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A Preliminary Geoelectrical Appraisal for Groundwater in Yalla, Southern Benue Trough, South-East Nigeria

F.A Ushie and H.O Nwankwoala

Department of Geology, University of Port Harcourt, Nigeria

Abstract: A geoelectrical survey has been carried out in Yalla, Southern Benue Trough, South-East, Nigeria to assess the occurrence of groundwater. The area is underlain by a Cretaceous Sedimentary sequence of predominantly indurated shale, sandy shale and clay units which have been variously intruded by igneous bodies of doleritic compositions. The presence and movement of groundwater here is commonly due to the development of secondary porosity resulting from weathering and fracturing. This study involved Vertical Electrical Sounding (VES) at twenty four (24) location using the Schlumberger Array and 2 horizontal profiles using the Wenner Configuration. Results from these measurements show that there are at least four geo-electric layers. The first layer which is generally dry is about 2m thick on the average and it is the top soil. This is underlain by a saturated zone which may extend to 80m. This however, is excluding zones of non-fractured (compact) shales which are characterized by abnormally high resistivities. These peculiar layers intercalate the 2 major layers, creating conditions of confinement all through the area.

Key words: Vertical Electrical Sounding · Groundwater · Cretaceous Sediments · Igneous Intrusives · Benue-Trough

INTRODUCTION

A good knowledge of the origin and activities of groundwater and the environment where it accumulates are necessary to understand the manner in which it can be located. Incorrect or incomplete knowledge of this derails many an investigation and renders misleading interpretations. This exercise was therefore undertaken with the aim of studying the hydrogeolgic conditions of the area with a view of delineating potential areas of taping groundwater. Secondly, to determine the resistivities and thicknesses of the subsurface formations in order to establish the continuity of otherwise of conducting layers which are usually water bearing.

In the recent past, the drilling of boreholes was done blindly, which often resulted in failed boreholes and non-production. In recent times however, emphasizes is towards a scientific and technologically driven method aimed at delineating areas with enhanced potential for consequent exploitation [1].

Electrical resistivity method has been widely used in groundwater exploration, engineering site investigation and in geological mapping [2].The Electrical sounding method is useful for the deduction of the number of geo-electric layers, estimation of depth to bedrock, depth to water table as well as aquifer thickness [3]. The electrical properties have been used with considerable success to predict the groundwater potential of an area [2, 4-6].

Generally, the electrical properties of the subsurface materials is not only useful in predicting the aquiferous zone but also assists in cost reduction and provide much more reliable platform in determining borehole drilling site, for productive borehole construction and installation. More importantly, in the study area which is located in an area where the aquifers are difficult to locate, pre-drilling geophysical survey is a useful tool, which must be carried out. In this context, this study is necessary owing to, not only its viability for borehole site selection, detection of saltwater-freshwater interface, estimation of drill depth but also in the determination of the type of geological formation (subsurface material) to be encountered. Not only is this study necessary for planning of borehole project, it is also very vital for material, labour and time management, in terms of productivity and cost. This study was therefore undertaken to assess the hydrogeological condition with a view of delineating potential areas for tapping groundwater.

Corresponding Author: F.A. Ushie, Department of Geology, University of Port Harcourt, Nigeria.

The Study Area (Locaton and Geology): The study area, Yalla (8° 15’W, 8° 00W and 6°00N and 5°40’N) is in the South Western tip of Ogoja in South-Eastern Nigeria (Fig.1). It is part of Cross River Plain and contributes the Southern featherage of the Lower Benue Trough of Nigeria.

Structurally, the Cross River Plain defines a syncline referred to as the Ogoja syncline [7]. Its sedimentary succession comprises of basal arkosic sandstone, known as the Manfe Formation, of early Albian age resting unconformably on the Basement Complex. This is overlain by the Asu-River Group which comprises of dark grey to olive brown fractured and splintery shales known as the Abakiliki Shale. Overlying this is a suite of tabular sandstones alternating with shales and shelly limestone known as the Awe Formation of early Cenomanian in age [8].

The early Albian Asu River Group (rich in ammonites) is deeply weathered and is associated with Pb-Zn mineralization. It represents the oldest sediments in this zone and is correlatable to the Neoconian sediments from the Calabar Flank [9].

Thin lavas and tuffs are interbedded and intruded into most of these Cretaceous units. The volcanic rocks are often altered to green and red clays or sometimes they display spheriodal weathering. They cover a wide range of composition from intermediate to basic, the rock type ranging from syenites through diorites to gabbros [10].

Field Measurements: The equipment used for this survey is the Signal Averaging System (SAS) ABEM Terrameter model 300B. It has a high resolution and gives a direct read-out of resistances, whose values are used to compute the apparent resistivities by multiplying with the appropriate Geometric Factor (G) for the particular electrode configuration.

Data acquisition involved two principal modes of operation viz: Vertical Electrical Sounding (VES) and Horizontal Resistivity Profilling. A total of 24 VES station, distributed among all the settlements were occupied. Three horizontal profiles were made (A - A^1, B - B^1, C - C^1) (Fig.2). The Sclumberger configuration was used for all the soundings while the Wenner array was employed for resistivity profiling. The maximum half current electrode separation (AB/2) for the Schlumberger array used was 250m while the constant electrode separation for the Wenner array used for the profiling was 50m. Fig. 2 is a sketch map of the study area showing location of VES stations and profile orientations.

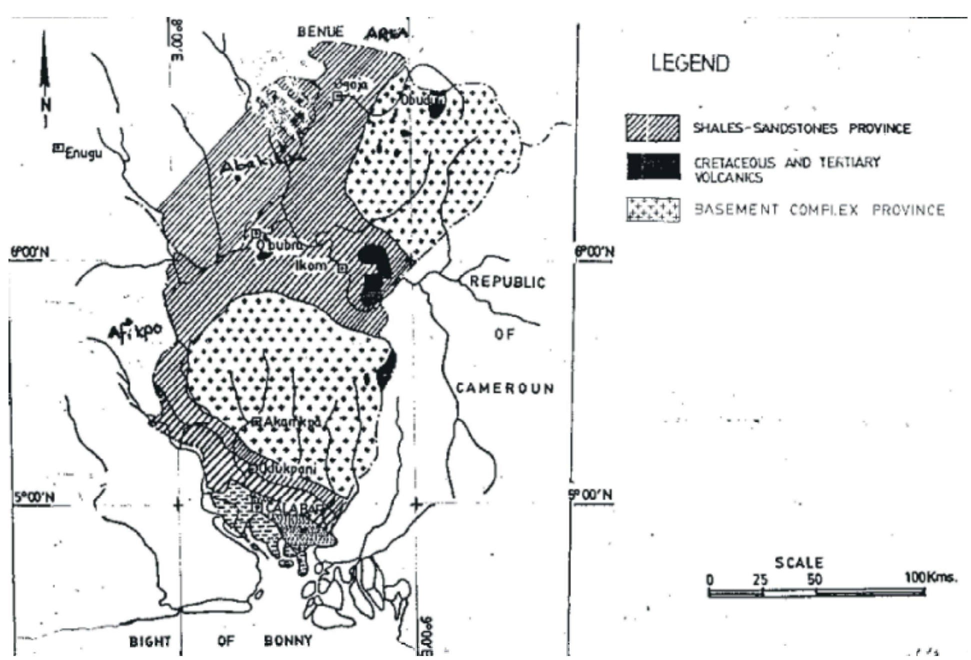

Fig. 1: Hydrogeoogical Provinces of part of South Eastern Nigeria Showing the Calabar Flank

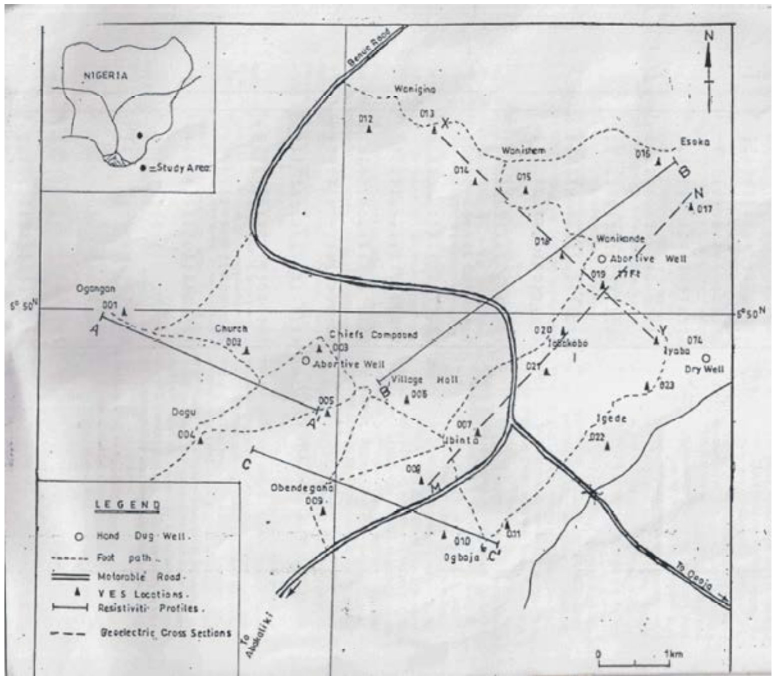

Fig. 2: Map of the Study Area Showing VES Locations

Analysis of Data: The VES data obtained were plotted conventionally on bi-log sheets. The curves obtained were interpreted quantitatively by partial curve matching with master curves and auxilliary Charts [11]. This interpretation was refined and confirmed by the computer modelling technique in which case, field curves were compared individually with computer generated curves (model curves) using the Res2Dinv software [12, 13]. The data for the resistivity profiles were plotted against station distances on an arithmetric scale graph sheets conventionally.

RESULTS AND INTERPRETATION

Vertical Electrical Sounding (VES): Results of curve matching provided starting models for computer modeling which gave the final accepted geo-electric structures [14]. The different types of curves encountered are the H, K, A, Q and KH types, all reflecting the presence of three or four geo-electric layers and in a few cases, five layers. Fig.3 shows a typical 3 and 4-layered curves, respectively.

From the results, the area (if assumed to be devoid of igneous intrusives) could be visualized as consisting of at least four geo-electric layers. The first layer of resistivity of between 73 and 1242 Ohm-m and is generally thin; ranging between 1 and 2m, the thickest being at Wanishem in the South West.

The second layer has a lower resistivity ranging from 27 Ohm-m to about 1,300 Ohm-m and very thick compared to the first and third layers. It ranges in thickness from 1m to 133m around Ogangan. The third layer, equally of moderate resistivity values is in some cases an extension of the second layer on account of its extensive thickness and some similarity in resistivity values. The fouth layer is encountered in a couple of cases where variable thicknesses are common. Table 1 is the field results of the VES and Table 2 shows the Geoelectric models from interpretations.

High resistivities ranging between 1000 Ohm-m and 500 Ohm-m are recorded in some cases, where highly indurated shale or igneous intrusive bodies are encountered. The igneous bodies and hard shales, often the impermeable boundaries assist in the localization on groundwater, in the second and third layers which in most cases are aquiferous. The aquiferous layers vary in depths, thicknesses and horizons. In many cases, they are the second, third or even fouth layers depending on the disposition of the beds and presence or absence of intruding igneous body.

Two geo-electric cross-section XY and MN were randomly chosen - See Figure 4a (XY) and Figure 4b (MN). From the resistivity values and thicknesses of the saturated zones, the depth to aquifer was computed as shown in Figure 5.

Table 1: Field Data from the Study Area

	Resistivities (OHM-M) /Ves Stations											
AB/2 (M)	1	2	3	4	5	6	7	8	9	10	11	12
1	980.22	1152	1212.1	141.1	166.12	261.11	1052	100	951.41	1160.6	135.2	468.12
2.5	917.67	553.2	1072.2	210.02	119.5	121.02	656.78	121.34	457.33	703.34	82.17	185.04
4	660.5	186.7	900.27	195.13	65.3	45.5	421.37	135.04	242.23	302.11	39.08	98.7
5	480.03	71.2	821.11	225.92	45.23	28.23	249.05	139	150.11	170.27	22.53	72.62
6	341.29	34.6	713.02	161.23	48.1	19.71	169.23	141.22	112.13	98.12	13.78	56.21
8	100.1	26.4	481.39	124.71	44.6	11.42	85.4	142.1	70.91	41.42	7.94	38.73
10	99.92	25.9	304.2	110.43	45.8	11.4	57.21	141.03	60.17	29.11	7.81	31.55
15	56.8	38.5	83.62	67.66	51.24	15.62	37.89	112.91	58.34	29.72	11.73	26.52
20	68.72	49.3	21.21	52.23	51.2	20.1	37.8	91.22	65.33	29.68	15.66	24.97
30	50.78	68.3	5.11	44.1	85.31	22.5	32.1	65.81	85.61	28.1	23.61	27.23
40	51.87	85.7	6.68	37.51	52.5	25	31.63	55.31	90	28.66	27.5	32.1
50	50.58	101.6	7.1	53.47	51.33	31.49	25.88	53.61	85.5	30.1	32.5	38.21
60	52.07	122.2	6.59	56.23	50.41	35.02	27.81	51.92	85.34	33.41	35.53	41.8
70	60.92	132.1	6.52	55.51	49.51	43.52	26.14	52.35	84.47	32.5	37.92	42.31
80	52.22	142.7	6.6	60.21	48.8	41.44	25.22	54.11	77.67	34.12	38.92	43.42
100	56.61	148.9	7.52	71.5	48.68	45.42	23.43	55.81	72.51	35.92	39.01	38.52
130	61.28	120.3	9.58	75.44	43.9	48.48	18.11	61.3	69.13	40.33	40.12	35.41
150	65.4	110.11	11.05	81.78	29.9	49.98	17.5	65.21	72.03	43.21	41.15	34.66
200	82.55	91.3	14.65	84.58	37.6	49.99	17.23	70.11	94.9	45.71	41.05	33.72
250	90.92	86.3	17.91	85.11	32.5	61.52	14.67	85.21	121.29	49.33	38.08	36.02

Table 1: Continue

	Resistivities (OHM-M) /Ves Stations											
AB/2 (M)	13	14	15	16	17	18	19	20	21	22	23	24
1	138.67	783.37	110.24	723.44	722.42	82.8	120.48	291.8	1792.52	90.1	182.29	232.78
2.5	160.18	866.34	112.07	619.92	420.55	82.8	252.01	502.61	1473.66	100.21	215.3	429.92
4	179.34	854.55	119.82	488.07	311.45	125.5	271.92	630.09	1000.48	115	361.61	503.47
5	179.55	761.48	122.43	340.02	281.24	150.2	251.32	635.02	703.33	119.33	395.49	475.57
6	179.57	552.33	118.64	255.41	283.56	153.4	250.86	610.24	492.61	120.72	440.55	492.66
8	180.03	324.82	109.42	91.25	282.11	155.2	235.04	550.22	268.93	121.04	501.2	581.15
10	210.5	220.2	91.53	50.5	275.06	150.61	210.67	501.4	155.5	119.21	549.11	611.09
15	250.51	17.12	63.43	34.59	250.5	133.62	162.5	273	80.74	112.91	639.9	543.26
20	235.88	44.5	50.01	32.12	234.08	90.5	142.6	160.29	52.25	110.22	695.92	510.54
30	175.46	34.11	36.82	27.52	192.44	61.6	109.87	64.62	73.48	81.11	775.88	524.77
40	112.56	35.68	31.5	25.08	230.3	33.02	87.5	44.41	75.66	77.3	825.17	508.92
50	70.07	52.33	26.67	15..34	246.12	25.91	70.42	35.21	95.2	69.41	885.5	642.32
60	49.01	31.02	27.72	25.47	291.4	20.29	58.12	31.92	110.71	61.11	922.21	655.85
70	36.66	28.52	28.25	25.66	342.03	20.66	55.17	32.52	115.82	63.31	971.08	660.73
80	31.5	30.72	22.51	26.24	422.21	18.25	50.21	32.02	138.47	73.7	1022.51	850.2
100	27.43	30.62	21.85	28.05	500.09	17.7	39.35	32.01	152.38	75	1129.82	1123.4
130	26.71	27.66	21.91	30.32	750.02	18	34.43	31.98	165.14	98.71	1290.11	1295.6
150	27.54	33.81	23.76	30.55	990.99	17.01	32.26	31.09	149.34	111.13	1290.3	1511.02
200	26.05	26.02	24.27	42.43	1300.02	16.24	26.82	30.92	151.05	139.51	1603.72	1788.78
250	26.08	27.44	25.52	46.33	1421.41	13.33	24.33	31.1	148.35	148.11	1874.5	1803.34

Table 2: Data from Resistivity Profiles

S/N	Station Distance (m)	Resistance Reading (Ohms)	Apparent Resistivity (Ohm-m)
1	150	0.631	198.22
2	300	0.418	131.22
3	450	0.441	138.72
4	600	0.435	136.71
5	750	0.481	151.08
6	900	0.674	211.82
7	1050	0.612	192.28
8	1200	0.915	287.50
9	1350	0.545	171.11
10	1500	0.479	150.61
11	1650	0.576	181.02
12	1800	0.449	141.09
13	1950	0.479	150.78
14	2100	0.673	211.61
15	2250	0.902	283.55
16	2400	1.173	554.03
17	2550	1.959	615.44
18	2700	1.442	452.90
19	2850	0.544	171.21
20	3000	0.601	189.09
21	3150	0.481	151.22
22	3300	0.446	140.07
23	3450	0.326	102.56

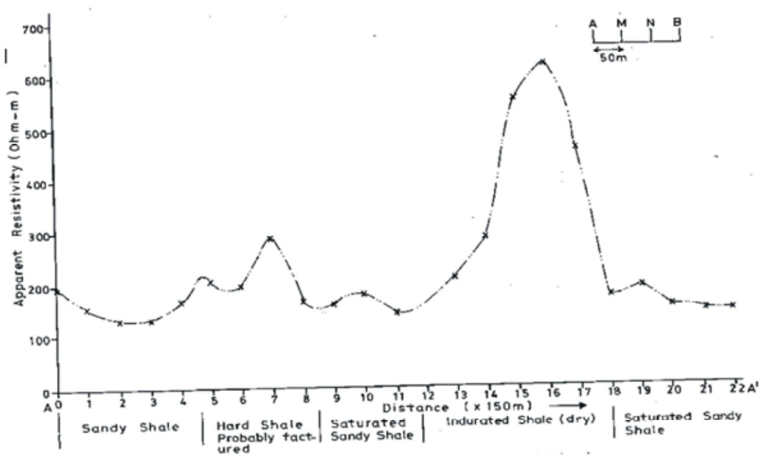

Fig. 3: Profile A-A1 (Ogangan-Dagu Junction, 3.5km)

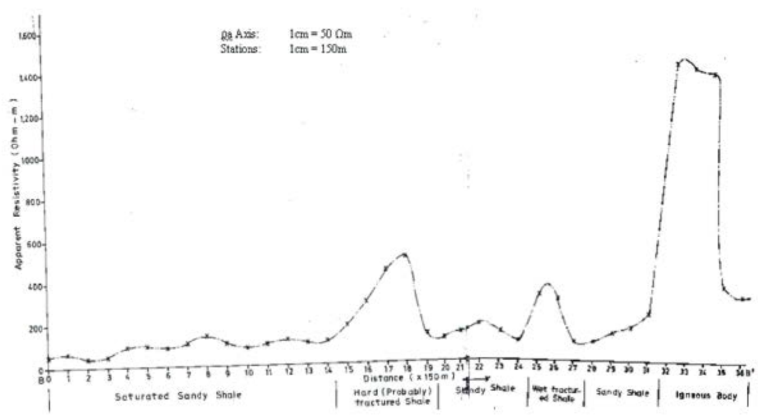

Fig. 4: Profile B-B1 (Village Hall-Esoka, 5.2km)

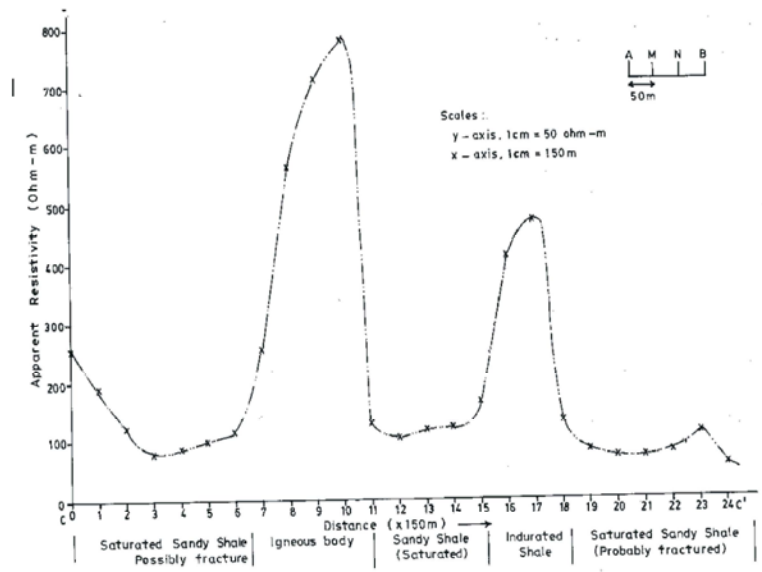

Fig. 5: Profile C-C1 (Dagu-Ogbaja, 3.5 km)

Resistivity Profiling: Two resistivity profiles were undertaken to establish lateral continuities of aquiferous zones. It was discovered that the zones occurred discretely, often bounded by impervious hard shales or igneous rocks and intrusives. These shales and igneous bodies act as the containing boundaries that help to localize the groundwater.

The study also reveals that there at least four subsurface geo-electrical layers of various thicknesses, discriminated on the basis of their electrical resistivities which is a reflection of their water content. Igneous bodies pervade the sedimentary layers in form of dykes and sills.

CONCLUSION

Yala is underlain by a sedimentary sequence consisting of shale and sandy shale units with lenses of clayey materials. Results from resistivity show that there are at least four geo-electric layers of various thicknesses discriminated on the basis of their electrical resistivities, which is, in turn, a reflection of their water content. Igneous bodies pervade the sedimentary layers in forms of dykes and sills.

Of these four layers estimated from resistivity study, the second and third layers and in a few cases, the fourth layers are potential aquifers. Since the dry first layer is just about 2m on the average, it can be deduced that the groundwater table occurs from 2m and below. This however excludes points where compact shales and igneous bodies occur.

REFERENCES

1. Olatunji, A.S., M.O. Oloruntola and A.F. Abimbola, 2007. Enhancing Groundwater Exploration through the combination of Electrical Resistivity with Spontaneous Potential Measurements: Case studies from SW Nigeria. Water Resources J., 17: 11-16.
2. Olayinka, A.I., 1992. Geophysical Sitting of Boreholes in Crystalline Basement areas of Africa. J. African Earth Sci., 14(2): 197-207.
3. Telford, W.M., L.P. Geldart, R.E. Sheriff and D.A. Keys, 1984. Applied Geophysics, Cambridge University Press, London, pp: 860.
4. Selemo, A.O., P.O. Okeke and G.I. Nwankwor, 1995. An appraisal of the usefulness of vertical electrical sounding (VES) in groundwater exploration in Nigeria. Water Resources J., 6(1and 2): 40-55.
5. Ofoma, A.E., O.S. Onwuka and O.C. Egbu, 2006. Hydrogeophysical Investigation in Nsukka Area, Southeastern Nigeria. J. Research in Physical Sci., 2(1): 25-34.
6. Nwankwoala, H.O. and J. Shalokpe, 2008. Groundwater Resource Evaluation of Amuwo Odofin, Lagos State, Nigeria. International J. Natural and Applied Sci., 4(3): 330-336.
7. Kogbe, C.A., 1976. The Cretaceous and Paleogene Sediments of Southern Nigeria, Elizabethan Pub. Co. Lagos.,
8. Petters, S.W., 1978. Strategic evolution of the Benue Trough and its implication for the Upper Cretaceous of West Africa. J. Geol., 86: 311-322

9. Amah, E.A. and E.O. Esu, 2007. Geophysical and hydrogeological studies of shallow groundwater aquifers of Calabar area, Southeastern Nigeria. Proceedings of 43rd Annual International Conf. of Nigerian Mining and Geosciences Society, pp: 32-33.
10. Burke, K.C., T.F. Dessauvagie and A.J. Whiteman, 1971. The Geological history of the Benue Valley and Adjacent area. In: African Geology, University of Ibadan, pp: 187-206.
11. Keller, G.V. and F.C. Frischknecht, 1971. Electrical methods in Geophysical Prospecting. Pergamon Press Inc. USA, pp: 517.
12. Griffiths, D.H. J. Turnbull and A.I. Olayinka, 1990. Two- dimensional resistivity mapping with a computer- controlled array, First Break, 8: 121-129.
13. Dobrin, M.B., 1976. Introduction to Geophysical Prospecting. Mc-Graw Hill Inc. USA, pp: 463.
14. Battacharya, B.B. and M.K. Sen, 1981. Depth of investigation of Colinear electrode arraya over homogenous anisotropic half space in direct current methods. Geophysic, 46(5): 768-780.