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Investigation of Flood Prone Areas in Oferekpe Ikwo Local Government Area Ebonyi State Using Electrical Resistivity Method

Agbo G.A[1], Aluge, U.D[2], Azi A.[3], Nnabo .P[4]

Department of Industrial Physics, Ebonyi State University.Abakaliki, Ebonyi State, Nigeria

Abstract: ***An electrical resistivity survey method of geophysical investigation was conducted at Oferekpe Ikwo L.G.A of Ebonyi State. The aim of the study was to ascertain the areas prone to flooding by investigating the nature of the subsurface geometry and aquifers. Eight shallow vertical electrical sounding (VES) using the schlumberger configuration were conducted within the area. The VES data presented a sounding curve which inferred that Oferekpe is underlain by clay, mudstone, sandstone and shale. The results showed that the VES consist mainly of three main curves; HA, AO, and H curve types. The three layers were delineated generally from the geoelectric sections and the results obtained showed that the subsurface has thickness between 3.0 and 32.0m and resistivities ranging from 1.80Ωm to 5007.1Ωm at different locations. The analysis clearly indicated that the location VES 2 has a higher tendency of flooding. Hence a small rain could cause the area to be filled up within a short time and can eventually cause flooding.***

Keyword: Flood Prone Areas, Electrical Resistivity, Vertical Electrical Sounding

1. Introduction

Geophysical investigation is a non-invasive method of looking into the ground to determine the presence and location of underground features. This technique is also the application of variety of intrusive or non-intrusive equipment to explore the subsurface of the earth to expose information about the physical properties and natural endowment embedded in the earth. In a more restricted application to the earth's subsurface, geophysical investigation can generally be understood as a systematic collection of geophysical data for spatial and temporal studies.

To avoid confusion, the use of physics to study the interior of the earth from land surface to the inner core is known as solid earth geophysics. This can be subdivided further into global or pure geophysics which is the study of the whole or substantial part of the planet. Applied geophysics on the other hand is concerned with investigation of the earth's crust and near sub-surface to achieve a practical aim, which include collecting and interpreting data to extract information about the subsurface conditions for practical purposes, including oil and gas exploration, mineral prospecting, geothermal exploration, groundwater exploration, engineering applications, archaeological interests, and environmental concerns.

Geophysical investigation has a wide range of application as it probes the earth's interior. Geophysical methods respond to physical properties of the subsurface media (rocks, sediments, water and voids) and can be classified as (a) passive methods which are those that detect variations with natural fields associated with the earth such as gravitational and magnetic fields. (b) active methods, such as those used in exploration seismology, in which artificially generated signals are transmitted into the ground which then modifies those signals in ways that are characteristic of the materials through which they travel. The altered signals are measured by appropriate detectors whose output can be displayed and ultimately interpreted.

Principally, geophysical investigations are considered to be indirect methods because they substitute direct field works. Thus, they may significantly save both, necessary finance expenses, in appropriate combination with direct methods as well as investment of the time necessary for survey of observed environment.

The application of geophysical investigation in this research will clarify and uncover problems connected with solution and prediction of phenomena, which indirectly lead to the catastrophic situations resulting from floods in some part of Ikwo Local Government Area of Ebonyi State.

The phenomenon of floods is from history a serious problem endangering functioning of human society and often also of nature. Flood is a great flowing or overflowing of water onto land that is not usually submerged. Flood happens when too much rain, brought by storms and strong winds fall and cannot be absorbed by the soil. Rivers burst their banks and the water spills onto the land. Strong winds blowing across the sea make waves that surge onto the land and flood coastal areas. The result of this overflow could endanger the life and property of people within the vicinity of occurrence of flood. Flood disaster undermines developmental achievements improvising people, states and nations. In the absence of combined effort to address the root causes, flood disasters represent an increasingly serious obstacle to the achievement of the Millennium Development Goal.

2. Aim of Study

The study was carried out to ascertain the areas prone to flooding in Oferekpe by investigating the nature of the subsurface geometry and aquifers

3. Geology of the Study Area

Regional Geology

Ebonyi state lies mostly in the Ebonyi (Aboine) River Basin and the Cross River plains. The area contains two main geologic formations from the east to the west and in terms of age and sequence of exposure, the formation are the Asu River group of the Albian age (lower Cretaceous) made up of shales, sandstone and siltstones. The sediments later became folded giving rise to two major structural features, the Abakaliki anticlinorium and the related Afikpo syncline. The Ezeaku shales formation of the Turonian age contains shales, siltstone, sandstone and limestone. Ebonyi state is an area of moderate relief (between 125 and 245m above sea level). The highest parts of the state are around Afikpo with elevation of about 170m above sea level. Drainage is controlled by the Cross River plain and its tributaries, especially the Ebonyi drainage system. Areas of moderate relief are often characterized by an intermediate condition of erosion between the extremes in areas with high relief on one hand where the underlying shales are easily eroded

Local Geology

This type of geologic formation of Ebonyi State is characterized by the Albian Asu River group of the Abakaliki Anticlinorium's. Ikwo Local Government Area falls within this category. The oldest sediment in the area is the lower Cretaceous Asu group. The Asu River shale's is researched to have been deposited in the Albian times and it's the dominant member of the group.This geological group is characterized by clay, mudstone and shale. The survey area has an altitude of roughly 110m along the internal line of survey.

4. Theory Of Electrical Resistivity Method

Electrical Methods

Electrical methods involve the use of electric current (natural or artificial, direct or alternating) introduced on the surface or into the ground to investigate the variations of the electrical property of the subsurface materials (rocks). The expected variations result in the build-up of varying potentials distributed according to the presence or absence of conducting materials in the earth. The potential distribution so generated can then be measured from the ground surface and these will provide information on the form and electrical properties of such subsurface inhomogeneities.

Theoretical Background

The electric field of a charge Q is a force exerted on another unit charge. Using Coulomb's law the force is given by:

$$F = \frac{Qq}{4\pi\varepsilon_o r^2} \quad (1)$$

where q is a unit charge
r is a distance between Q and q
ε_o is the electric permittivity of the medium between Q and q.

The electric field is also representable by the number of lines of force per unit area. A positive charge usually has an imaginary lines of force going radialy outward from it while the negative charge is usually inward. Hence, in the presence of a pair of opposite charges, lines diverge from positive and converge on the negative. From equation 1, the strength of the field is strong near the source but weakens rapidly with distance. In order to move a charge close to an identical one, work is required to accomplish it. The amount of work/energy needed to move a charge from infinity to any point within the area of the electrical field is called the Electric Potential. If we move a distance dr against the field E, the potential changes by an amount du equal to the work done against E given by –E dr (work = force x distance).

$$\therefore du = -E\, dr \quad (2)$$

$$E = \frac{-du}{dr} \quad (3)$$

The electric field is equal to the negative of the potential gradient.
From equation 2

$$U = \int du = -\int_{\infty}^{r} E dr. = -\int_{\infty}^{r} \frac{Qdr}{4\pi\varepsilon_o r^2} \quad (4)$$

$$\therefore \frac{Q}{4\pi\varepsilon_o r} \quad (5)$$

The energy required to move a unit charge from one point to another within the electric field of Q is the Potential difference between the two points.

Current Flow and Resistivity

Ohm's law established that

$$V = IR \quad (6)$$

ρ = resistivity of the material in Ohm-m.
From equation 6

$R = \frac{V}{I}$ and for small changes of R we have $dR = \frac{dV}{dI}$

$$\therefore \frac{RdA}{dI} = \frac{dV}{dI}.\frac{dA}{dI} \quad (7)$$

But

$$\frac{dV}{dI} = \rho \frac{dI}{dA} \quad (8)$$

Equation 8 can be rewritten as

$$E = \rho J \quad (9)$$

J = current density.
Using equation 8, the cross sectional area for an infinite half-space is - $2\pi^2$ at a distance r from source.

$$\frac{dV}{dr} = -\rho \frac{I}{2\pi r^2} \quad (10)$$

$$V_r = \int dV = -\int \frac{\rho}{2\pi r^2} dr$$

$$V_r = \frac{\rho I}{2\pi r} \qquad (11)$$

Equation 11 allows the calculation of the potential at any point on or below the surface of a homogenous half space.

5. Resistivity Survey

In the electrical resistivity survey method, artificially generated electrical currents are put into the ground and the resulting potential differences are measured at the surface. The technique exploits the fact that there is a large contrast in resistivity of ore bodies and their surrounding host rocks and between wet and dry sedimentary rocks. The technique is in principle relatively simple. Two electrodes are used to supply a controlled electrical current to the ground. The line of current flow adapt to the subsurface resistivity pattern so that the potential difference between two points on the ground surface can be measured using a second pair of electrodes. Deviation from the pattern of potential differences often expected from a homogenous ground may provide information on the formation and electrical properties of subsurface inhomogeneities. A simple direct current could be used but this can cause charges to accumulate on the potential electrodes, resulting in spurious signals. A common practice is to commutate the direct current so that its direction is reversed very few seconds or alternatively use a low-frequency alternating current.

Consider an arrangement consisting of a pair of current electrodes and a pair of potential electrode (fig 3). The current electrodes A and B act as source and sink respectively. In this case there are two points (potential electrodes positions) where we need to find the electric potentials due to the source (current electrode, A) and also due to the sink (current electrode, B) and hence obtain the potential difference between the two point using equation 11, the potential at the point C due to A is $+\frac{\rho I}{2\pi r_{AC}}$ and due to B is $-\frac{\rho I}{2\pi r_{CB}}$

The combined potential at C is given by

$$V_c = \frac{\rho I}{2\pi}\left(\frac{1}{r_{AC}} - \frac{1}{r_{CB}}\right) \qquad (12)$$

Similarly, the resultant potential at D is

$$V_D = \frac{\rho I}{2\pi}\left(\frac{1}{r_{AD}} - \frac{1}{r_{DB}}\right) \qquad (13)$$

The potential measured by a voltmeter connected between C and D is:

$$AV = V_c = \frac{\rho I}{2\pi}\left[\frac{1}{r_{AC}} - \frac{1}{r_{CB}}\right] - \left[\frac{1}{r_{AD}} - \frac{1}{r_{DB}}\right] \qquad (14)$$

All the quantities in this equation can be measured at the ground surface except the resistivity ρ, which is given by:

$$\rho_a = \frac{2\pi v/_I}{\left(\frac{1}{r_{AC}} - \frac{1}{r_{CB}}\right) - \left(\frac{1}{r_{AD}} - \frac{1}{r_{DB}}\right)} \qquad (15)$$

When the ground is uniform, the resistivity calculated from the last equation should be constant and independent of both electrode spacing and surface location. When surface inhomogeneities exist, however, the resistivity will vary with the relative positions of the electrodes. Any computed value is then known as the apparent resistivity (ρ_a) and will be a function of the form of the inhomogeneity. The above equation is the basic equation for calculating the apparent resistivity for any electrode configuration.

There are practical limits on the depths of penetration attainable by normal resistivity method due to the difficulty of laying out lengths of the cable and generation of sufficient power. Depths of penetration of about 1km are the limit for normal equipment.

Equation 15 can be rewritten as:

$$\rho_a = \frac{2\pi R}{\left(\frac{1}{r_{AC}} - \frac{1}{r_{CB}}\right) - \left(\frac{1}{r_{AD}} - \frac{1}{r_{DB}}\right)} \qquad (16)$$

The denominator of equation 16 is known as the Geometric factor (G) of the electrode configuration or electrode spread.

$$G = \left[\left(\frac{1}{r_{AC}} - \frac{1}{r_{CB}}\right) - \left(\frac{1}{r_{AD}} - \frac{1}{r_{DB}}\right)\right] \qquad (17)$$

Equation 16 and 17 can then be generally written as

$$\rho_a = \frac{2\pi R}{G} \qquad (18)$$

6. Methodology

This survey was conducted at Oferekpe of Ikwo Local Government Area Ebonyi state. The study was carried out to ascertain the areas prone to flooding by investigating the nature of the subsurface geometry and aquifers. This would help to understand the nature of the geomaterials and their permeability or porosity, as well as pore structures, and hence the underground water potential and subsurface feature of the sites being investigated.

Electrical resistivity method of prospecting was adopted during the period of investigation because of its more diversified nature than many other geophysical methods. Some of the methods such as self potential and telluric currents depend on naturally occurring fields as in magnetic and gravity prospecting, while others depend on artificial fields as in seismic techniques. Electrical resistivity surveying involves the detection of surface effects produced by electric currents flowing in the ground and it is affected by clay contents, groundwater conductivity, soil or formation porosity and degree of water saturation. A wide variety of electrical surveying techniques exist unlike most geophysical surveying methods where a single field of force or anomalous property such as gravity, elasticity, magnetism and radioactivity is used. In electrical methods of prospecting, potentials, currents, electromagnetic fields, which may occur naturally or be introduced artificially in the earth, may be measured. The measurements can be made in a variety of ways to determine a variety of results. It is the variation in electrical conductivity (or resistivity) found in different rocks and minerals that makes electrical methods possible. The acquisition of data in this work involved the Schlumberger array as shown in figure 2. The choice of this array other than some other prospecting methods is for convenience and reliability as well as to ensure that the effect of shallow resistivity variations is constant with fixed potential electrode. In vertical electrical sounding (VES) and using Schlumberger array, electrode movement of the current electrode, C_1C_2 are outwardly moved symmetrically about the entire fixed electrodes P_1P_2. The measured quantities are current and potential voltages such that the apparent resistivity was calculated using;

$$\rho_a = k\left(\frac{\Delta V}{I}\right) \quad (19)$$

where k = electrode geometry = $\frac{\pi L^2}{2l}$ for Schlumberger array (see figure 2).

where L= $\frac{1}{2}C_1C_2$ = current electrode spacing

$l = \frac{1}{2}P_1P_2$ = potential electrode spacing

7. Data Processing

All raw field data were processed by using the appropriate constants such as the geometric factor k and pi and also analyzed using WINRESIST Computer software program. The VES data are then presented as sounding curves which are obtained by plotting graphs of apparent resistivity versus half-current electrode spacing on double logarithmic graph sheets and further verified using curve matching.

8. Result/Conclusion

From the results, it was inferred that Oferekpe Ikwo is a mountainous plain surrounded by water bearing valleys with several surface and groundwater flow sources. The result of the investigation showed that VES for Oferekpe Ikwo consists mainly of three main curves; HA, AQ, and H curve types. Three layers were delineated generally from the geoelectric sections.

VES 1 and 2 were carried out along transverse one. The result from the interpretation of the field data showed that the probed area has three layers; the topmost soil, the sandy/shale and the clay. VES 1 and 2 showed that the first layer consists of the topmost soil to a depth of about 8.2 meters followed by the second layer made of sandy shally soil of about 8.2 meters thick and the third layer consists of plastic clay formation as shown in figs 3 and 4. The result suggests that this layer houses shallow water saturated zones.

VES 3 and 4 were carried out along transverse two. The results obtained from the inversion of the data at this point showed that there are three lithologic units, comprising of top soil, dry clay and wet clay. The thickness of the layers range between 4.6m and 34.7m and their resistivities are between 8.9Ωm and 691.9Ωm. A fracture zone is located at a depth of 20.6m.

VES 5 and 6 were carried out along traverse three. There are three lithologic units at this point comprising of the top most soil, shale and clay. The layers have thicknesses between 3.0m and 23.3m, while their resistivities range between 23.4Ωm and 1832.2Ωm. A fracture zone can be found at a depth of 17.8m.

VES 7and 8, were carried out along traverse four. The result obtained from the inversion of the data along this traverse shows that the depth of investigation made comprised of top most soil, porous sandy shale, mudstone and wet clay. The thicknesses of the layers along this traverse are between 5.1m and 6.3m and their resistivities range between 4.0Ωm and 5007.1Ωm. A fracture zone may be located between 21.4m and 25.3m. The inversion of VES 8. The high RMS error of gotten in the data was due to the noisy data obtained on the field at the location where this VES was carried out.

From the above analysis of the results obtained, three lithologic units namely the top soil, sandy shale and lateritic clay, were delineated although these layers have different arrangements at different locations. The top most soil has thicknesses between 3.0m and 32.0m and resistivities ranging from 1.8Ωm to 5007.1Ωm.

The analysis clearly indicated that location where VES 2 was carried out was the area which is highly prone to flooding. This is indicated by the low resistivity (1.8Ωm) in the area which is a good indication of high saturation of level of water table in the area, and hence, a small rain could cause the area to be filled up within a short time and can eventually cause flooding.

Resistivity survey was carried out to probe the areas that are prone to flood in Oferekpe Ikwo, in Ebonyi State, Nigeria. The results obtained from the inversion show that the area is a sedimentary terrain, made up of three lithologic units namely the top most soil and paralic sequence of sand/shale and lateritic clay. The top most soil has a thickness between 3.0m and 32.0m and resistivities ranging from 1.8 Ωm to 5007.1 Ωm. The aquifer zones in all the survey sites are generally located between depths of 13.3m and 43.3m

From the inversion, it was observed that the top most soil comprises of mud and the first few meters of the subsurface. The sand layers have relatively low resistivities as compared to the lateritic clay layers and this is due to the porous, permeable and transmissible nature of sand. So the sandy shale absorbs water when it rains, but it allows this water to flow through it into deeper layers in the subsurface because of its porous nature. The lateritic clay in the subsurface due to the compact nature of its pore is not permeable and not transmissible and thus has very high resistivity values. Therefore whenever it rains, it stored water but does not allow water to pass through it, so that the water continues accumulating on top of it until the water gets to the surface and this causes flooding. Also, because the depth of the water table in these areas is shallow, it quickly gets filled up when it rains and this is another reason why flooding occurs in this area especially during the wet season

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Table 1: Community/Location; Oferekpe 1 VES Number: 1 (Equipment; Allied Ohmega. Profile Orientation: N06.17734, E008.04510. Date; 10th March 2012)

S/No	L/2(m)	l /2(m)	K	R(Ω)	ρ(Ω.m)
1	1	0.5	1.20	113.2	135.84
2	2	0.5	5.89	35.17	207.15
3	3	0.5	13.75	19.36	266.2
4	6	0.5	76.59	31.90	1791.2
5	9	0.5	17.67	38.23	2928.0
6	9	2.0	86.80	0.300	5.301
7	8	2.0	243.90	11.94	1036.4
8	15	2.0	626.83	14.64	3570.69
9	25	2.0	980.30	0.032	20.06
10	40	2.0	2207.63	0.027	26.47
11	50	2.0	433.99	0.021	46.36
12	75	2.0	777.65	0.027	11.72
13	75	10.0	1759.52	0.052	40.44
14	100	10.0	3134.15	0.023	33.58
15	150	10.0	7061.65	0.039	68.62

Table 2: Community/Location; OFEREKPE 2 VES Number: 2. (Equipment; Allied Ohmega Profile Orientation: N06.17736, 007.04519 Date;1st November 2012)

S/N	L/2(m	l /2(m)	K	R(Ω)	ρ(Ωm)
1	1	0.5	1.20	369.5	443.4
2	2	0.5	5.89	68.88	405.7
3	3	0.5	13.75	28.90	397.37
4	6	0.5	76.59	24.89	1397.82
5	9	0.5	17.67	38.18	2928.04
6	9	2.0	86.80	10.72	5.301
7	9	2.0	243.90	7.747	136.98
8	15	2.0	626.83	8.413	730.25
9	25	2.0	980.30	14.01	8781.89
10	40	2.0	2207.63	26.83	26301.48
11	50	2.0	433.99	31.34	69187.12
12	75	2.0	777.65	0.581	252.148
13	75	10.0	1759.52	0.327	254.29

14	100	10.0	3134.15	0.217	383.58
15	150	10.0	7061.65	0.007	21.94

Table 3: Community/Location; Oferekpe 3 VES Number: 3. (Equipment; Allied Ohmega. Profile ORIENTATION: N06.17734, E007.04321. Date; 10TH March 2013)

S/N	L/2(m)	l /2(m)	K	R(Ω)	ρ(Ωm)
1	1.5	0.5	6.28	285.40	1792.3
2	2	0.5	11.78	123.20	1451.3
3	2.5	0.5	18.84	65.18	1227.9
4	3.5	0.5	37.68	23.98	903.6
5	4.5	0.5	62.80	11.21	703.9
6	6	0.5	112.3	5.034	565.3
7	8	0.5	200.0	3.076	615.2
8	10	0.5	313.21	2.489	779.6
9	15	0.5	706.71	4.514	3190.6
10	10	3.5	39.36	2.729	107.4
11	15	3.5	95.43	0.949	90.56
12	20	3.5	173.28	0.551	95.86
13	25	3.5	274.80	0.336	92.35
14	35	3.5	544.00	0.347	188.77
15	45	3.5	903.36	0.306	276.43
16	55	3.5	1352.0	0.198	267.7
17	45	14	205.1	0.164	33.64
18	55	14	317.0	0.120	38.04
19	75	14	608.98	0.062	37.77
20	95	14	991.11	0.038	107.01
21	125	14	1230	0.087	107.01

Table 4: Community/Location; Oferekpe 4 VES Number: 4. (Equipment; Allied Ohmega. Profile Orientation: N06.17654, E008.04321. Client: Date; 3RD November 2012

S/N	L/2(m)	l /2(m)	K	R(Ω)	ρ(Ω.m)
1	1.5	0.5	6.28	46.96	294.91
2	2	0.5	11.78	23.93	281.90
3	2.5	0.5	18.84	13.97	262.86
4	3.5	0.5	37.68	6.923	246.30
5	4.5	0.5	62.80	3.922	224.71
6	6	0.5	112.3	2.001	181.00
7	8	0.5	200.0	0.9050	141.10
8	10	0.5	313.21	0.4505	173.36
9	15	0.5	706.71	0.2453	116.74
10	10	3.5	39.36	2.966	77.25
11	15	3.5	95.43	0.8095	59.42
12	20	3.5	173.28	0.3429	42.81
13	25	3.5	274.80	0.1558	43.11
14	35	3.5	544.00	0.0792	59.68
15	45	3.5	903.36	0.0660	66.34
16	55	3.5	1352.0	0.0490	41.02
17	45	14	205.1	0.200	42.80
18	55	14	317.0	0.135	44.09
19	75	14	608.98	0.0724	46.43
20	95	14	991.11	0.0476	47.09
21	125	14	1230	0.0140	298.8

Table 5: Community/Location; OFEREKPE 5. VES Number: 5. (Equipment; Allied Ohmega. Profile Orientation: N06.59692, E007.0545 Date; 11th March 2013).

S/N	L/2	l /2	K	R(Ω)	ρ(Ω.m)
1	1.5	0.5	6.28	149.8	940.74
2	2	0.5	11.78	79.24	933.45
3	2.5	0.5	18.84	46.15	869.47
4	3.5	0.5	37.68	18.10	682.01
5	4.5	0.5	62.80	8.245	516.14
6	6	0.5	112.3	2.815	316.13
7	8	0.5	200.0	0.8547	170.94
8	10	0.5	313.21	0.445	139.38
9	15	0.5	706.71	0.1257	88.84
10	10	3.5	39.36	4.263	167.79
11	15	3.5	95.43	0.8215	78.40
12	20	3.5	173.28	0.5369	93.01
13	25	3.5	274.80	0.3911	107.47
14	35	3.5	544.00	0.2463	133.99
15	45	3.5	903.36	0.1448	130.81
16	55	3.5	1352.0	0.1458	197.12
17	45	14	205.1	0.5299	108.68
18	55	14	317.0	0.3559	481.18
19	75	14	608.98	0.2453	149.38
20	95	14	991.11	0.1699	168.39
21	125	14	1230	0.1240	152.52

Table 6: Community/Location; OFEREKPE IKWO 6 VES Number: 6. (Equipment; Allied Ohmega. Profile Orientation: N06.59692, E007.054. Date; 11th March 2013)

S/N	L/2(m)	l /2(m)	K	R(Ω)	ρ(Ω.m)
1	1.5	0.5	6.28	15.48	97.21
2	2	0.5	11.78	8.168	96.21
3	2.5	0.5	18,84	4.796	90.36
4	3.5	0.5	37.68	2.071	780.35
5	4.5	0.5	62.80	1.045	65.60
6	6	0.5	112.3	0.452	50.76
7	8	0.5	200.0	0.2081	41.62
8	10	0.5	313.21	0.1176	36.83
9	15	0.5	706.71	0.2423	171.24
10	10	3.5	39.36	0.9632	9.54
11	15	3.5	95.43	0.0939	16.27
12	20	3.5	173.28	0.0861	23..62
13	25	3.5	274.80	0.0156	8.514
14	35	3.5	544.00	0.0704	63.57
15	45	3.5	903.36	0.0468	63.34
16	55	3.5	1352.0	0.0157	3.21
17	45	14	205.1	0.3907	4.97
18	55	14	317.0	0.0703	42.85
19	75	14	608.98	0.0464	46.43
20	95	14	991.11	0.0782	96.12
21	125	14	1230	0.0140	298.8

Table 7: Community/Location; OFEREKPE 7 VES Number: 7 Equipment Allied Ohmega. Profile Orientation: N06.15438, E007.04761 Date; 11th March, 2012.

S/No	L/2(m)	l /2(m)	K	R (Ω)	ρ(Ω.)
1	1.5	0.5	6.28	4.412	27.71
2	2	0.5	11.78	2.817	33.18
3	2.5	0.5	18.84	1.666	31.39
4	3.5	0.5	37.68	0.817	30.82
5	4.5	0.5	62.80	0.361	22.72
6	6	0.5	112.3	0.0605	6.800
7	8	0.5	200.0	0.1302	26.04
8	10	0.5	313.21	0.0274	8.560
9	15	0.5	706.71	0.5290	370.7
10	10	3.5	39.36	0.1756	6.900
11	15	3.5	95.43	0.1696	16.180
12	20	3.5	173.28	0.0311	5.400
13	25	3.5	274.80	0.0370	0.900
14	35	3.5	544.00	0.002	1.100
15	45	3.5	903.36	0.062	56.0
16	55	3.5	1352.0	0.0144	19.46
17	45	14	205.1	0.0688	14.1
18	55	14	317.0	0.0350	11.1
19	75	14	608.98	0.4230	257.59
20	95	14	991.11	0.0571	264.89
21	125	14	1230	0.2351	288.24

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Table 8: Community/Location; OFEREKPE 8. VES Number: 8. (Equipment; Allied Ohmega .Profile Orientation: N06.18745, E007.03293. Date; 28th March 2013)

S/N	L/2(m)	l /2(m)	K	R(Ω)	ρ(Ω.m)
1	1.5	0.5	6.28	285.40	1792.3
2	2	0.5	11.78	123.20	1451.3
3	2.5	0.5	18.84	65.18	1227.9
4	3.5	0.5	37.68	23.98	903.6
5	4.5	0.5	62.80	11.21	703.9
6	6	0.5	112.3	5.034	565.3
7	8	0.5	200.0	3.076	615.2
8	10	0.5	313.21	2.489	779.6
9	15	0.5	706.71	4.514	3190.6
10	10	3.5	39.36	2.729	107.4
11	15	3.5	95.43	0.949	90.56
12	20	3.5	173.28	0.551	95.86
13	25	3.5	274.80	0.336	92.35
14	35	3.5	544.00	0.347	188.77
15	45	3.5	903.36	0.306	276.43
16	55	3.5	1352.0	0.198	267.7
17	45	14	205.1	0.164	33.64
18	55	14	317.0	0.120	38.04
19	75	14	608.98	0.062	37.77
20	95	14	991.11	0.038	107.01
21	125	14	1230.23	0.087	107.01

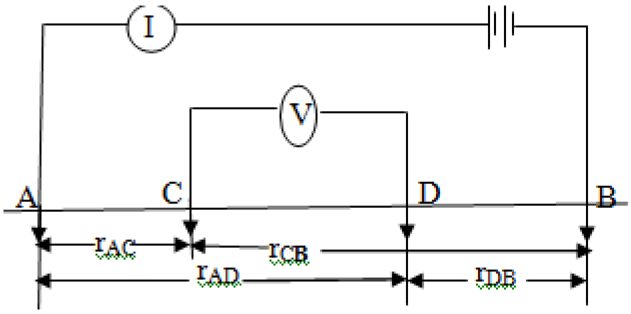

Figure 1: General four electrode configuration for resistivity

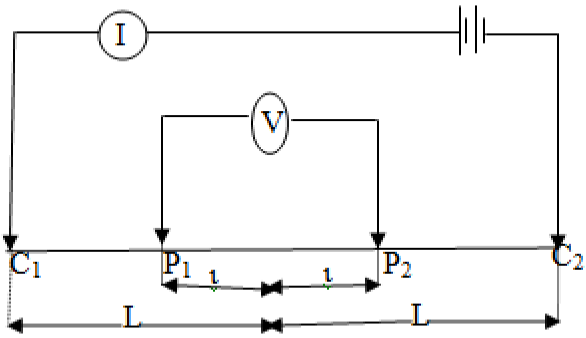

Figure 2: Electrical resistivity method (Schlumberger array)

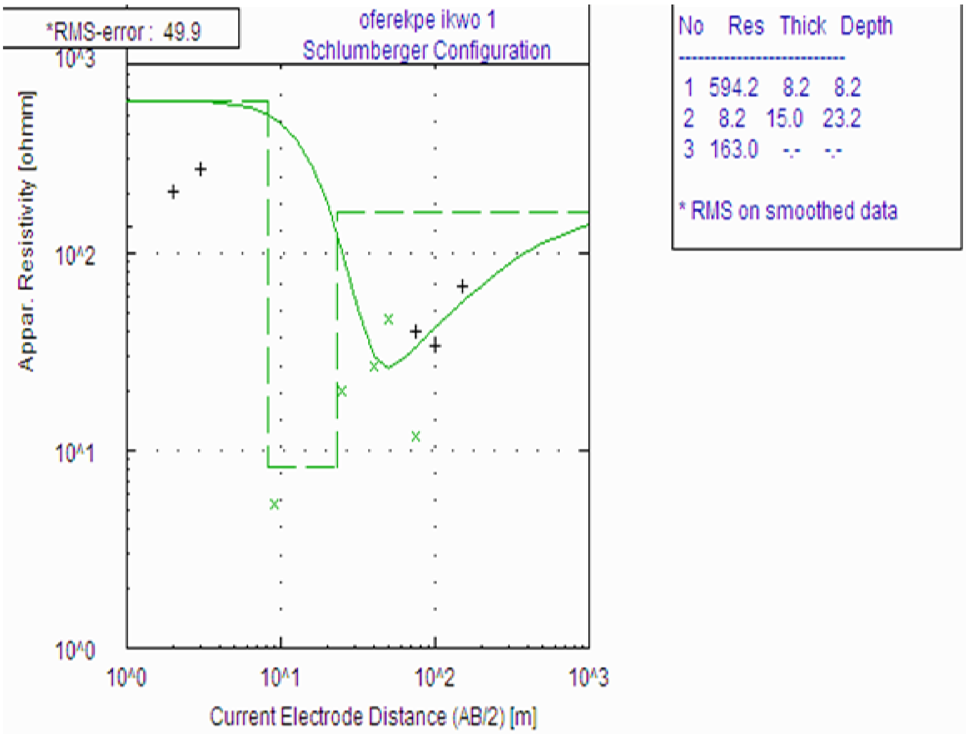

Figure 3: VES 1 Computer Modelling and Smothed Geoelectric Parameter-HA curve type

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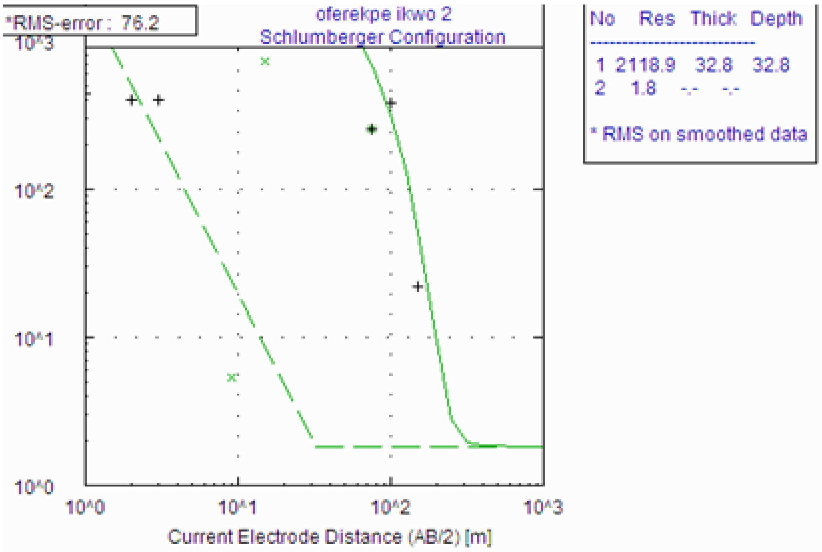

Figure 4: VES 2 Computer Modelling and Smothed Geoelectric Parameter-H curve type

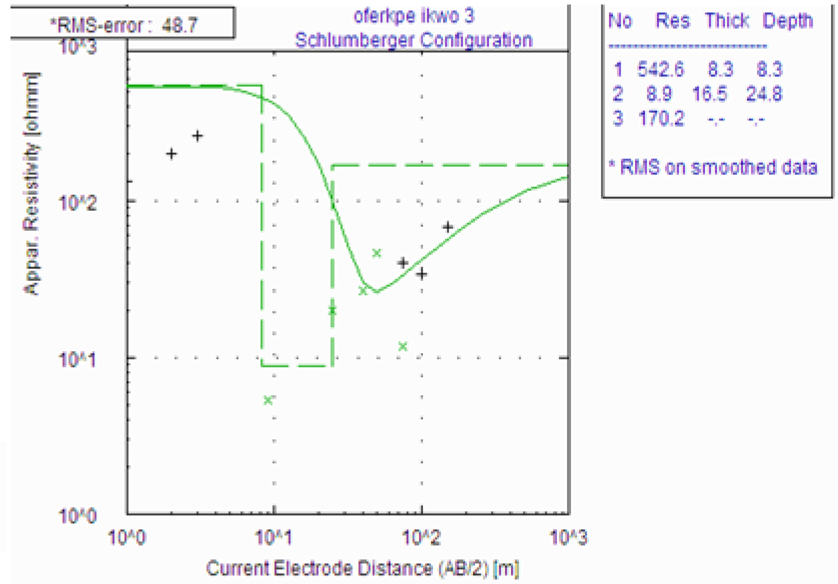

Figure 5: VES 3 Computer Modeling and Smoothed Geoelectric Parameters –HA curve type

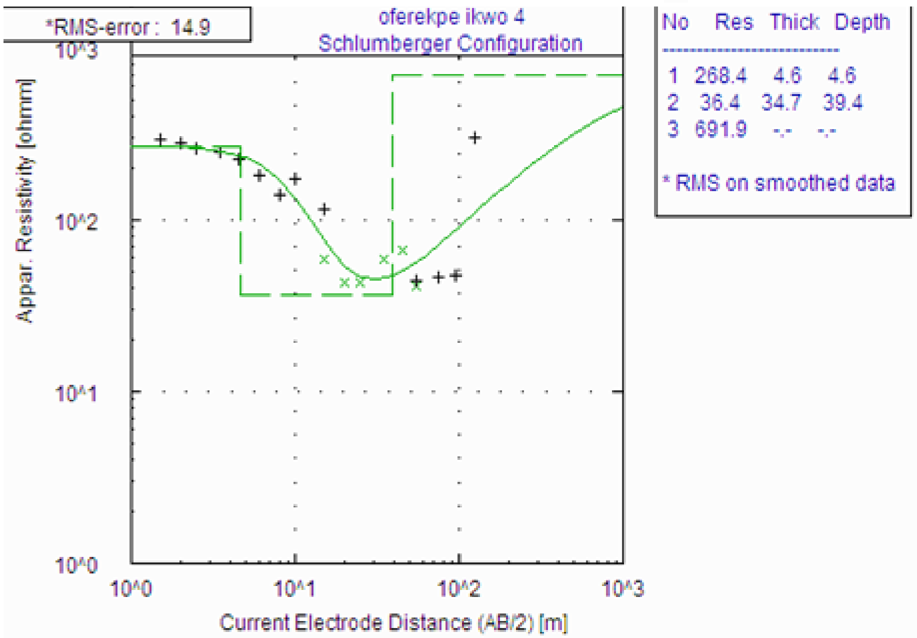

Figure 6: VES 4 Computer Modeling and Smoothed Geoelectric Parameters –HA curve type

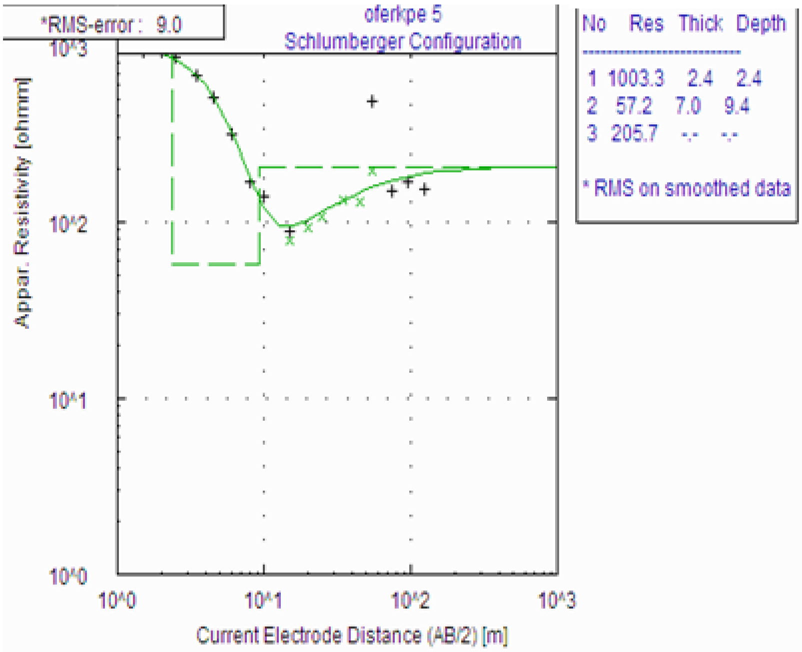

Figure 7: VES 5 Computer Modeling and Smoothed Geoelectric Parameters –HQ curve type

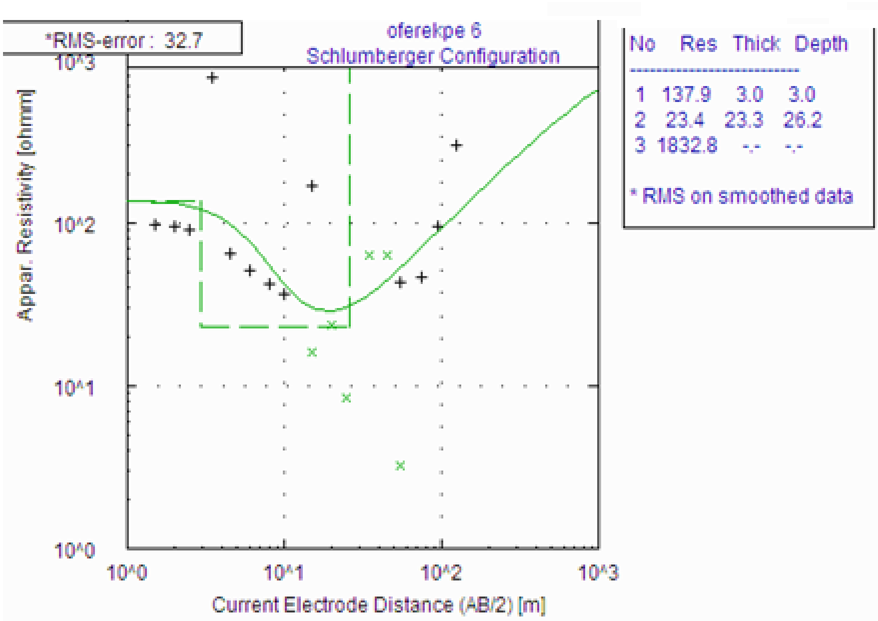

Figure 8: VES 6 Computer Modeling and Smoothed Geoelectric Parameters–HA curve type

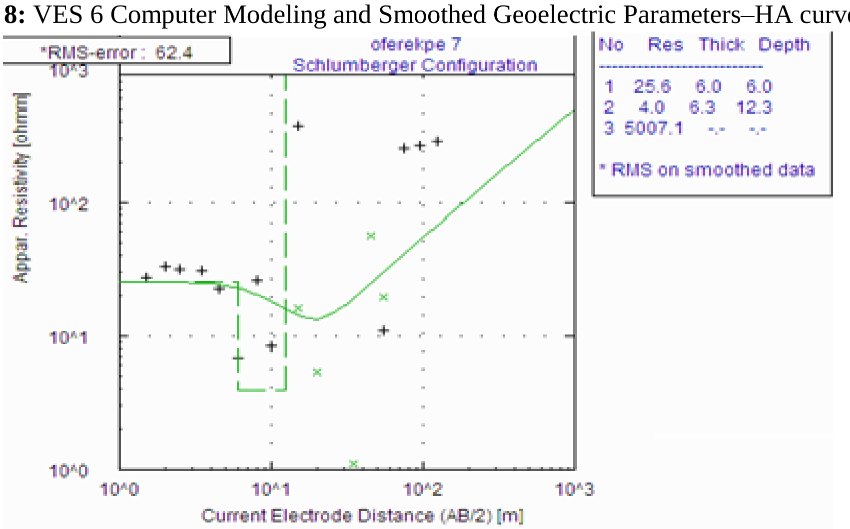

Figure 9: VES 7 Computer Modeling and Smoothed Geoelectric Parameters–HA curve type

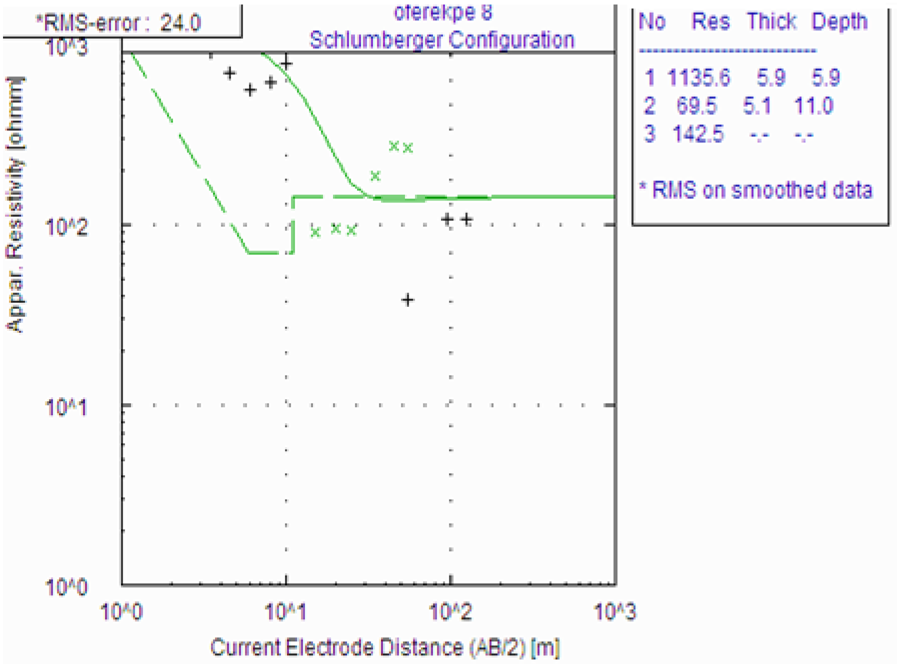

Figure 10: VES Computer Modeling and Smoothed Geoelectric Parameters–H curve type