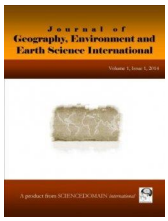

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A Geoelectrical Investigation of Groundwater Potentials in Dorowa and its Environs, Plateau State, North Central Nigeria

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Authors' contributions

This work was carried out in collaboration between all authors. Author MOL designed the study, wrote the protocol, and the first draft of the manuscript. Author FAA managed the literature searches and wrote the final draft of the manuscript. Author FXOU supervised the study. All authors read and approved the final manuscript.

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ABSTRACT

A geoelectrical investigation for potable groundwater potentials in Dorowa and its environs, Plateau State, North Central Nigeria has been carried out. The area is part of Jos-Bukuru Younger Granite Complex and is underlain by seven main rock types namely: Vom Microgranite (Vm), Rayfield Gona Biotite Granite (RGB), Ngell Biotite Granite (NGB), Vom Hornblende Biotite Granite (VHB), Shen Hornblende – Fayalite Granite (SHF), Porphyritic Biotite Granite (PBG) and Jos Biotite Granite (JBG). Interpretation of field structures and GIS data reveal lineaments trending NW-SE and NE-SW. Vertical electrical soundings conducted within Ngell biotite granite reveals that the area is underlain by three geoelectric layers. The top layer is mainly made up of laterite at depth between 0 - 5 m with resistivity values ranging from 79 – 202 Ωm, the second layer is made up of weathered granite at depth between 3 – 16 m with resistivity between 46 - 396 Ωm and the third layer is made up of slightly weathered to fresh granite at depths greater than 4 m with resistivity greater than

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113 Ωm. The zones of medium groundwater potential vary from 15 -16 m. Weathering depth in areas of fair water potentials varies from 13m – 14m with the best water potentials on VES 10 and VES 6. Zones of low groundwater potentials cover most part of the study area at depth less than 12 m.

Keywords: Groundwater potentials; electrical soundings; resistivity; layers; weathered.

1. INTRODUCTION

The objective of the work is to assess the groundwater potentials of Dorowa and its environs using basic geological and geoelectrical characteristics of the area. The area which host the Police staff College of Nigeria is located within Latitude 8°50'E – 8°54'E and Longitude 9°41'N – 9°45'N (Fig. 1) and covers an area of about 66km^2. The area is part of the crystalline rock areas of Nigeria that are characterized by poor groundwater yield [1]. Despite their poor hydrogeological characteristic, they remain a very important source of water for majority of the rural dwellers in Nigeria [2]. An earlier study of surface water and groundwater quality in the area indicated that groundwater in the area is of acceptable quality unlike the surface water that has colliform bacteria [3]. In this study, an electrical resistivity survey was carried out to locate acceptable groundwater and determine the depth to water table in the area.

1.1 Geomorphology, Drainage and Geology of the Area

The area lies within the guinea savannah of Nigeria, characterized by grassland, scattered trees, perennial shrubs and few cactus plants [4]. The average temperature of the area ranged from about 12.8°C to 27°C [4]. The mean annual rainfall in the area varies from about 1000mm to about 1460 mm.

The area is part of the Jos-Bukuru Younger Granite Complex, located in Jos-South Local Government Area of Plateau State, north central Nigeria. The average elevation of the Plateau is about 400 ft (121.92 m) with Younger Granites hills rising to about 600 ft (182.88 m) above the surface in some places [5]. The Kaduna/Bauchi plains slope gently away from the upland areas and range in altitude from about 279 m to 186 m. The area has naturally developed radial pattern of drainage with streams flowing into four major river systems, namely; Lake Chad, River Benue and River Kaduna. The streams develop a trellis pattern controlled by jointing in areas where they actively down cut through basement or the Younger Granitic rocks. The rivers of the Plateaux are entrenched in narrow valleys partly in-filled with basalt tin-bearing sand and gravels overlain by soft grey clays containing woody fragments. The rivers also cut into these sediments.

The rocks in Dorowa and its environs comprise Younger Granites with the oldest rocks in the area being the Jos Biotite Granite and Porphyritic Biotite Granite (Fig. 2). Others are the Ray-field-Gona Biotite Granite, Vom Hornblende-Biotite Granite and N'gell Biotite Granite, with the Shen Hornblende-fayalite Granite occurring within the N'gell Biotite Granite (Fig. 2). All the rocks are Younger Granites having preferred boundaries.

2. MATERIALS AND METHODS

A detailed geological mapping of the area was carried out using the Geological Survey Agency of Nigeria (GSN), sheet 168 of 1965 as base map. This was followed by the geoelectrical investigations using vertical electrical soundings (VES) technique of resistivity survey. A total of thirty vertical electrical soundings were carried out in the area with VES 1, VES2, VES 3, VES 10, and VES 15 carried out across N'gell Biotite Granite within the Nigerian Police Staff College, Jos using ABEM 300B SAS Terrameter. Schlumberger configuration with half current electrode spread, AB/2, varying from 1 m to 100 m and half potentials electrode separation MN between 0.5 m and 5.0 m respectively were adopted. The depth sounding data field curves (Appendix A) were interpreted by partial curve matching techniques [6] and by iterative computer program [7].

3. RESULTS

Results of field data and interpretations of VES 1, VES2, VES 3, VES 10, and VES 15 acquired from the Police Staff College in the area are shown in Appendix A. Summary of curve representing each type of curve considering thickness, resistivity and layers are shown in Appendix B. Results of interpretations of geoelectric soundings in the area are shown in

Appendix C. Results of depth to basement and groundwater potential map showing the demarcated zones of medium, fair and low groundwater potentials are shown in Appendix D.

4. DISCUSSION

The VES curve models indicate 3-4 geoelectric layers, namely H-type ($P_1 < P_2 > P_3$), KH-type ($P_1 < P_2 > P_3 < P_4$), QH-type ($P_1 > P_2 > P_3 < P_4$) and HKH-type ($P_1 > P_2 < P_3 > P_4 < P_5$).

The first geoelectric layer ranges from 0-5 m with resistivity values from 79 Ωm - 202 Ωm representing topsoil and laterite. The second geoelectric layer consists of weathered granite, the weathering ranges from 3 m-16 m with low resistivity from 46 Ωm - 396 Ωm. This primarily is the zone of water saturation where there is appreciable depth of weathering. The third geoelectric layer consists of slightly weathered to fresh granite. The depth ranges from 4 m down with resistivity greater than 113 Ωm to infinity. Where weathering is minimal, fractures were suspected. Where exceptional cases were seen, VES values suggested probable water zones in the area with weathering depth ranging from 15 m -16 m. Weathering of materials is more on both flanks of the layer and lowest in the middle with resistivity values between 130 Ωm and 246 Ωm. The middle is characterized by shallow weathering at depths less than 3 m with possibility of fractures.

The zones of medium groundwater potential range from depth of 15 m and above. (They represent the weathered zone). VES 16, VES 29, VES 25, VES 23, VES 11, VES 12 and VES 30 fall within this area in the north-eastern, western and southern parts of the college. Areas of fair groundwater potential zones fall within the southern and north western part of the college with VES 10 and VES 6 giving the best water potential with weathering depth ranging from 13-14 m.

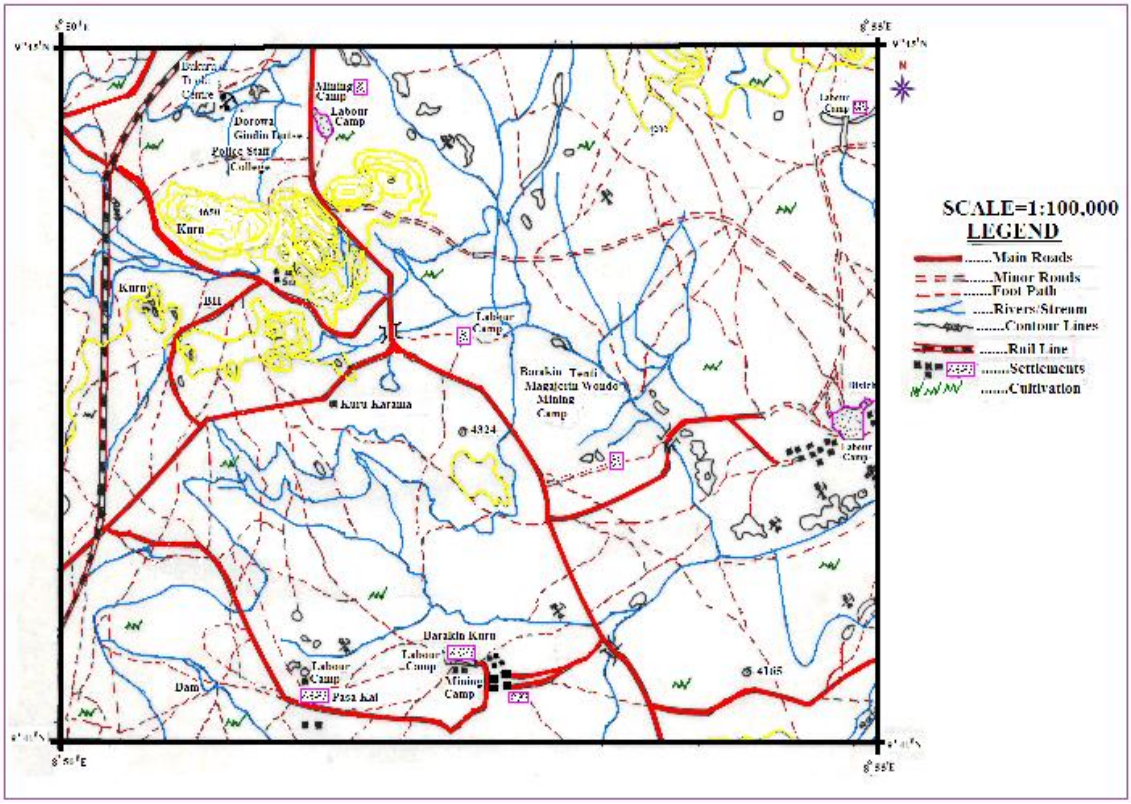

Fig. 1. Location map of the study area

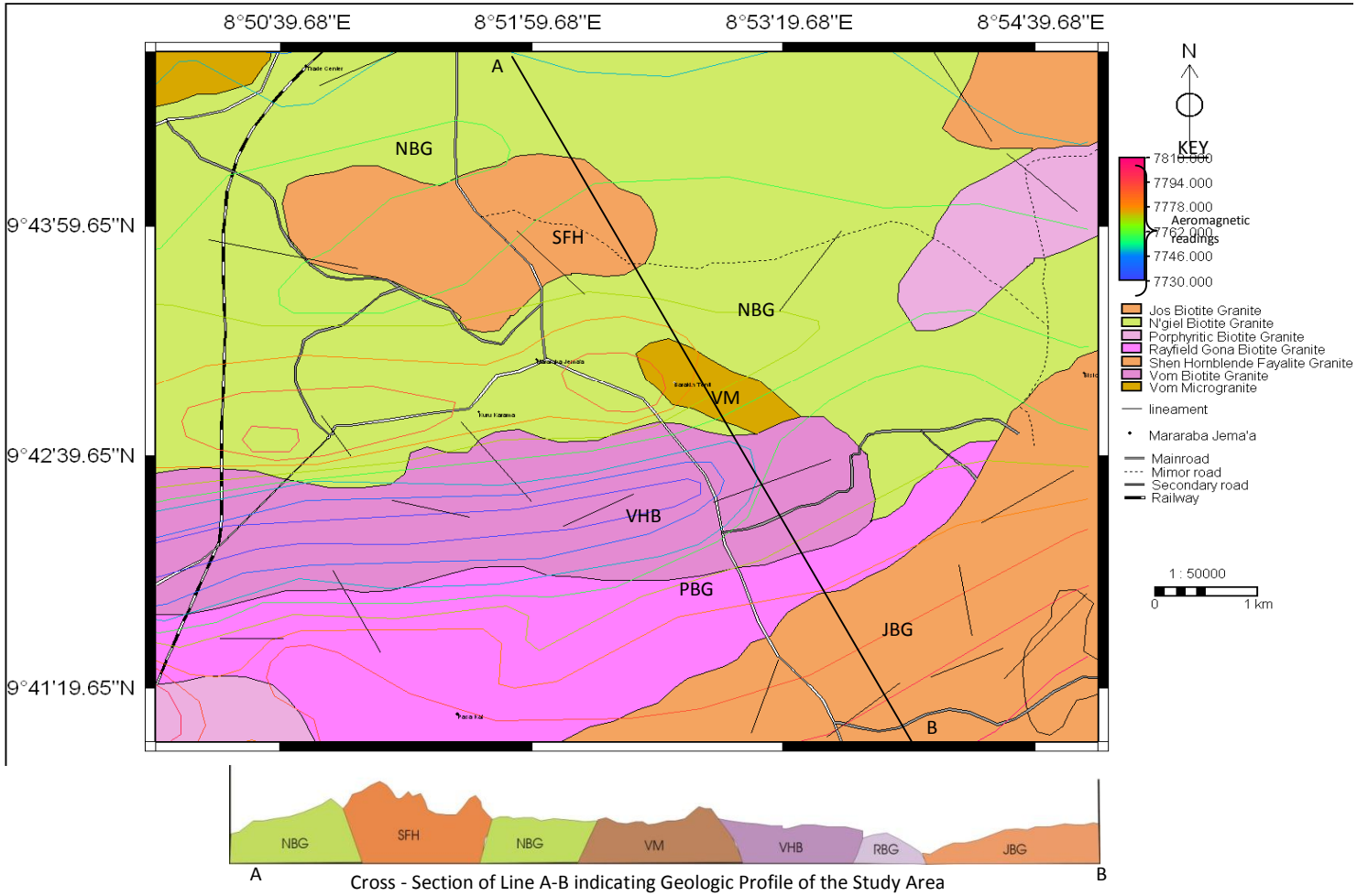

Fig. 2. Aeromagnetic map and lineament superimposed on the Geologic map of the area

The last zone is the zone of low groundwater potential which covers most parts of the college (central, eastern and south western parts of the area). VES 1-VES 5, VES 7, VES 8, VES 9, VES 15, VES 17, VES 18, VES 19, VES 20, VES 21, VES 22, VES 24, VES 26, VES 27 and VES 28 are within the area. The depth of weathering is below 12m. However, the saturated thickness of aquifer determined, ranges from 13m to 20m.

5. CONCLUSION

Interpretation of Vertical electrical soundings conducted across the N'gell Biotite Granite in Dorowa (within the Nigeria Police Staff College premises) indicates that the area is underlain by 3 to 4 geoelectric layers with the top layer made up of laterite, followed by weathered granite and slightly weathered to fresh granite. A fourth geoelectric layer was delineated in areas where fractures were encountered. Three Potential groundwater zones were identified based on depth to basement map (Appendix D) at maximum resistivity of 395 Ωm. They are zones of medium groundwater potential ranging from 15 m and above of weathering in the northeastern, western and southern parts of the College, zones of fair groundwater within the southern and northwestern part of the College with weathering depth ranging from 13 m to 14m and zone of low groundwater potential which covers the central, eastern, and southwestern parts of the police staff College with the depth of weathering falling below 12 m.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

B

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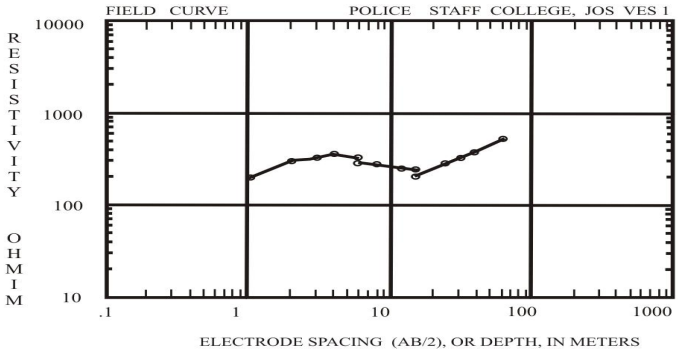
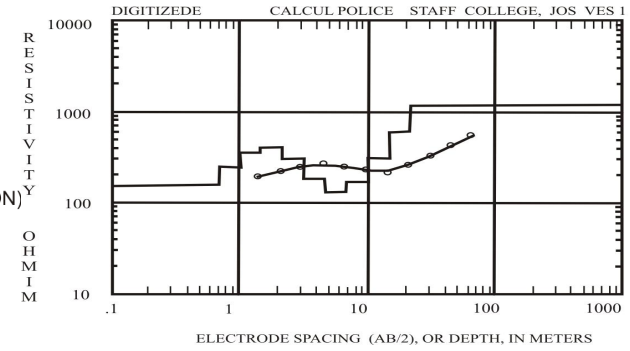
APPENDIX A

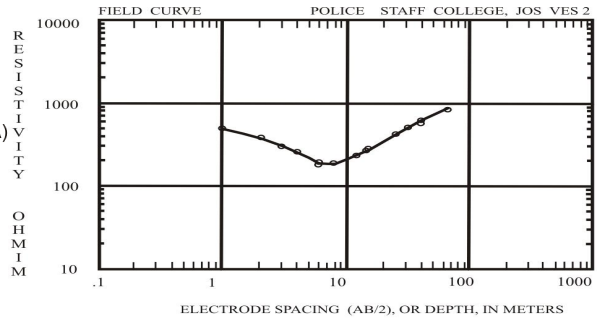
AB/2	App. Res.	AB/2	App. Res. (FIELD DATA)
1.00	204.10	12.00	256.05
2.00	303.82	15.00	251.64
3.00	333.08	15.00	213.47
4.00	366.94	25.00	287.65
6.00	334.79	32.00	324.92
6.00	291.79	40.00	379.50
		40.00	383.02
8.00	298.27	65.00	530.93



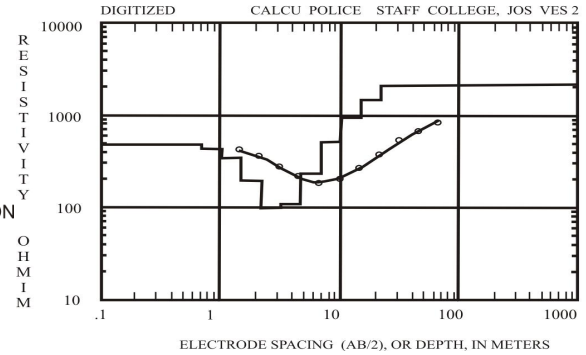
Depth	Resis	Depth	Resis (INTERPRETATION)
0.68	157.77	4.64	181.25
1.00	250.97	6.81	130.05
1.47	359.16	9.99	168.86
2.15	398.39	14.66	302.63
3.16	307.63	21.52	573.96
		99999.0	1105.11



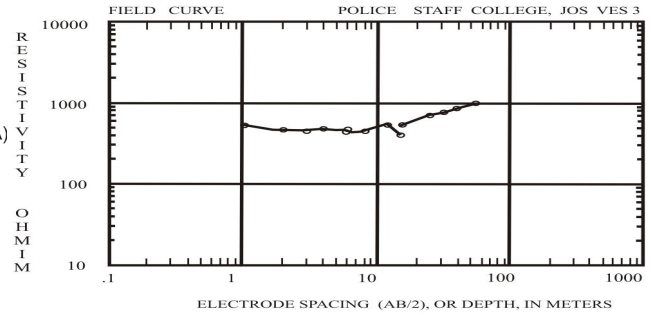
AB/2	App. Res.	AB/2	App. Res. (FIELD DATA)
1.00	479.79	12.00	223.93
2.00	376.95	15.00	272.14
3.00	294.63	15.00	253.06
4.00	250.32	25.00	406.44
6.00	189.77	32.00	485.77
6.00	174.63	40.00	550.41
		40.00	600.00
8.00	179.55	65.00	800.00



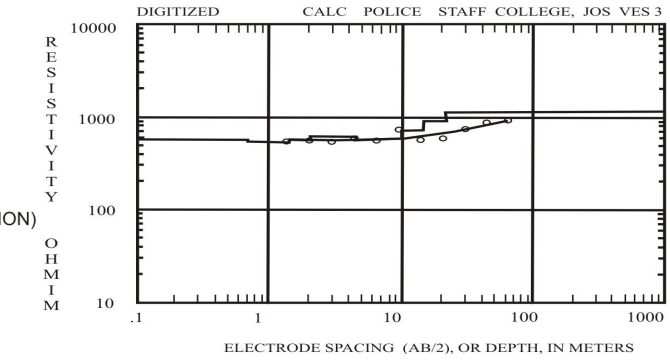
Depth	Resis	Depth	Resis (INTERPRETATION
0.68	470.44	4.64	106.82
1.00	416.65	6.81	227.81
1.47	337.03	9.99	492.32
2.15	191.44	14.66	899.32
3.16	94.98	21.52	1417.34
		99999.0	2042.52



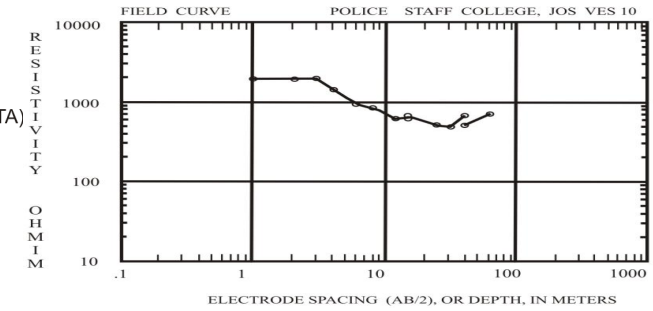
AB/2	App. Res.	AB/2	App. Res. (FIELD DATA)
1.00	536.23	12.00	412.13
2.00	447.58	15.00	395.84
3.00	442.22	15.00	523.08
4.00	473.50	25.00	700.92
6.00	456.90	32.00	743.13
6.00	415.08	40.00	839.10
		40.00	853.51
8.00	440.32	65.00	950.36



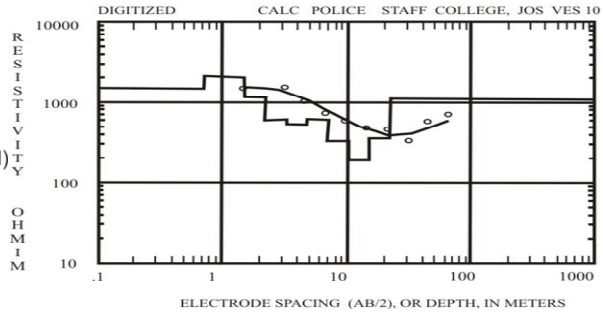
Depth	Resis	Depth	Resis (INTERPRETATION)
0.68	560.00	4.64	616.90
1.00	531.76	6.81	568.25
1.47	530.83	9.99	579.50
2.15	565.38	14.66	714.66
3.16	615.07	21.52	932.08
		99999.0	1149.93



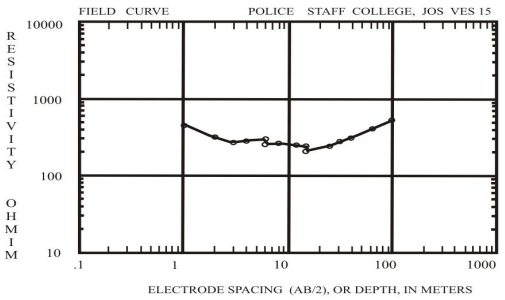
AB/2	App. Res.	AB/2	App. Res. (FIELD DATA)
1.00	1878.00	12.00	593.98
2.00	1874.70	15.00	598.00
3.00	1849.19	15.00	646.42
4.00	1383.29	25.00	500.69
6.00	936.43	32.00	464.86
6.00	920.63	40.00	650.94
		40.00	492.60
8.00	830.38	65.00	690.21



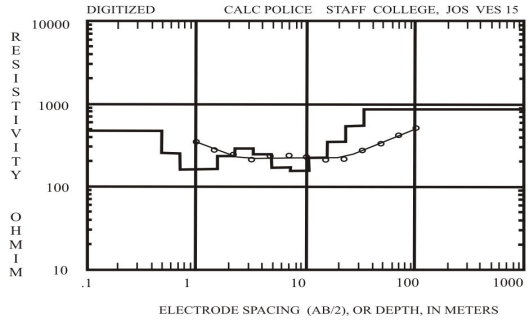
Depth	Resis	Depth	Resis (INTERPRETATION)
0.68	1415.47	4.64	520.91
1.00	2021.35	6.81	600.74
1.47	1984.62	9.99	332.53
2.15	1156.62	14.66	193.36
3.16	590.20	21.52	358.86
		99999.0	1082.40



AB/2	App. Res.	AB/2	App. Res. (FIELD DATA)
1.00	440.23	15.00	233.26
2.00	308.35	15.00	208.52
3.00	263.52	25.00	235.62
4.00	279.47	32.00	273.45
6.00	285.00	40.00	301.59
6.00	252.21	40.00	301.59
8.00	257.36	65.00	398.20
12.00	244.29	100.00	502.66



Depth	Resis	Depth	Resis (INTERPRETATION)
0.49	463.73	4.86	243.67
0.71	254.22	7.13	166.57
1.05	160.43	10.47	153.75
1.54	163.34	15.37	217.70
2.26	233.40	22.56	344.99
3.31	288.93	33.11	543.34
		99999.0	855.89



APPENDIX B

Summary of curve representing curve types considering thickness, resistivity and layers

VES 1: KH Curve type (ρ1 < ρ2 > ρ3 < ρ4)

Layer	Thickness (m)	Resistivity Ω m)	Inferred lithology
1	1	204	Topsoil
2	2.2	355	Laterite
3	6.8	160	Weathered granite
4	11.5	438	

VES 2: H- Curve type (ρ1 > ρ2 < ρ3)

Layer	Thickness	Resistivity (Ωm)	Inferred lithology
1	1.5	408	Topsoil
2	3.2	131	Weathered granite
3	16.9	759	Fresh granite

VES 3: A - curve type (ρ1 < ρ2 < ρ3)

Layer	Thickness	Resistivity (Ωm)	Inferred lithology
1	2	546	Topsoil
2	7.8	5.96	Slightly weathered and fractured granite
3	11.5	923	Fresh granite

VES 4: QH – Curve type (ρ1 > ρ2 > ρ3 < ρ4)

Layer	Thickness (m)	Resistivity (Ωm)	Inferred lithology
1	2.2	1644	Laterite
2	4.7	571	Sandy laterite
3	7.9	113	Sandy clay
4	6.9	351	Fresh granite

VES 5: HKH – Curve type (ρ1 > ρ2 < ρ3 > ρ4 < ρ5)

Layer	Thickness (m)	Resistivity (Ωm)	Inferred lithology
1	0.7	359	Topsoil
2	0.8	162	Weathered granite
3	3.3	255	Fresh granite
4	5.6	160	Fractured granite
5	22.6	369	Fresh granite

APPENDIX C

Interpretation of Geoelectric Soundings in the Nigerian Police Staff College

Vertical Electrical Soundings P.1
Curve type: KH-type (P1<P2>P3< P4)

Coordinates
Longitude 80.8433 E
Latitude: 90.73831 N
Altitude: 1296 m

Table 1.

Layer	Depth(m)	Resistivity (Ωm)	Inferred lithology
1	0-0.68	157.77	Topsoil, Sandy
2	0.68 – 3.16	250.97-398.39	Laterite
3	3.16 – 9.99	130.05 – 181.25	Weathered granite
4	9.99 – 21.52	302.63-573.96	Slightly weathered to fresh granite

Vertical Electrical Soundings P.2
Curve type: H-type (P1>P2<P3)

Coordinates
Longitude 80.84412E
Latitude: 90.7376N

Table 2.

Layer	Depth (m)	Resistivity (Ωm)	Inferred lithology	Remarks
1	0-2.15	191.44-470.44	Laterite	
2	2.15-4.64	94.98-106.82	Weathered granite	
3	4.64-21.52	227.81-1417.34	Slightly weathered to fresh granite	

Vertical Electrical Soundings P.3
Curve type: KH-type (P1<P2>P3<P4)

Coordinates
Longitude 80.8460 E
Latitude: 90.7365 N
Altitude: 1310 m

Table 3.

Layer	Depth(m)	Resistivity(Ωm)	Inferred Lithology	Remarks
1	0-2.15	530.83-565.38	Laterite	
2	2.15-4.64	615.07-616.90	Granite	
3	4.64-9.99	568.25-579.50	Slightly fractured granite	
4	9.99-21.52	714.66-932.08	Granite	

Vertical Electrical Soundings P.10
Curve type: QH-type (P1>P2>P3<P4)

Coordinates
Longitude 80.8471 E
Latitude: 90.7381 N
Altitude: 1302 m

Table 4.

Layer	Depth(m)	Resistivity(Ωm)	Inferred Lithology	Remarks
1	0-2.15	1156.62-2021.35	Laterite	
2	2.15-6.81	520.91-600.74	Laterite, sandy	
3	6.81-14.66	193.36-332.53	Sand/sandy clay	Possibly aquiferous
4	14.66-21.52	358.86	Slightly weathered granite	

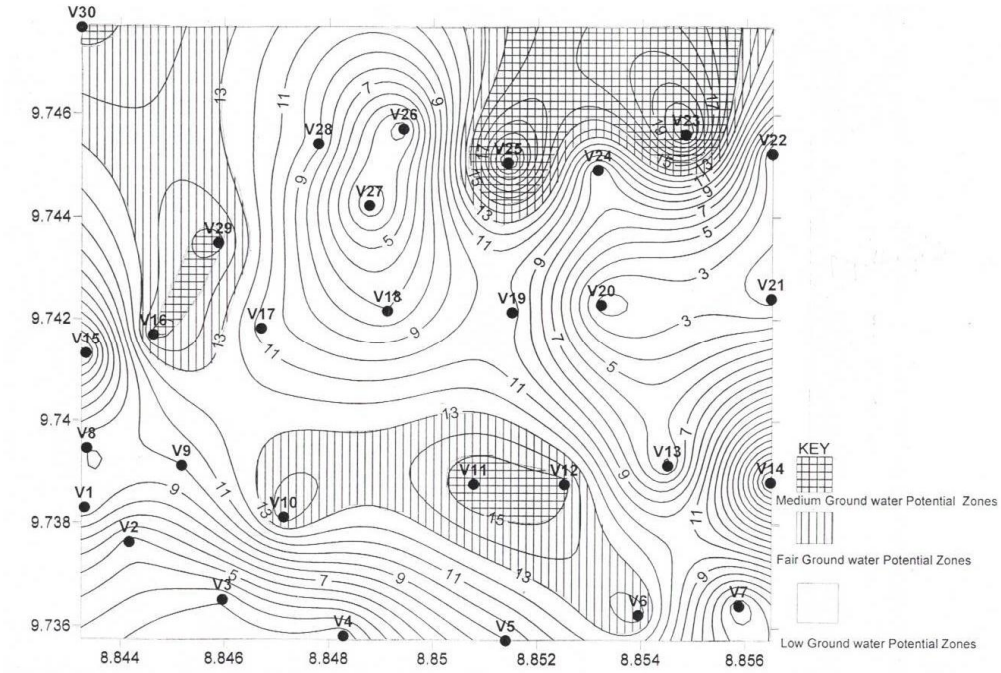
Vertical Electrical Soundings P.15
Curve type: HKH-type (P1>P2<P3>P4<P5)

Coordinates
Longitude 80.8433 E
Latitude: 90.7413 N
Altitude: 1280 m

Table 5.

Layer	Depth(m)	Resistivity(Ωm)	Inferred Lithology	Remarks
1	0-0.71	254.22-463.73	Topsoil, lateritic	
2	0.71-1.54	160.43-163.34	Weathered granite	
3	1.54-4.84	233.4-288.93	Slightly weathered granite	
4	4.84-10.47	153.75-166.57	Fractured granite	Possibly aquiferous
5	10.47-33.11	217.70-543.34	Slightly weathered to fresh granite	

APPENDIX D



Depth to Basement and groundwater potential Map

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