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Electrical Resistivity Technique for Delineating the Aquifer in Parts of Rufus Giwa Polytechnic, Owo, Ondo State, Nigeria.

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ABSTRACT

An electrical resistivity survey was carried out at Rufus Giwa Polytechnic, Owo, Southwestern Nigeria to study the groundwater potential using parameters such as depth, thickness, and resistivity of subsurface materials which are indicative of sustainable groundwater development. Eight (8) geo-electrical soundings were employed using Schlumberger configuration with two of them located astride already existing hand-dug wells in order to validate the field resistivity measurements by correlating them with observe well information. The field data were processed using the IP12win inversion program which automatically generates model curves using initial layers parameters in calculating the true layer parameters of the geo-electric sections. The results show that the water table in the area falls between 5.73m and 12.57m with aquifer resistivity ranging from 40.5 Ωm to 777.8 Ωm. An aquifer with a depth range of 15.13m to 48.2m, delineated around the Students' Union building, is most suitable for a good borehole development even at commercial quantity as suggested by the thickness of the aquifer there. The survey demonstrates the usefulness of the Vertical Electrical Soundings in characterizing local hydrogeology, as there existed very strong correlation between the depth to the water table obtained from field measurements and that measured in nearby wells.

KEYWORDS – *Aquifer, Delineating, Electrical Resistivity, Groundwater, Owo.*

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I. INTRODUCTION

Inadequate potable water supply has been identified as one challenge that Rufus Giwa Polytechnic has confronted in recent months, having to provide water for the populace in the school community as well as make water available in commercial quantity through its OSPO Water Company. Recent growth in student and staff population has imposed significant stress on the existing inadequate water scheme, based solely on groundwater abstraction from the few boreholes within the campus.

The inability of the few boreholes sunk in the last one and half year to produce quality water can be traced to insufficient pre-drilling information available which is needed to guide a successful drilling process to accurate depth that can support a proposed abstraction rate of water from the well which has a direct bearing on the thickness of the aquifer at the location of the borehole. Hence, the adoption of a geophysical survey which is a cost-effective and a non-intrusive pre-drilling procedure that could offer adequate information about subsurface.

The electrical method of geophysics has been widely tested as applicable in groundwater evaluation which include identification of aquifer units, delineation of depths to and thicknesses of aquifer, identifying aquitard or confining units, locating preferential fluid migration paths and mapping groundwater contamination [1],[2],[3],[4],[5],[6],[7]. The electrical resistivity technique involves the measurement of the apparent resistivity of the soil and rock as a function of the depth or position [8].

Groundwater is water located beneath the ground surface in soil pure space and in the fracture of litho logic formations. A unit of rock or an unconsolidated deposit is called an aquifer when it can yield a useable quantity of water. The depth at which soil polar space or fractures and voids in rock become completely saturated with water is called water table. The volume of groundwater in an aquifer can be estimated by measuring water levels in local wells and by examining geologic records from well-drilling to determine the extent, depth and thickness of water-bearing sediments and rocks [9].

The focus of this paper was to delineate the study area into hydro-geologic zones in order to have sufficient pre-drilling information to enhance sinking of more effective boreholes in the study area.

II. DESCRIPTION OF THE STUDY AREA

Geologically, Owo, where Rufus Giwa Polytechnic is located, belongs to the basement complex of South-West Nigeria, which is underlain by Precambrian rocks. The major rocks in the area are granite, charnockites, quarzites, granite gneisses and migmatite gneisses. The granite rocks which are member of the older granite suite occupy about 65% of the total area. The magmatite gneisses, being the oldest rocks in the Nigerian basement, are both litho- and tectonostratigraphically basal to all superjacent lithologies and orogenic events [10].

Owo is the headquarters of Owo Local Government Area of Ondo State. It is located about 45 kilometers East of Akure, the Ondo State Capital. Owo lies on latitude 7^0 15' North of the Equator and longitude 5^0 35' East of Greenwich Meridian [11]. The survey layout covers between latitude $7^0 4^1 20.749^{11}$N to $7^0 4^{132}.518^{11}$N and longitude $5^0 42^1 36.381^{11}$E and $5^0 42^1 40.081^{11}$E (Fig. 1). Elevation averages about 150 meters above means seal level. The town falls within the sub equatorial region characterized by a Monsoon climate. A recent borehole drilled at Rufus Giwa Polytechnic indicated the presence of pegmatite. Pegmatite is a coarsely crystalline igneous or plutonic rock composed primarily of feldspar and quartz, normally with muscovite and or biotite mica. It is chemically identical to granite, but has a much coarser crystal structure.

III. METHODOLOGY

The electrical resistivity method is based on measurements using two electrodes, of the potential distribution arising when electric current is transmitted into geological layers through two other electrodes [12]. Eight (8) Vertical Electrical Soundings (VES 1 to VES 8) were carried out at the developed 'village' area of the polytechnic using the Campus Ohmega resistivity meter. VES 3 and VES 4 were run astride already existing hand-dug wells W2 and W1 respectively (Fig 1.0). The well information is to be used to constrain the resistivity measurement in order to check their correlation. A maximum current electrode spacing of AB=200m and potential electrode spacing of MN=12m was occupied for all the points except VES 3 which was restricted to AB=160m due to limitation of space. Finally, a record of the variation of the apparent resistivity of the subsurface with depth for each survey line was obtained.

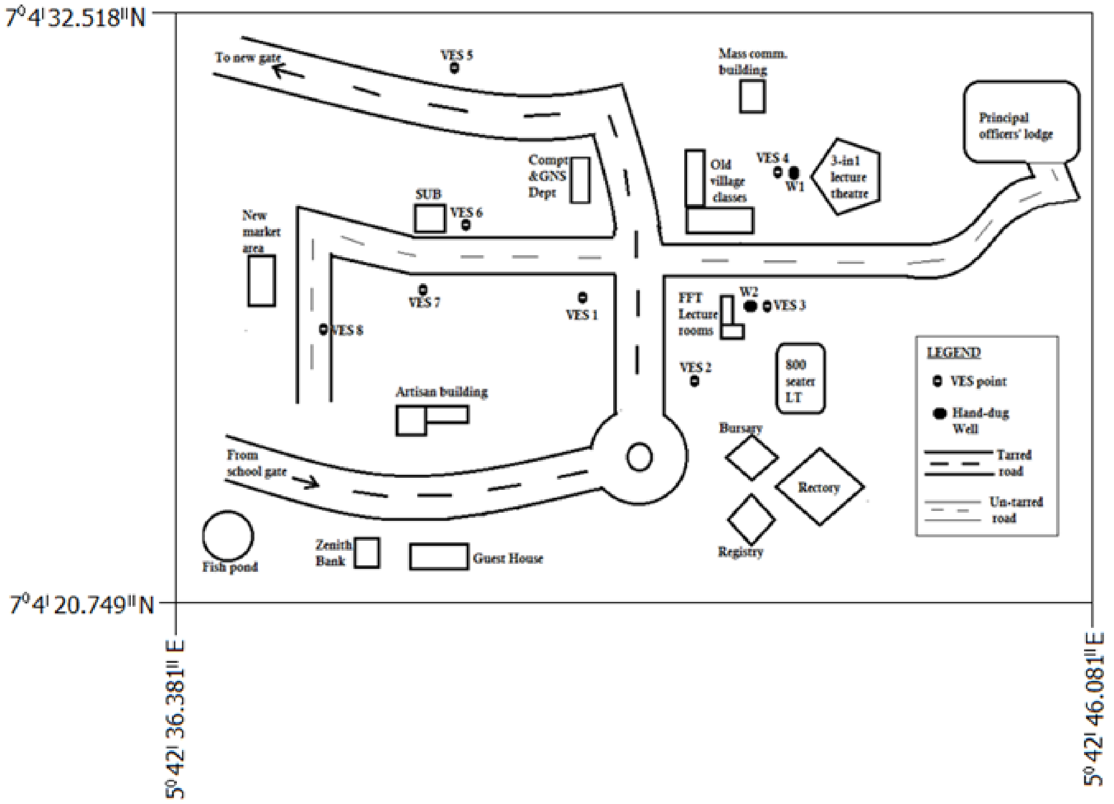


Fig. 1: Base map of the study area.

IV. DATA PROCESSING AND PRESENTATION OF RESULTS

The VES field data were processed using the IP12win inversion program which automatically generates model curves using initial layers parameters, derived from partial curve matching of the field curves with standard curves, in calculating the true layer parameters of the geo-electric sections, and calculates the true layer parameters of the geo-electric section [13]. The results are presented in terms of the resistivities and depths of the geo-electric section for the eight VES positions (Table 1 and Fig. 3 to Fig. 10). Qualitative interpretation of the sections was based on the predominant geologic formations in the study area.

TABLE 1: Layer Parameters of the Geo-electric Sections (VES 1 to 8)

S/N	Layer no	Resistivity (Ωm)	Depth (m)	Thickness (m)	INTERPRETATION
VES 1	1	94.6	0.5	0.5	Top soil
	2	138	2.32	1.82	Sandy quartzite from weathered layer
	3	40.5	47.6	45.2	Weathered basement saturated with water
	4	4337	-	-	Basement rock
VES 2	1	95.6	1.15	1.15	Top soil
	2	449	1.83	0.675	Lateritic Sandy clay
	3	143	3.1	1.28	Sandy porous layer draining the surface rain water
	4	399	6.29	3.19	Weathered basement layer
	5	14.8	17.9	11.6	Fractured basement rock permeated by water
	6	5387	-	-	Basement
VES 3	1	8.54	0.518	0.518	Top soil
	2	2.76	4.88	4.36	Lateritic Sandy clay
	3	1402	20.1	15.2	Weathered to fractured basement fully saturated with water
	4	8446	-	-	Basement
VES 4	1	231	1.008	1.008	Top soil
	2	365.5	2.116	1.158	Sandy quartzite
	3	67.95	3.994	1.828	Lateritic Sandy clay
	4	2255	5.738	1.744	Weathered basement rock not saturated by water
	5	125.3	24.05	18.31	Fractured basement rock saturated by water
	6	316.2	-	-	Fractured basement rock permeated by water
VES 5	1	163	1.3	1.3	Top soil
	2	260	7.06	5.76	Sandy quartzite layer
	3	1181	14.9	7.82	Lateritic Sandy clay
	4	253	28.7	13.8	Weathered basement rock not saturated by water
	5	331	-	-	Fractured basement rock saturated by water
VES 6	1	386.5	1.323	1.323	Top soil
	2	562.3	3.457	2.134	Sandy soil layer
	3	199.7	12.57	9.12	Lateritic Sandy clay
	4	80.53	35.44	22.9	Weathered basement rock not saturated by water
	5	357.1	-	-	Fractured basement rock containing by water
VES 7	1	260	0.5	0.5	Top soil
	2	734	1.17	0.669	Sandy quartzite
	3	100	7.57	6.4	Weathered basement containing water
	4	55.9	28.4	20.8	Weathered/fractured basement fully saturated by water
	5	25499	-	-	Impermeable basement rock
VES 8	1	143	1.01	1.01	Top soil
	2	601	2.3	1.29	Sandy quartzite
	3	42.1	5.73	3.43	Lateritic Sandy clay
	4	27.5	17.5	11.7	Weathered basement rock fairly saturated by water
	5	413	-	-	Fractured basement rock not saturated by water

1.0 Correlation:

There are two hand-dug wells W1 and W2 which are respectively beside VES 4 and VES 3. The static water level was measured in each case and their values compared with results from the interpreted VES.

1.1 VES 3: This has four geologic layers. The first layer is interpreted as the top soil consisting of porous sandy structure with a resistivity of 8.54Ωm at a depth of 0.518m. The second layer has a resistivity of 2.76Ωm and it is an indication of a sandy soil layer containing clayey materials which is about 4.36m thick. This layer, with a reduced resistivity, could also be due to the percolating rain water that has drained from the top soil to that layer. The rain fell on the day before this field data acquisition. At a depth of 20.1m a relatively high resistivity of 1402Ωm was encountered. This is the third geologic layer interpreted as weathered layer consisting of water. This is the layer of interest for an unconfined aquifer with a thickness of 15.2m. The water table was estimated at about 20.1m which correlates well with the actual depth to the water surface in the nearby hand-dug well W2 measured as 18.4m. The variation of about 1.7m could be attributed to the rise in the water table level due to the perched aquifer. The fourth geo-electric layer is interpreted as the basement rock that is impermeable hence the high resistivity of 8446Ωm.

1.2 VES 4: This has six geo-electric layers. The top soil is indicated by a resistivity of 231Ωm while the second layer falls within the resistivity of sandy-lateritic range encountered at a depth of 2.17m. The next layer of decreasing resistivity is seen as a layer through which rainwater is percolating hence the reduction of resistivity from 304Ωm to153Ωm. The third geologic layer is however relatively high resistive considered as a weathered metamorphic basement rock layer. The fourth layer has a low resistivity of 56Ωm at a depth of 18m with a thickness of about 7.6m. This is interpreted as a saturated zone underlain by a resistive layer that has a resistivity of 387Ωm. The depth to the water table here is obtained as 18m. The potentiometric surface of well water in the nearby well W1 is 15.1m. The difference of about 3m observed is as well associated with the fact that the water table has been raised from the actual depth to the potentiometric surface. It was also noted that the VES location was topographically higher in elevation than the well location to the range of about 1.5m. Thus, we can conclude that there is a strong correlation between the field result and the actual depth where groundwater was tapped. The area between VES 7 and VES 1 is recommended as the best location to site a borehole because the weathered and fractured layer is thickest there and it has the highest overburden thickness which shows depression into the basement. Other VES stations that are also good borehole locations are VES3, VES 5 and VES 6 while VES 3 is bound to lose water to VES 1 and VES 4 due to their slope. Their thicknesses are also lesser compared to that of VES 1 and VES 7 and this may hinder the good water quality in the zones.

2.0 Aquifer delineation

A pseudosection across three VES points (VES 7, VES 1 and VES3) was obtained and it reveals the lateral orientation of the depth of occurrence, width, thickness and dip of the aquifer at the area (Fig. 2). The basement rock dips from below VES 3 towards VES 7 where the overburden thickness is highest. The aquifer thickness of 20.8m and an overburden thickness of 28.4m makes the area around the Student Union Building (SUB) and artisan workshop area to be very suitable for a sustainable commercial water borehole.

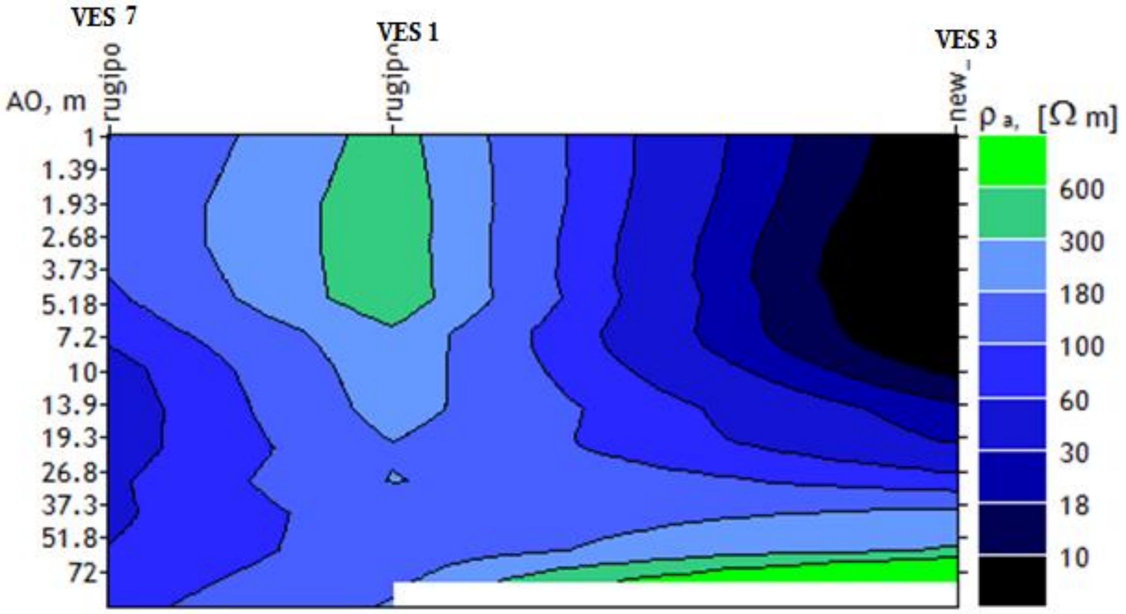
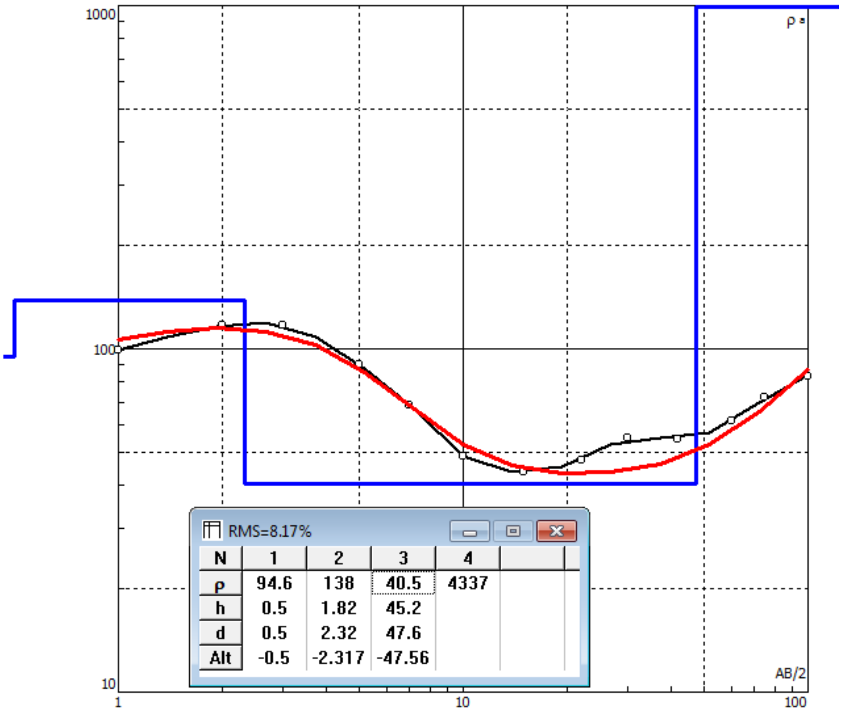


Fig. 2: Pseudosection cross section of VES 7, VES 1 and VES 3

V. CONCLUSION

From the deductions in this study, it is therefore confirmed that the weathered and fractured layers are the major aquifer formations in the area. The area between VES 7 and VES 1 is recommended as the best location to site a borehole because the weathered and fractured layer is thickest there and it has the highest overburden thickness which shows depression into the basement. Boreholes located within depression zones are capable of higher yield of groundwater when compared to those on ridges as water flows from ridges into zones of depressions under the influence of gravity.

Recommended depth to drill in the rich aquiferous area should be between 40m and 72m. This will actually tap into the weathered and fractured zones with good yield of potable groundwater. Finally, it is recommended that future explorations should involve detailed survey with a combination of other geophysical techniques such as ground penetrating radar (GPR) and very low frequency (VLF) seismic refraction.



RMS=8.17%

N	1	2	3	4
ρ	94.6	138	40.5	4337
h	0.5	1.82	45.2	
d	0.5	2.32	47.6	
Alt	-0.5	-2.317	-47.56	

Fig. 3: VES 1 Geo-electric layers: their resistivities, thicknesses and depths.

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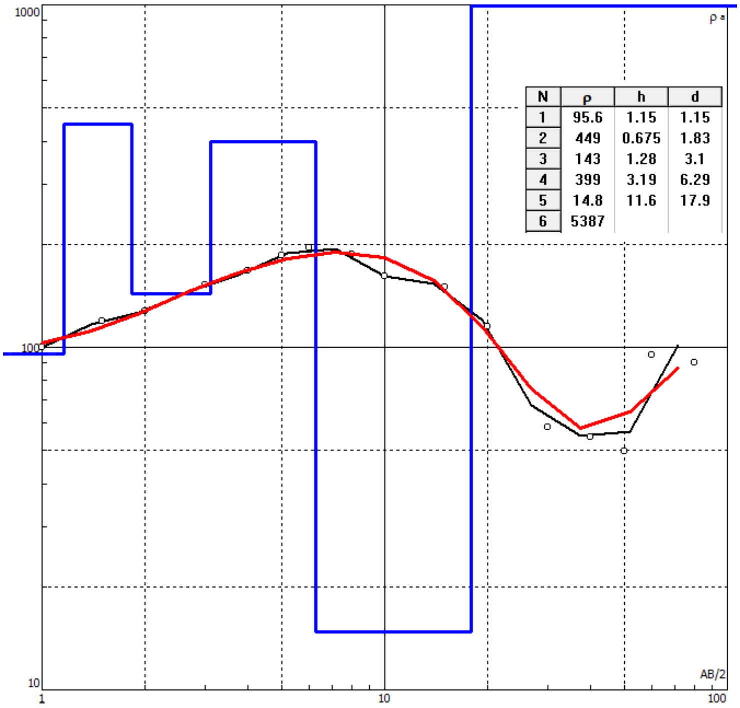
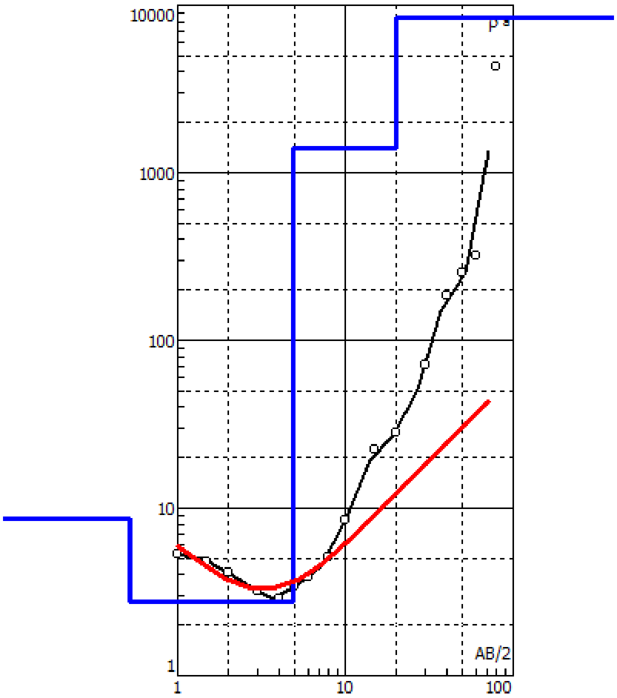


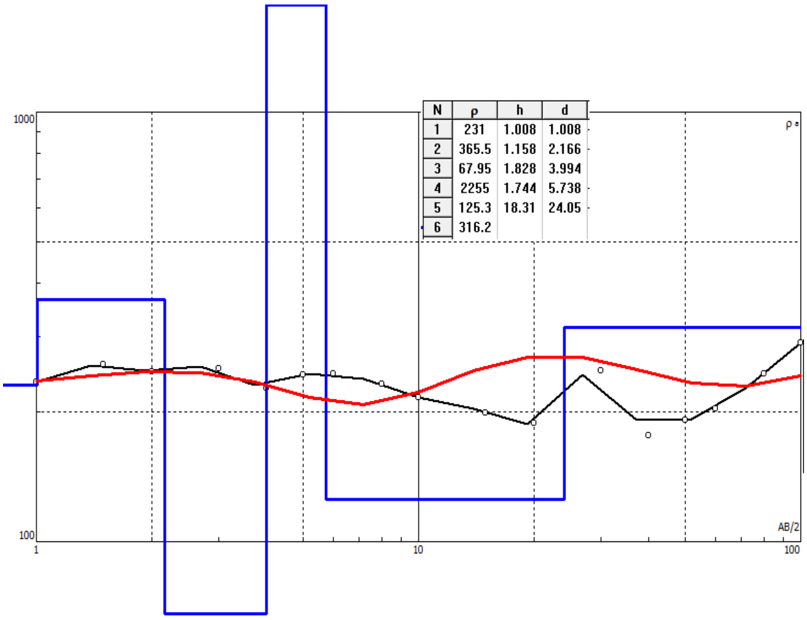
N	ρ	h	d
1	95.6	1.15	1.15
2	449	0.675	1.83
3	143	1.28	3.1
4	399	3.19	6.29
5	14.8	11.6	17.9
6	5387		

Fig. 4: VES 2 Geo-electric layers: their resistivities, thicknesses and depths.



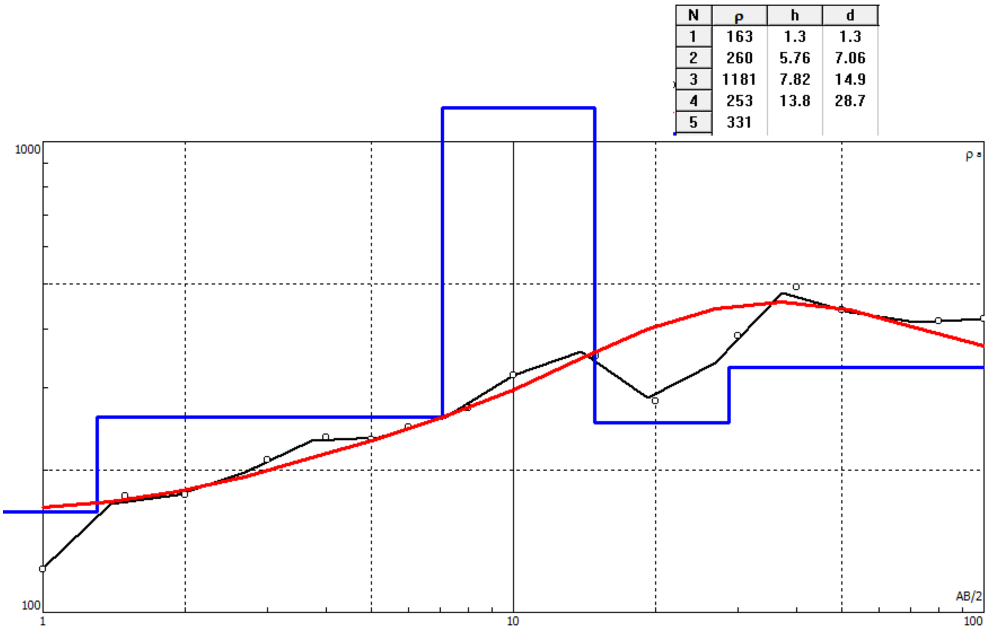
N	1	2	3	4	
ρ	8.54	2.76	1402	8446	
h	0.518	4.36	15.2		
d	0.518	4.88	20.1		

Fig. 5: VES 3 Geo-electric layers: their resistivities, thicknesses and depths.



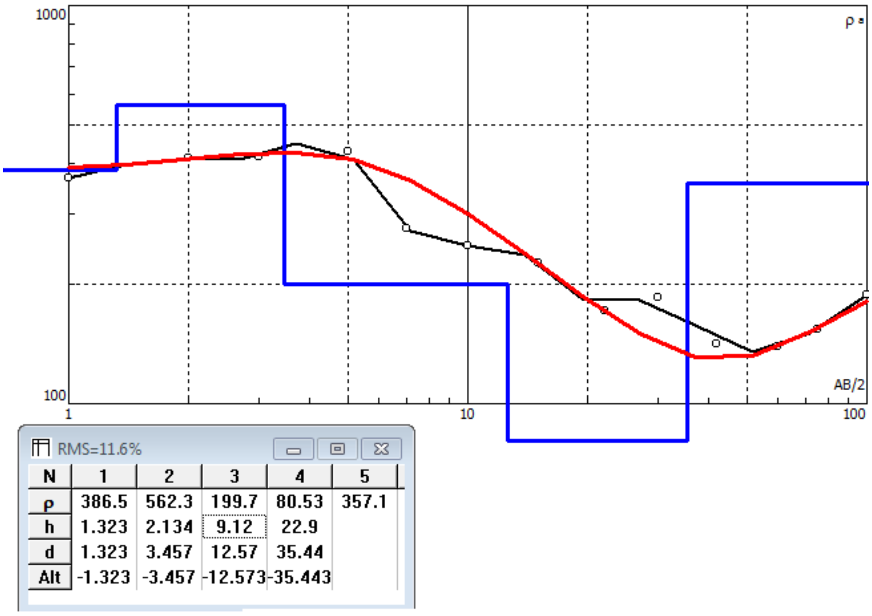
N	ρ	h	d
1	231	1.008	1.008
2	365.5	1.158	2.166
3	67.95	1.828	3.994
4	2255	1.744	5.738
5	125.3	18.31	24.05
6	316.2		

Fig. 6: VES 4 Geo-electric layers: their resistivities, thicknesses and depths.



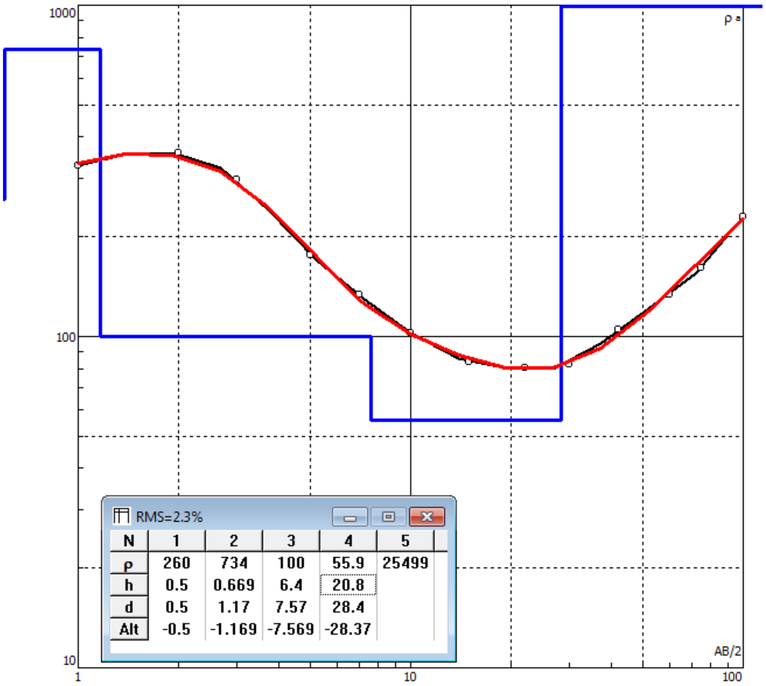
N	ρ	h	d
1	163	1.3	1.3
2	260	5.76	7.06
3	1181	7.82	14.9
4	253	13.8	28.7
5	331		

Fig. 7: VES 5 Geo-electric layers: their resistivities, thicknesses and depths.



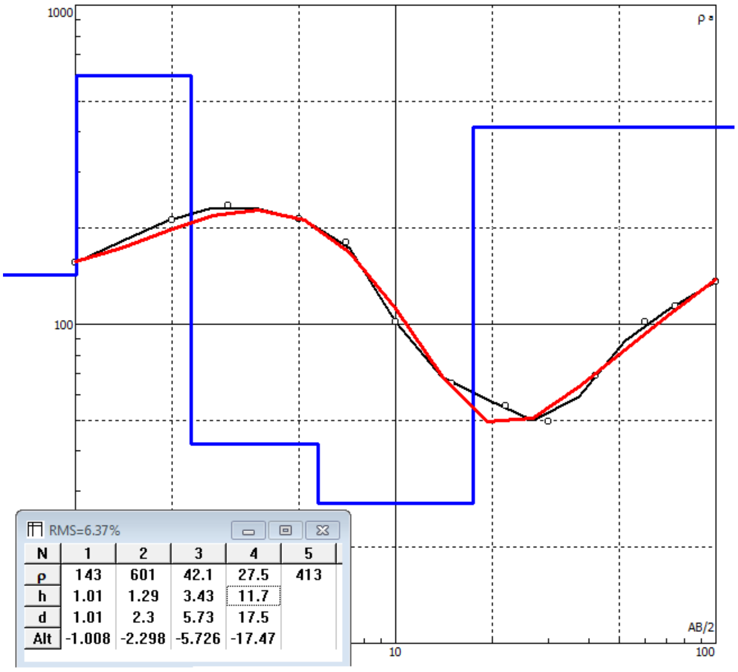
N	1	2	3	4	5
ρ	386.5	562.3	199.7	80.53	357.1
h	1.323	2.134	9.12	22.9	
d	1.323	3.457	12.57	35.44	
Alt	-1.323	-3.457	-12.573	-35.443	

Fig. 8: VES 6 Geo-electric layers: their resistivities, thicknesses and depths.



N	1	2	3	4	5
ρ	260	734	100	55.9	25499
h	0.5	0.669	6.4	20.8	
d	0.5	1.17	7.57	28.4	
Alt	-0.5	-1.169	-7.569	-28.37	

Fig. 9: VES 7 Geo-electric layers: their resistivities, thicknesses and depths.



N	1	2	3	4	5
ρ	143	601	42.1	27.5	413
h	1.01	1.29	3.43	11.7	
d	1.01	2.3	5.73	17.5	
Alt	-1.008	-2.298	-5.726	-17.47	

Fig. 10: VES 8 Geo-electric layers: their resistivities, thicknesses and depths.

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