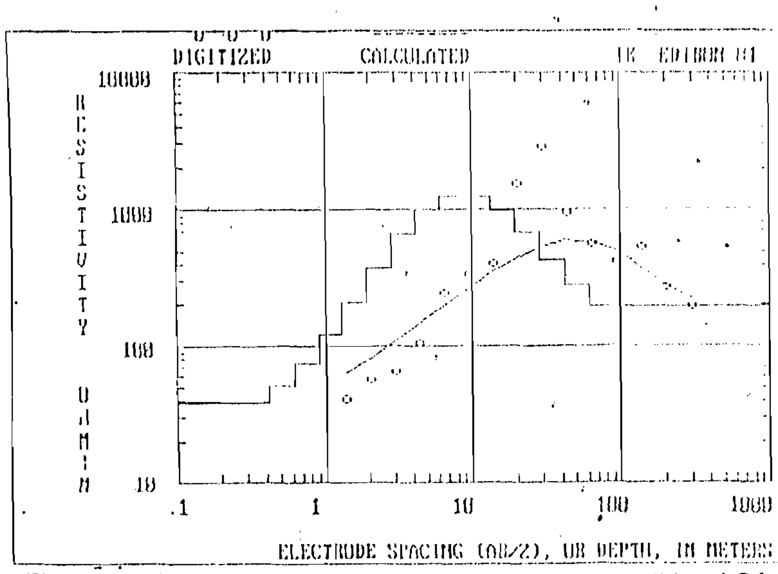

Figure 3a VES 1 modelled curve for Ikot Edibon, Nsit Ubium LGA.

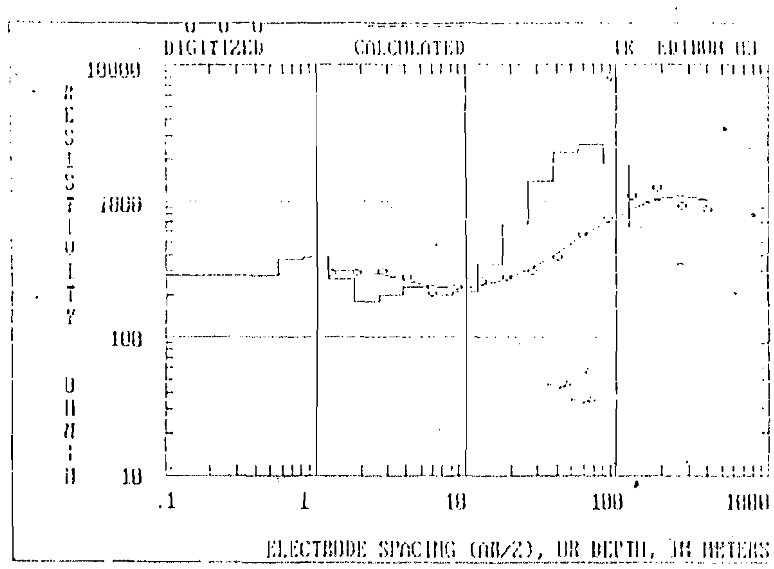

Figure 3b VES 3 modelled curve for Ikot Edibon, Nsit Ubium LGA.

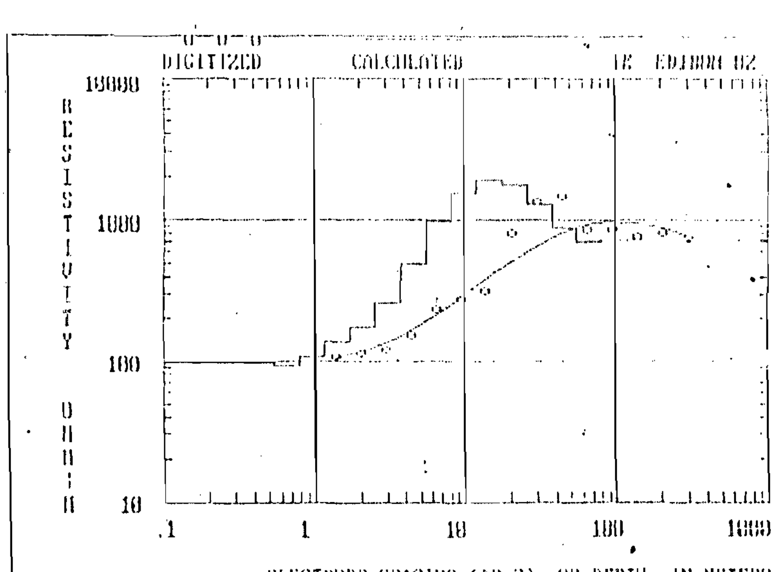

Figure 3a VES 2 modelled curve for Ikot Edibon, Nsit Ubium LGA.

Table 7: Lithological log data at Ibakang, Nsit Atai LGA Piezometric surface =18m

Depth (m)	Description
3.0	Brownish, semectitic clay
6.0	Brownish, semectitic clay
9.0	Fine-grained brownish sands
12.0	Fine-grained brownish sands
15.0	Fine-grained brownish sands
18.0	Fine-grained brownish sands
21.0	Medium-brownish sands
24.0	Medium-grained brownish sands
27.0	Medium-grained highly ferroginised sands
30.0	Medium- grained highly ferroginised sand
34.0	Gravelly sands
37.0	grained highly ferroginised
40.0	Fine-grained brownish sands
43.0	Fine-grained brownish sands
46.0	Very fine-grained whitish sands
48.0	Very fine-grained whitish sands
52.0	Fine-grained whitish sands
55.0	Fine-grained brownish sands
58.0	Fine-grained brownish sands
61.0	Fine-grained brownish sands
64.0	Fine-grained whitish sands
67.0	Fine-grained brownish sands
70.0	Medium-grained brownish sands
73.0	Medium-grained brownish sands
76.0	Fine-grained brownish sands
79.0	Fine-grained whitish sands with lignite disseminants
83.0	Fine- grained whitish sands with lignite disseminants
85.0	Fine-grained brownish sands
88.0	Fine-grained whitish sands

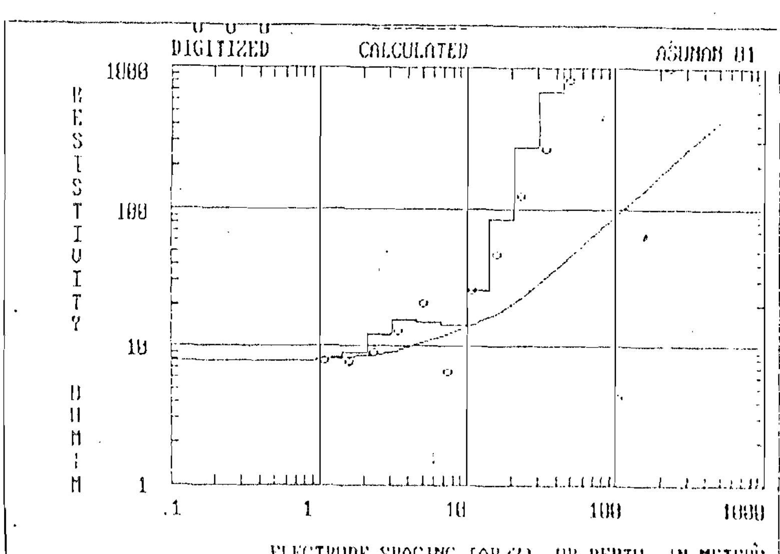

Figure 4a VES 1 modelled curve for Asunan, Etinan LGA.

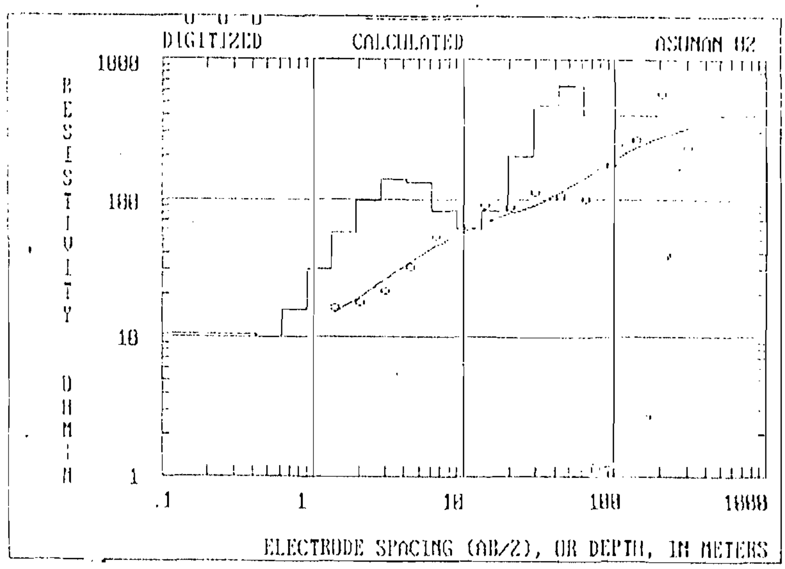

Figure 4b VES 2 modelled curve for Asunan, Etinan LGA.

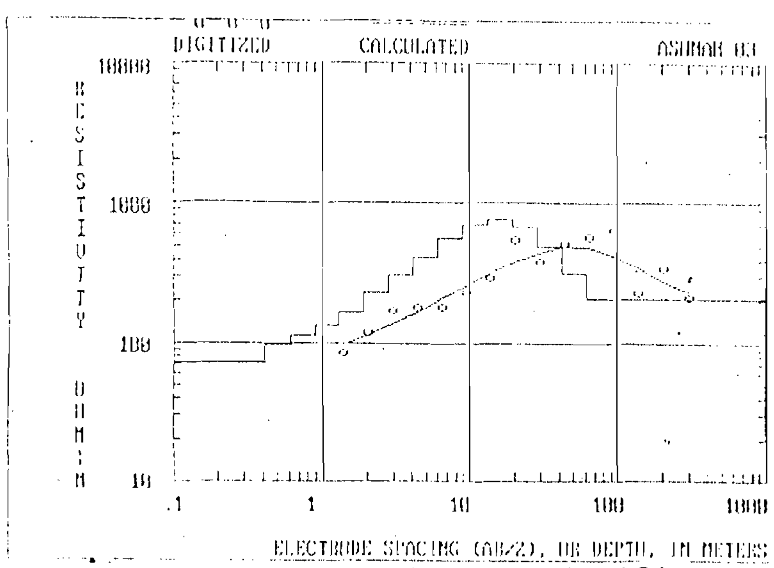

Figure 4c VES 3 modelled curve for Asunan, Etinan LGA.

and 10^{0} by Esu et al (1999). Drilled cuttings from wells within sectors A and B (tables 3 and 4) show a good agreement except for the frequencies of clay occurrences. Topographically, zone B rests on a higher ground based on the mean GPS reading of 87ft (26.5m).

In zone C, which comprises Ibiono Ibom, Ikono, Itu and the eastern part of Ikot Ekpene Local Government Areas, the results are unexpectedly different from those of zone A and B. Table 5, figures 3 and 6 which are the interpreted VES data of zone C do not reveal the occurrence of a shallow aquifers at all giving the resolving power of Terrameter SAS 300 used in the surveys. Villages within this sector clearly sit on a relatively higher elevated ground following a GPS reading of 167-186ft. Geologic mapping in the area reveals dominant occurrence of compacted clays, belonging to the Imo shales of Murat (1972) with minor sand stringers in places. Shales are known to have high porosities and very low permeabilities (Rider, 1986, North, 1990) and so generally inhibit free movement of ground water. Their resistivities which should at least give a fair correlation with those of zones A and B which defines the first and second aquifers are rather low (20-44Ωm) in most of the sounding points. It s therefore apparent that the aquifer units which stretches from zone A through B are either pinched-out getting to zone C or are rather dipping in the region, beyond resolvable depth. This may in parts lend credence to the considerable number of boreholes failures in this part of Akwa Ibom State. On the other hand, shallow unconfined aquifers exist at depth slightly greater 20m. Owing to the fact that saturated aquiferous units are apparent based on interpretations made from figure 6, it could be inferred that the areas within Ikot Obio Okon are in a transition zone which straddles the Tertiary-Cretaceous hydrostratigraphic units of Esu et al (1999). Hydrogeological potentials for communities within this region, even though classified into zone C subsector (southernmost

Table 8: Lithological log data at Ekom Iman, Etinan LGA Piezometric surface = 15m

Depth (m)	Description
3.0	Fine-grained brownish clayey sands
6.0	Brownish clay
9.0	Fine-grained, reddish sandy-clay
12.0	Fine-grained, brownish sands
15.0	Fine-grained, brownish sands
18.0	Fine-grained, brownish sands
21.0	Grayish, fine-grained sands
24.0	Medium –grained brownish sands
27.0	Medium-grained whitish sands
30.0	Medium –grained brownish sands
34.0	Medium-grained whitish sands
37.0	Medium-grained whitish sands
40.0	Medium-grained whitish sands
43.0	Medium-grained whitish sands
46.0	Fine-grained whitish sands
48.0	Fine-grained whitish sands
52.0	Medium-grained whitish sands
55.0	Coarse-grained grayish sands
58.0	Coarse-grained sandy-clay
61.0	Coarse-grained sandy-clay
64.0	Coarse-grained sandy-clay
67.0	Coarse-grained sandy-clay
70.0	Coarse-grained whitish sand
73.0	Fine-grained whitish sands
76.0	Fine-grained whitish sands
79.0	Fine-grained whitish sands
83.0	Fine-grained whitish sands
85.0	Fine-grained whitish sands
88.0	Fine-grained whitish sands
91.0	Fine-grained whitish sands

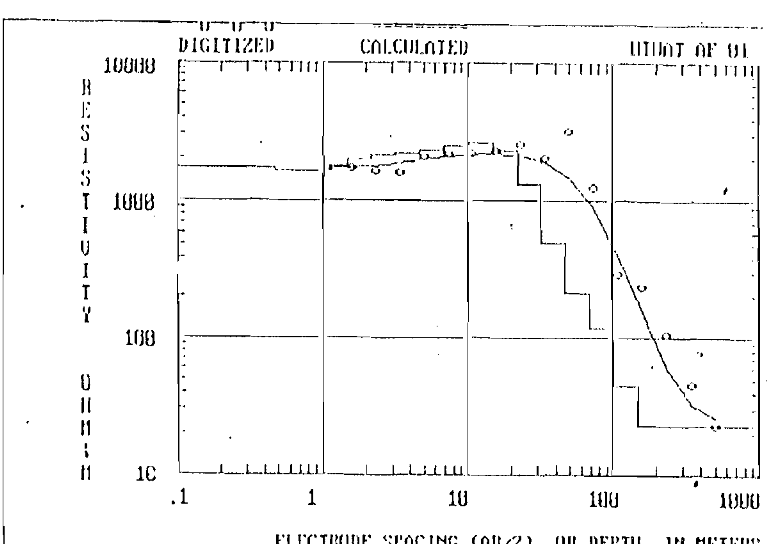

Figure 5a VES 1 modelled curve for Utuat Afaha, Ibiono Ibom LGA.

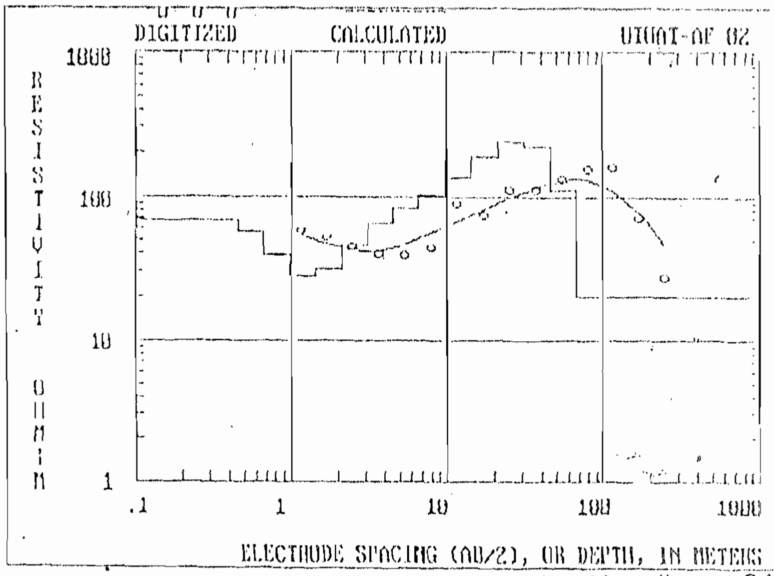

Figure 5b *VES 2 modelled curve for Utuat Afaha, Ibiono Ibom LGA.*

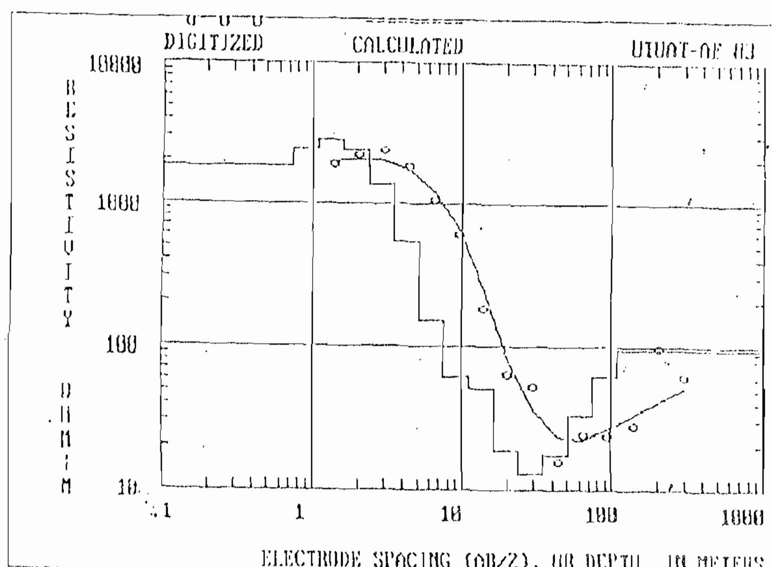

Figure 5c *VES 3 modelled curve for Utuat Afaha, Ibiono Ibom LGA.*

section) is expected to be high even though drilling into slightly relatively higher depth would necessarily have to be done owing to topographic variations in comparison with those of zones A and B.

CONCLUSION

Aquifer distribution patterns in Akwa Ibom State are greatly influenced by geologic and topographic variations. Within the coastal regions and the hinterlands, groundwater exploitation is very feasible owing to the predominance of saturated sands within relatively shallow depth intervals whereas up north within Ibiono Ibom and Itu Local Government Areas where topography is relatively higher together with the dominance of thick compacted clays as the main lithofacies, aquifers are lacking within considerable limit of the resolving power of Abbem Terrameter 300SAS, used in the investigation. Groundwater occurrence in this part of the study area therefore appears to favour surface water development schemes rather than the conventional borehole project involving particularly handpump wells.

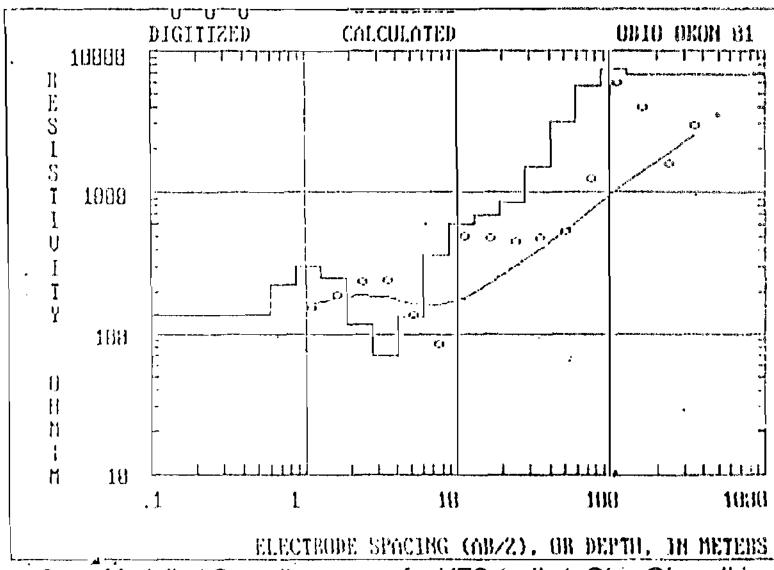

Figure 6a *Modelled Sounding curve for VES 1, Ikot Obio Okon, Ibiono Ibom LGA*

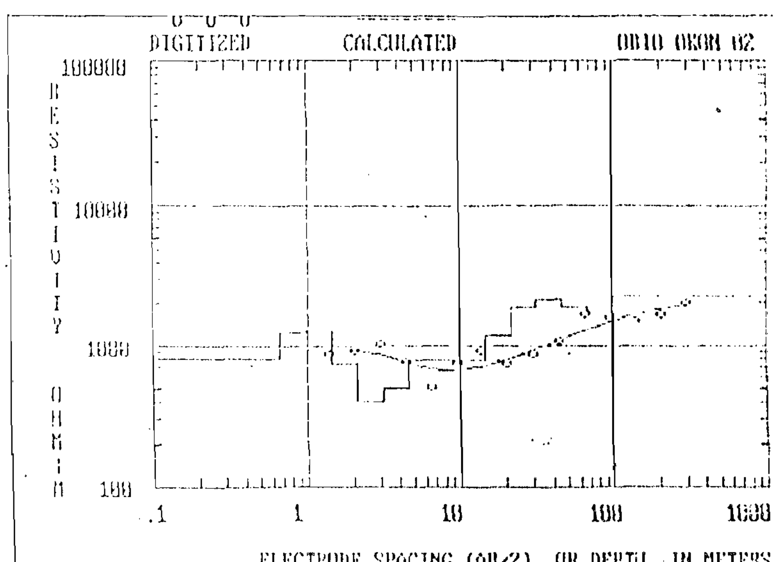

Figure 6b *Modelled Sounding curve for VES 2, Ikot Obio Okon, Ibiono Ibom LGA*

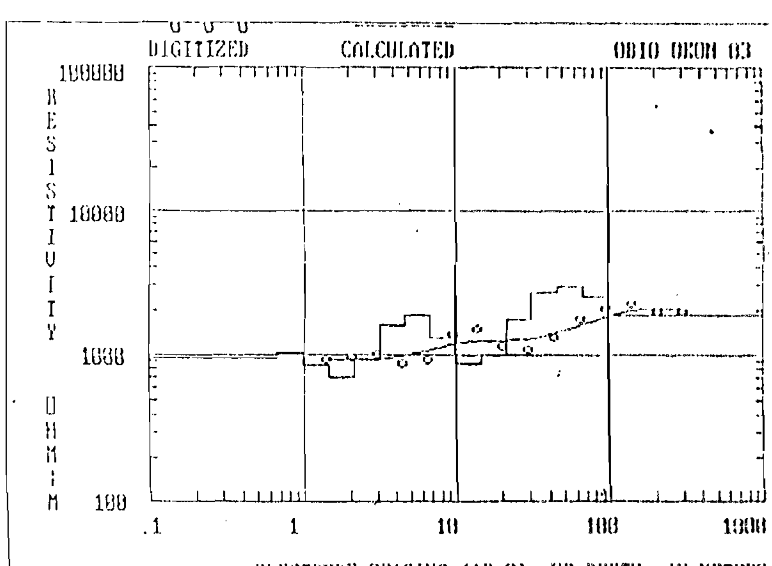

Figure 6c *Modelled Sounding curve for VES 3, Ikot Obio Okon, Ibiono Ibom LGA*

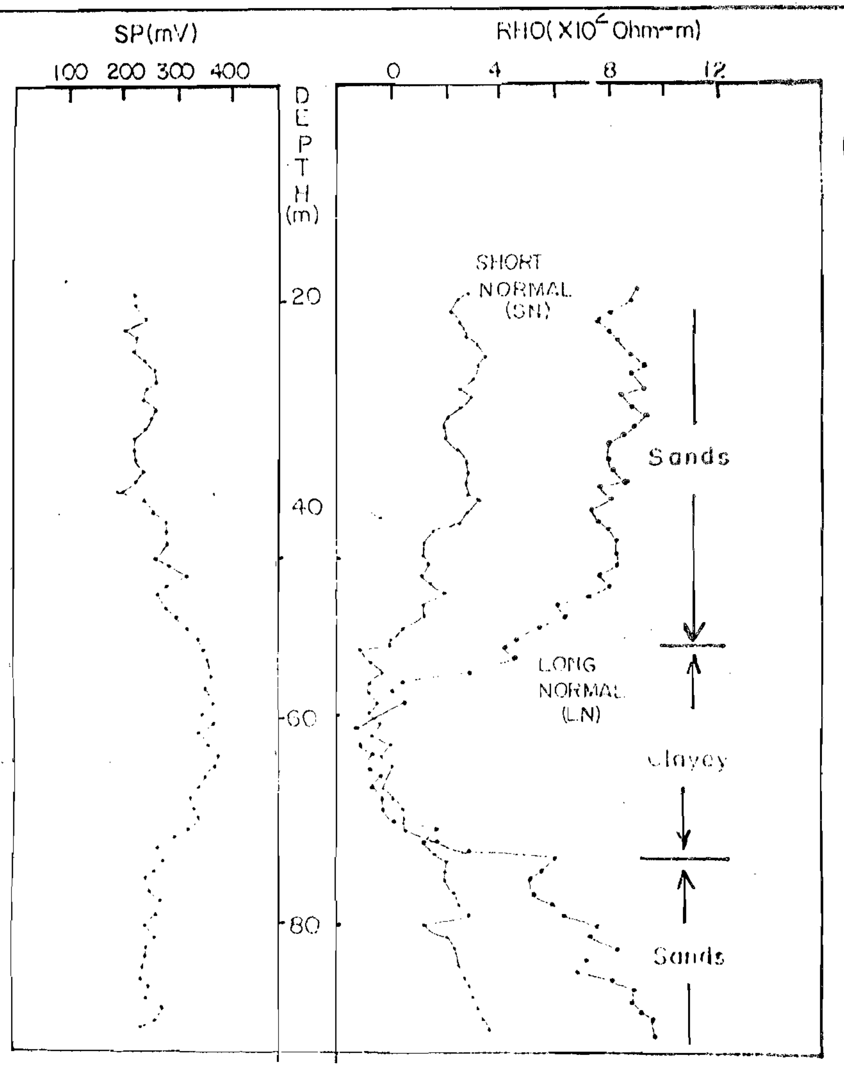

Figure 7 SP and Resistivity (SN and LN) logs at Ekom Iman, Etinan LGA

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REFERENCES

Amajor, L.C., 1986. Alluvial fan facies in the Pliocene Coastal plain sands. Niger Delta, Nigeria. Sed. Geol., (49): 1-20.

Effanga, K.S. and Chuku, D.U., 1995. Utilization of gravel in construction and other allied industries with reference to chalice gravel in parts of Akwa Ibom State. 31st NMGS Annual Conf. Abs.: 12

Esu, E.O., Okereke, C.S. and Edet, A. E., 1999. Regional Hydrostratigraphy study of Akwa Ibom State. Southeastern Nigeria. Global Journal of Pure and Applied Sciences, (5) 1: 89-96.

Inyang, D.O., 1995. Sedimentology of Gravel beds in Akwa Ibom State, Unpublished M.Sc Thesis: 1-182.

Masasan, J. A. and Quinn-Young, C. L., 1977. A Visual Geography of Nigeria. Evans Brothers Limited. London, p.86.

Murat, R.C., 1972. Stratigraphy and Palaeography of the Cretaceous and Lower Tertiary in Southern Nigeria. In: Dessauvagie, T.J.F. and Whiteman, A.J. (Eds). African Geology, University of Ibadan, Nigeria: 251-266.

North, F. K., 1990. Petroleum Geology. (2nd Ed) Unwin Hyman, Boston (Publ.) pp. 631.

Petters, S. W., 1989. Akwa Ibom State Physical background, soils and Land Use Ecological problems. Technical report of the task Force on soils and Land Use Survey. Akwa Ibom State, Government Printers, Uyo.

Rider, M. H., 1986. The Geological interpretation of well logs. John Wiley and sons (publi). New York: 175.