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Investigation of Groundwater Potential Using Electrical Resistivity Method, in Iddo Community Grammar School, Iddo-Okpella, Edo State

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ABSTRACT

Vertical electrical sounding (VES) resistivity technique was used to investigate the ground water potential at Iddo Community Grammar School, Iddo-Okpella, Edo State, Nigeria. A total of 36 VES points consisting of six profiles with six VES points per profile were covered. Data from the Schlumberger vertical electrical sounding were presented as geo- electric sections, iso-resistivity maps, regolith and depth to basement maps. The resistivity field data were interpreted using partial curve matching approach and iterative resistivity sounding interpretation software-WinResist Version 1.0. The results from the interpretations showed that three to four geoelectric sections were delineated: the top layer has a thickness ranging from 0.2 m to 2.1 m with resistivity range of 91.5 Ωm to 1195.5 Ωm, the thickness of the second layer ranges from 2.0 to 14.2 m with resistivity values ranging from 20.5 Ωm to 916.80 Ωm and the thickness of the third layer ranges from 2.7 m to 14.7 m with resistivity values between 8.0 Ωm and 4328.10 Ωm and resistivity of the basement has the maximum of 4328.10 Ωm. VES C6, D3, D6, E4, E5, F1, F2 and F5 in the study area have relatively high regolith thickness and high conductivity values. Considering the aquifer characteristics in terms of thickness-resistivity values, it is recommended that groundwater developments should be concentrated around VES C6 (10.6m), D3(9.0m), D6(15.0m), E4(12.8m), E5(16.7m), F1(10.8m), F2(11.1m) and F5(12.1m) of the study area.

Keyword: Vertical electrical sounding, resistivity, conductivity, regolith, groundwater and Basement

Background to the Study

The existence and livelihood of people is dependent on water. Today, the world population has steadily increased causing a concomitant increase in the demand for clean water as elixir. A lot of people in several places of the world are deficient of the fresh, portable water needed for their survival; if they are to prosper, more secure and low cost water supplies are needed. The maintenance of secure water supplies for drinking, industry and agriculture would be impossible without groundwater which is the largest and most reliable of all fresh water resources. In so many areas, most drinking water is groundwater which is up to 80% in Africa and even more in other parts of the world, (UNDP, 2006).

Unlike other natural resources, groundwater is available throughout the world. To meet out the demand for water, people are relying on aquifers. Corollary, the area under study is underlain by hard rock formations and faces serious water shortages in terms of irrigation and drinking purposes. The occurrence of groundwater in this type of terrain is restricted to weathered and fractured zones and upper unconsolidated materials. To locate groundwater potential in the hard rock province, the main target is fractured zones. Geophysical surveys using electrical resistivity method has proved to be efficient tools because they are capable of defining the significant contrast in the geo-electric parameters of the top soil and in-situ weathered material, fractured zone and fresh basement rock, Oloruniwo and Olorunfemi (1987).

Electrical techniques are extremely used in groundwater geophysical investigations because of the correlations that often exist between electrical properties, geologic formations and their fluid content (Zohdy and Jackson, 1969; Zohdy *et al.,* 1974). In view of these, Vertical Electrical Sounding (VES) technique was used to investigate the groundwater potential in Iddo Community Grammar School, Iddo-Okpella, Edo State, Nigeria.

Schlumberger array system was used for this survey. The vertical variations in the ground apparent resistivity were measured with respect to a fixed centre of array. The survey was carried out by gradually expanding the electrode spacing about a fixed centre of the array. The presence of horizontal or gently dipping beds of different resistivities was best detected by expanding the spread (Kearey and Brooks, 2002). Hence, the method is useful in determining depth of overburden; defining the horizontal strata and resistivity of flat-lying sedimentary beds and possibly of the basement.

The technique used is Vertical Electrical Sounding using Schlumberger array. The technique is basically used mainly in the search for water bearing formations, stratigraphic correlations, oil fields and in prospecting for conductive ore bodies. In this technic, artificially generated electric currents are introduced into the ground and the resulting potentials differences are measured at the surface. Therefore, resistivity of a material is normally defined as the resistance in ohm (Ω) between the opposite faces of a unit cube of the material. For instance, a conducting cylinder of resistance ∂R, length ∂L and cross-sectional area ∂A, therefore, the resistivity is given by:

$$\rho = \frac{\partial R \partial A}{\partial L} \quad (1)$$

Location of Study

The study area, Iddo Community Grammar School (ICGS) and environs is strategically located in the northern fringes of Edo State bordering Kogi State. It is one of the major gateways opening Edo State to Northern Nigeria. Figure 1 shows the location of the study area. The area lies between Latitudes 7^0 and 7.25^0 North and Longitudes 6.15^0 and 6.38^0 East The study area is easily accessible through network of roads and developed footpaths. The exact site surveyed covers a total area of 500 m by 500 m (250, 000 m^2) of Iddo Community Grammar School and its environs.

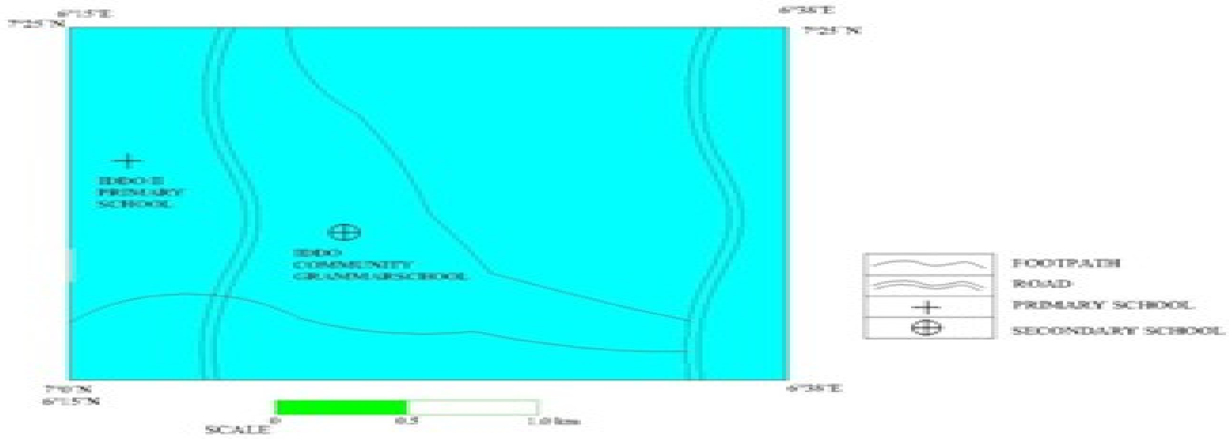


Figure 1: Location of Study Area

Geology of the Study Area

The study area, which lies within the Basement Complex of South-South Nigeria, is underlain by undifferentiated older Granite mainly coarse grained granite and porphyritic granite of the Pan-African older Granitoids, (Figure 2). There are intercalations of shale and mudstone in the study area. The rocks are generally in the NW direction and dipping to the East. The Older Granites were first distinguished from the "younger" alkaline granites by Falconer (1911). They are also known as Pan-African Granites and range in size from batholiths to plutons. Rocks that make up the Older Granite suite include; Porphyritic/porphyroblastic muscovite granites. Granites, hornblende-biotite granites, non-porphyritic/porphyroblastic fine to medium grained granites, granodiorites, adamellites, quartz monzonites, syenites, aplites, diorites, quartz diorites, and pegmatites but granitic and granodioritic compositions are most common.

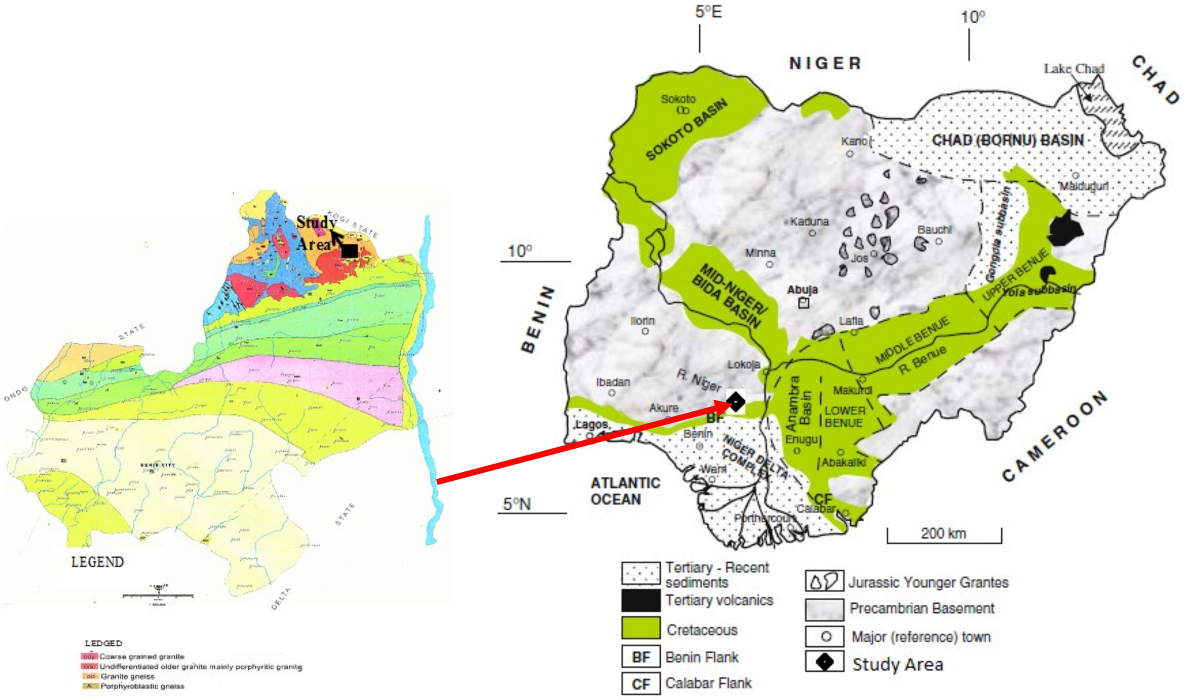


Figure2: Detailed geological map of Edo State culled from the Nigerian Geological Map (Obaje, 2009)

But resistivity is one of the most variable of physical properties. Most rocks forming minerals are insulators and electrical current is carried through a rock mainly by the passage of ions in pore waters. Therefore, most rocks conduct electricity by electrolytic rather than electronic processes Kearey and Brooks (2002). If a current (I) is passed through the cylinder causing a potential drop between the ends of the element, (Ohm's) law relates that

$$\partial V = \partial RI \qquad (2)$$

We can conveniently state that the basic equation for calculating ρ for any electrodes configuration is:

$$\rho = \frac{2\pi \Delta V}{I} K \qquad (3)$$

where K is the geometric factor Kearey and Brooks (2002).

Sounding data are presented as sounding curves by plotting apparent resistivity against electrode spacing (AB/2) in meters on a bi-log paper.

Materials and Methodology

In this survey, the data were collected using ABEM Terrameter SAS 4000. Schlumberger configuration of electrical sounding was employed for electrical drilling (VES data). The maximum current electrode separation of 200 m and potential electrode separation of 30m were used. There was no need for data reduction or repeated measurement since the receiver of ABEM Terrameter SAS 4000 discriminates noise and measures voltages correlated with transmitted signal current. The system has in-built function to average the best measurement of maximum of four stacking with the standard deviation of unity or even less. Apparent resistivity data were determined from the resistance values collected using $\rho = KR$, where K is the geometric factor, and R is the resistance. A total of thirty-six VES stations were sounded (Figure 3). Iterative software called Win Resist was used to interpret the data. This software performs automatic interpretation of the Schlumberger sounding curves which gives the equivalent n-layer model input from the apparent resistivity data of each sounding point. It converts the apparent resistivity as a function of electrode spacing to the true resistivity as a function of depth. The VES data were interpreted in terms of geoelectric sections and iso-resistivity maps using computer iterative window-based application software (Surfer 9.0).

Results and Discussion

The resistivity sounding curves of the thirty six stations obtained from the study area vary from three-layer, which are H-type curves to four-layer curves which are QH-type HK, KH Figures 4a and Figure 4b.Visual inspection of the Win Resist curves based on their distinct geo-electric characteristics were used to classify the various curve types. This is in agreement with works of many authors, Ofomola *et al.* (2009); Adesida and Omosuyi (2005); Ayolabi *et al.* (2009). The two dimensional views of the geo electric parameters obtained from the VES are presented as geo-electric sections, Iso resistivity maps, regolith contoured maps and depth to basement maps, Figures 5a, 5b, 6a,6b, 7a,7b, 8a, 8b, 9a, 9b, 10a and 10b.

The digitized data were summarised in Table1. They were obtained through averaging of similar resistivity values that span through several depths. Both resistivity values and corresponding depths were averaged. The difference between successive depths gives the thickness of a layer; while the resistivity values, (average) correspond to the resistivity of that particular layer. This process was repeated for the whole VES points from the study area. The analysis and interpretation of the geo-electric parameters indicated that the subsurface geologic layer delineated are: the top soil, the weathered basement, fractured basement and fresh crystalline basement.

Vertical Geo-electric and Geologic sections through Profiles

Figures 5a-10a are subsurface vertical section through profiles A-F, and Figures 5b-10b are their corresponding vertical sections contoured at 50 Ωm. The first layer of profiles A to F were characterised with an average resistivity range between 390 Ωm and 656 Ωm. This layer has the thicknesses range from 0.3 m at VES point F6 to 2.1 m at VES point B4. This layer is characterised with sandy soil, loam and lateritic top soil. The second layer (which is regarded as the weathered basement) has an average resistivity value between 100.58 Ωm and 302.1 Ωm. Its thicknesses also range from 0.3 m (VES A6) to 15.9 m (at VES E5). The third layer been characterised as the fractured basement, has the resistivity range between 24.5 Ωm and 128.8 Ωm. It also has the thicknesses value that varies from 0.3 m (at VES A1) to 14.7 m (at VES D6). The layer merges with the weathered basement and the down warping architecture of this layer makes it a good site for optimum ground water potential. The architecture of the fractured basement reveals that some VES points in fractured basement merged with the weathered basement like as obtained on profile D and E and some other VES points. The fresh basement is characterised with high resistivity value of 2562.9 Ωm and above.

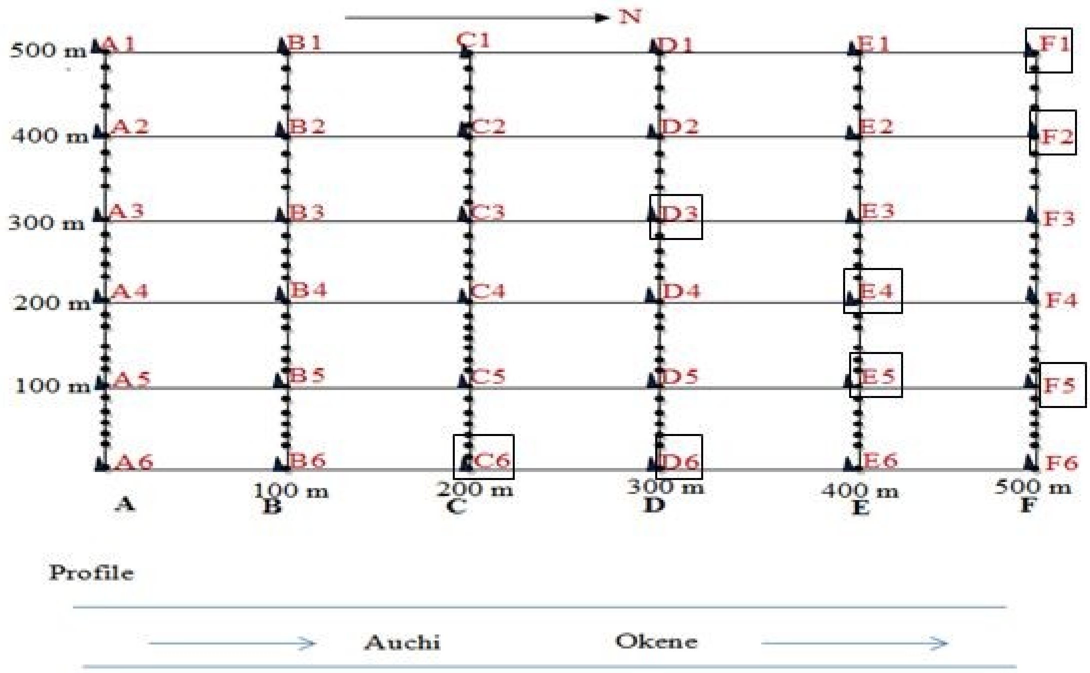


Figure 3: The profile layout for VES data collection (North- South) - ▲-: VES Points. VES marked with rectangular block are possible points for groundwater potential.

Iso-Resistivity Contour Maps at Various Depths and Deductions

The Iso-resistivity contour maps were generated for different depths in order to investigate the resistivity variation beneath the sounding locations at depth of interest. Resistivity data were picked such that, both resistivity values and corresponding depths were averaged. The difference between successive depths gives the thickness of a layer; while the resistivity values, (average) correspond to the resistivity of that particular layer in a way that is like that of the vertical sections. The difference here is that, the data for each depth were picked for the whole area (36 VES) stations before moving to the next depth or layer. This process was repeated until the depths of interest were contoured for the entire area. The layer resistivities at depth of interest were contoured with surfer 9.0 version. The contoured maps using surfer 9.0 versions show the conductivity pattern with depth through slicing of the whole study area horizontally.

Figure 11 shows the Iso-Resistivity contour map at a depth of 1 m. The map shows relatively high resistivity values at the western and south-eastern portions of the study area. The highest resistivity values of about 1205 Ωm and 1195 Ωm at 1 m depth were recorded around VES B2 and VES B5 respectively. The relatively high resistivity values could indicate presence of an outcrop of the fresh basement rock.

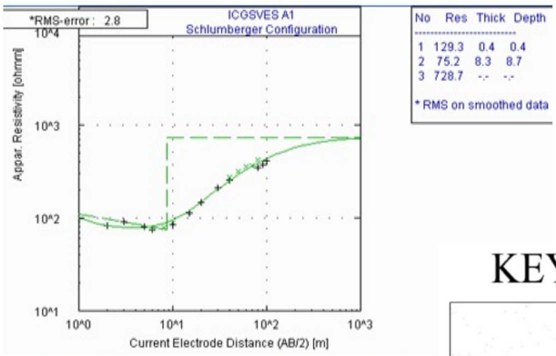
The iso-resistivity contoured map at 5 m depth is presented in Figure 12. The resistivity values recorded at this depth are lower than those recorded at 1m depth. This is the case of resistivity inversion, which is a decrease in resistivity downwards. This could have resulted from the presence of water saturated geologic formation below the surface, which should be given utmost priority in sinking bore-hole in the study area. However, relatively high resistivity values were recorded at the north western and south-eastern parts of the study area around A1 and F6. The basement seems to be shallowest where the resistivity values are high.

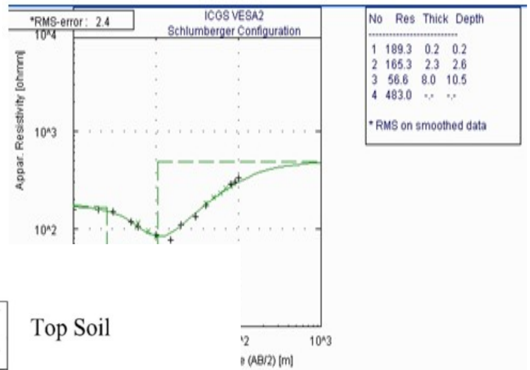
The iso-resistivity contour map at 10 m depth was contoured at 50 Ωm interval, Figure13. The map shows that the study area is characterised by lower resistivity values than at 5 m depth. At the extreme south-eastern portions of the study area resistivity values are relatively high. VES A, B, C, D and F in the study area may have high groundwater yield for their relatively low resistivity and high thickness values.

Table 1: Summary of the interpreted electrical resistivity survey of the study area

VES Points	Layer Resistivity (Ωm)				Layer thickness (m)			Layer Depth To bottom (m)			Curve Types
	ρ1	ρ2	ρ3	ρ4	d_1	d_2	d_3	h_1	h_2	h_3	

A1	129.3	75.2	728.7		0.4	8.3		0.4	8.7		H
A2	189.3	165.3	56.6	483.0	0.2	2.3	8.00	0.2	2.6	10.5	QH
A3	1205.3	261.1	19.9	809.3	0.4	2.7	4.9	0.4	3.1	8.0	QH
A4	1170.3	361.9	46.9	571.2	0.7	2.0	5.1	0.7	2.7	7.8	QH
A5	1147.5	32.3	453.4		1.0	5.9		1.0	6.9		H
A6	91.5	916.8	327.5	361.4	0.3	1.9	6.7	0.3	2.1	11.4	KH
B1	401.4	75.7	8.0	165.5	1.1	3.0	3.0	1.1	4.1	7.1	QH
B2	480.5	317.8	13.1	209.7	0.5	4.0	2.7	0.5	4.5	7.2	QH
B3	902.5	554.3	14.6	415.6	0.6	1.9	3.1	0.6	2.6	5.7	QH
B4	497.8	125.2	529.9		2.1	4.6		2.1	6.7		H
B5	1195.2	84.0	446.0		1.6	6.6		1.6	8.2		H
B6	288.1	33.4	682.0		1.4	9.6		1.4	11.1		H
C1	347.4	49.2	1836.3		1.0	1.1		1.1	9.9		H
C2	845.8	255.0	23.6	1627.4	0.4	2.5	8.5	0.4	2.9	11.4	QH
C3	244.5	185.0	45.8	558.8	0.6	3.3	5.2	0.6	3.9	9.1	QH
C4	529.0	246.7	57.2	679.8	0.8	2.5	3.4	0.8	3.2	6.7	QH
C5	501.1	47.7	474.6		1.9	11.6		1.9	13.5		H
C6	450.7	257.9	20.3	217.6	1.1	2.5	7.3	1.1	3.6	10.9	QH
D1	329.8	20.5	330.7		1.1	9.2		1.1	10.3		H
D2	242.1	227.5	12.5	720.2	0.8	1.4	3.7	0.8	2.3	6.0	QH
D3	849.6	221.2	24.1	1534.4	0.6	2.7	5.6	0.6	3.4	9.0	QH
D4	440.9	211.7	31.5	442.9	0.6	3.1	4.5	0.6	3.7	8.2	QH
D5	263.7	66.0	327.8		1.9	2.3		1.9	4.2		H
D6	770.8	90.0	447.2	217.6	0.7	3.5	14.7	0.7	4.2	15.0	HK
E1	313.3	97.4	1091.5		1.3	14.2		1.3	15.5		H
E2	267.3	107.3	610.3		1.1	5.0		1.1	6.0		H
E3	846.2	98.1	543.2		0.7	5.4		0.7	6.1		H
E4	311.4	115.2	1002.7		1.1	11.7		1.1	12.8		H
E5	428.6	116.5	1969		0.8	15.9		0.8	16.7		H
E6	172.0	69.0	375.9		1.0	6.4		1.0	7.4		H
F1	616.1	209.6	2035		1.1	9.7		1.1	10.8		H
F2	873.3	57.2	3190.5		0.8	10.4		0.8	11.1		H
F3	399.1	98.1	4328.1		0.9	11.9		0.9	12.9		H
F4	427.5	68.3	986.2		0.7	9.9		0.7	10.7		H
F5	249.8	116.4	1969		1.1	11.1		1.1	12.1		H
F6	305.5	198.9	69.9	2868.6	0.3	2.7	6.4	0.3	3.1	9.5	QH





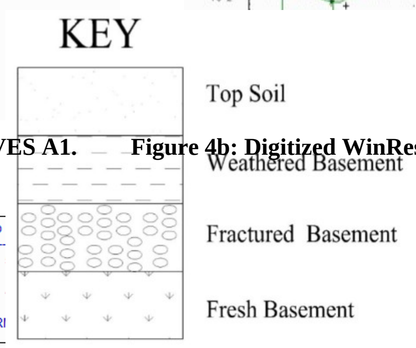
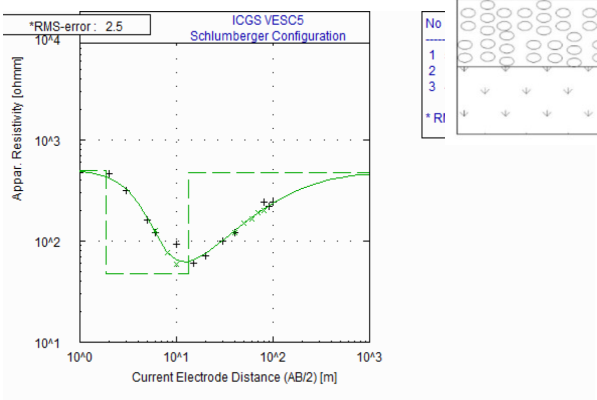


Figure 4a: Digitized WinResist Curve for VES A1. The curve type is H

Figure 4b: Digitized WinResist Curve for VES A2. The curve type is QH



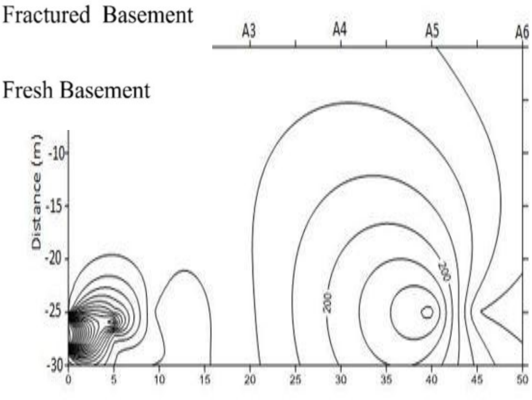
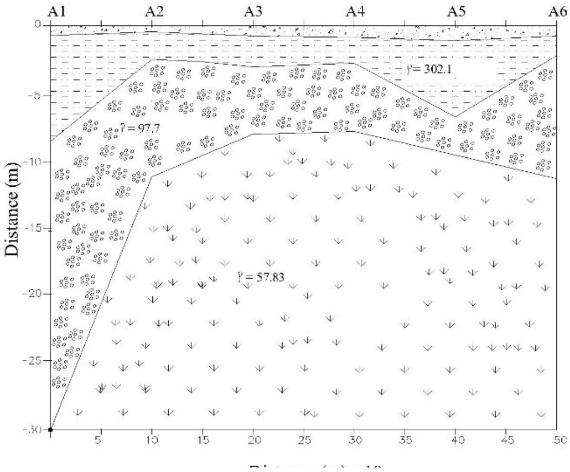


Figure 4c: Digitized WinResist Curve for VES A6.
The curve type is KH.

Figure 5a: Vertical geo-electric Section of Profile A
(Contour interval is 50 Ωm)



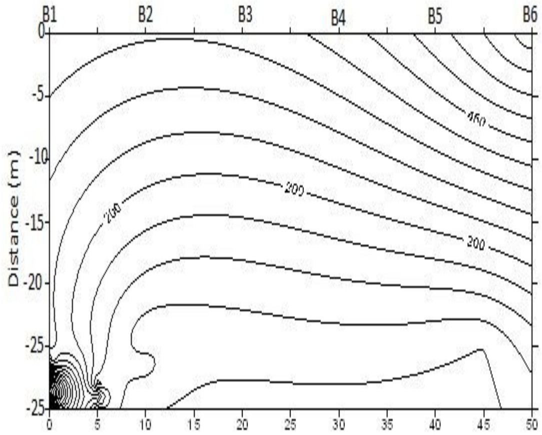
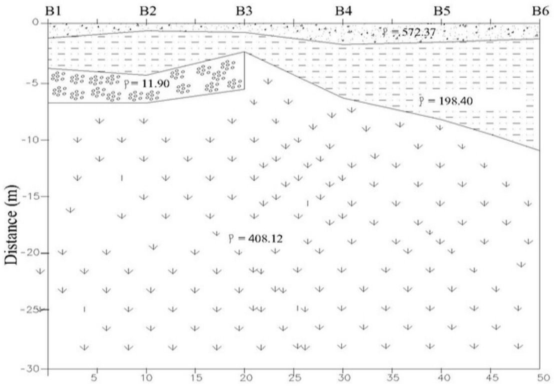


Figure 5b: Vertical Geologic Section of Profile A
Distance (m) x 10

Figure 6a: Vertical geo-electric Section of Profile B
(Contour interval is 50 Ωm)



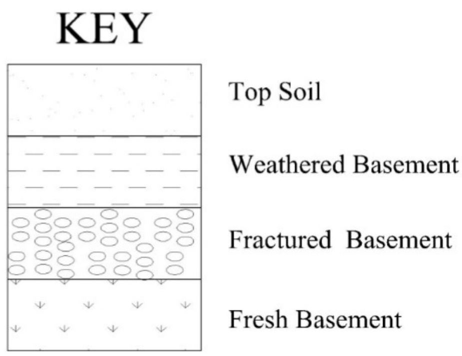


Figure 6b: Vertical Geologic Section of Profile B
Distance (m) x 10

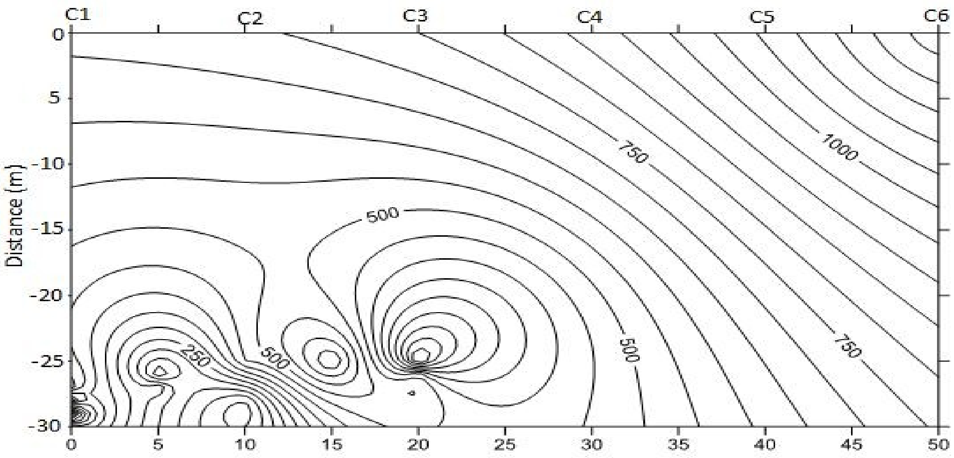


Figure 7a: Vertical geo-electric Section of Profile C
(Contour interval is 50 Ωm)

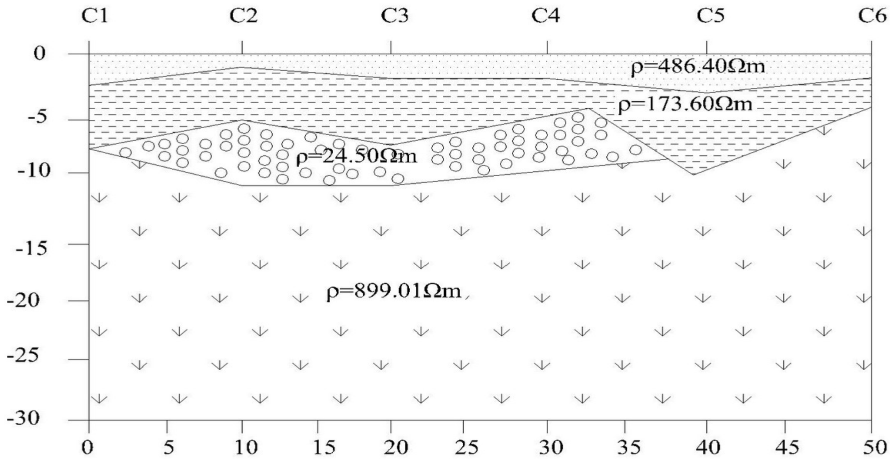
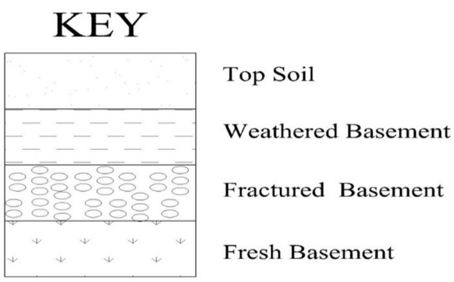


Figure 7b: Vertical Geologic Section of Profile C
Distance (m) x 10



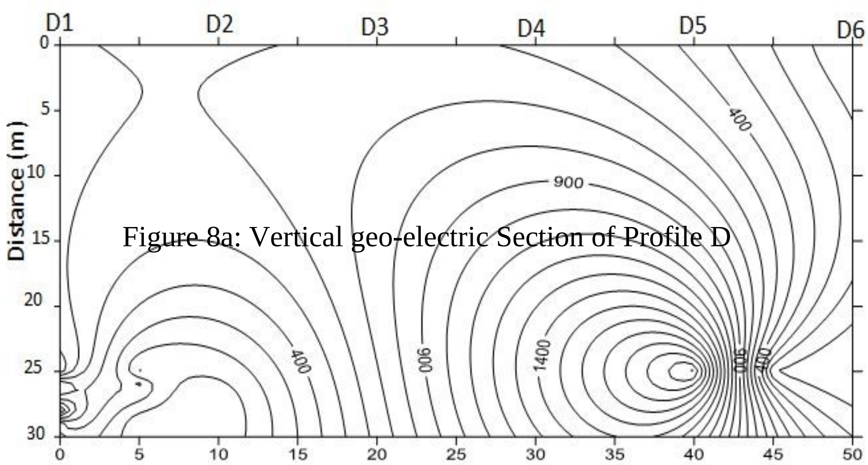


Figure 8a: Vertical geo-electric Section of Profile D

(Contour interval is 50 Ωm)

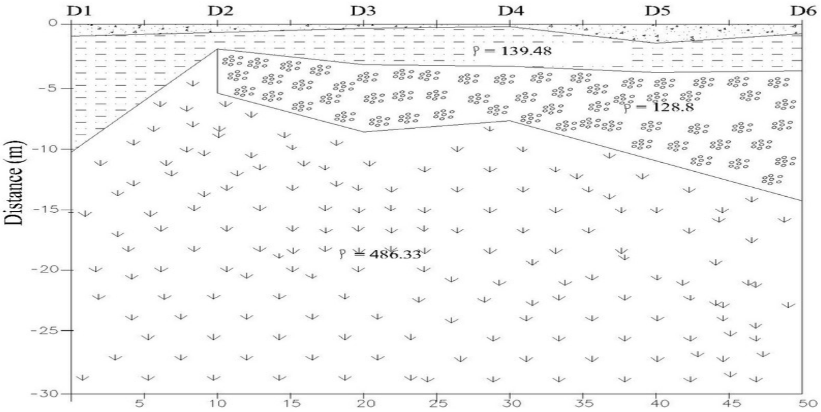
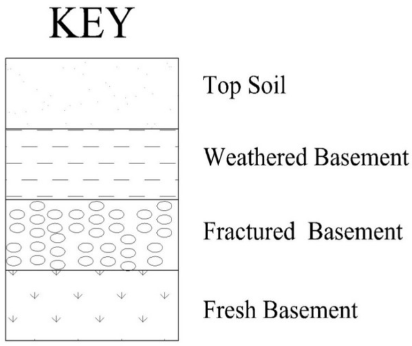


Figure 8b: Vertical Geologic Section of Profile D
Distance (m) x 10



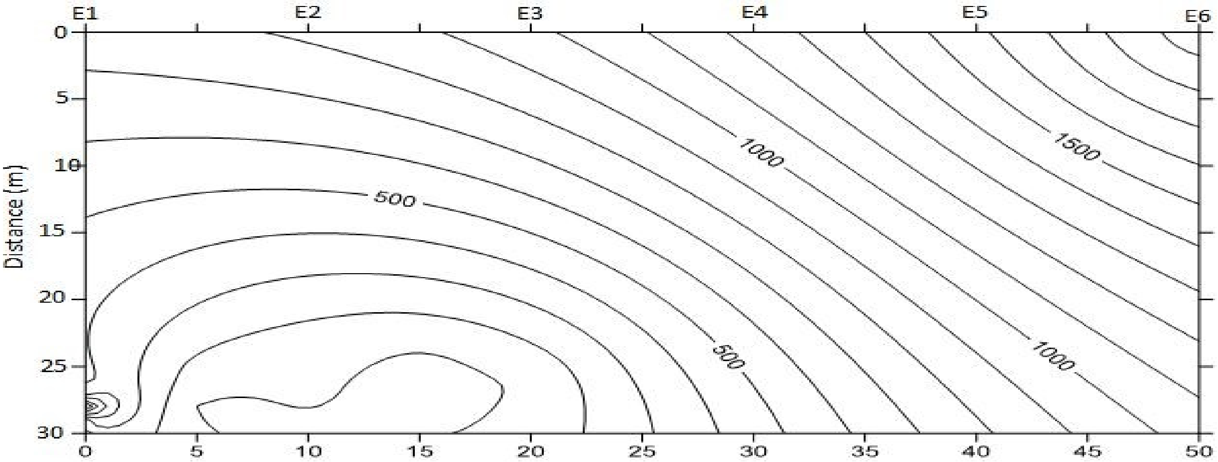
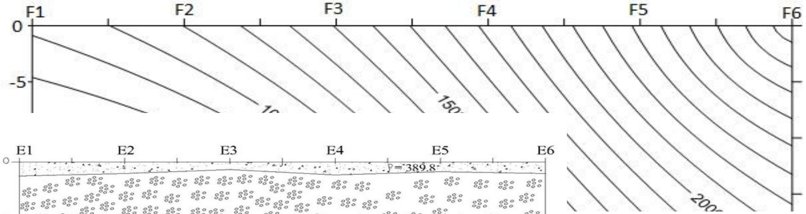
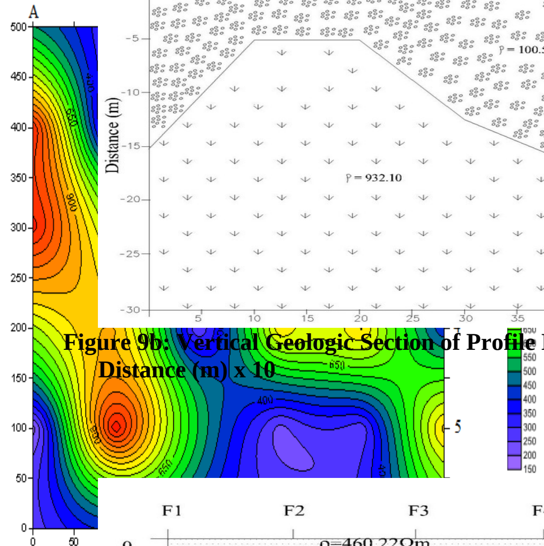


Figure 9a: Vertical geo-electric Section of Profile E
(Contour Interval is100 Ωm)





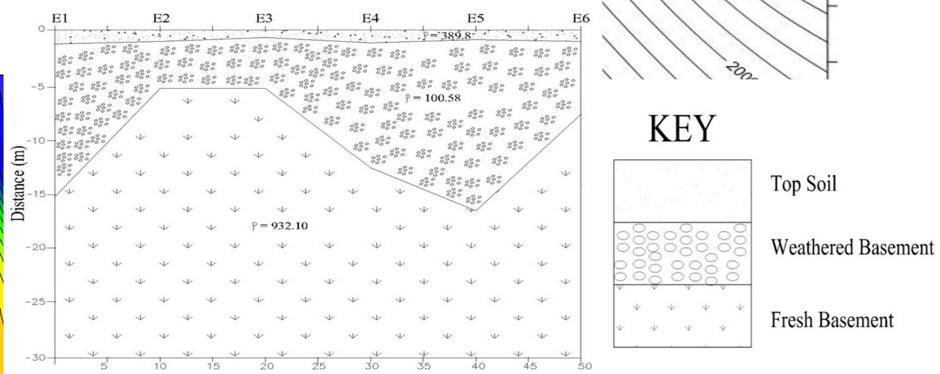


Figure 9b: Vertical Geologic Section of Profile E Distance (m) x 10

Figure 10a: Vertical geo-electric Section of Profile F (Contour Interval is 100 Ωm)

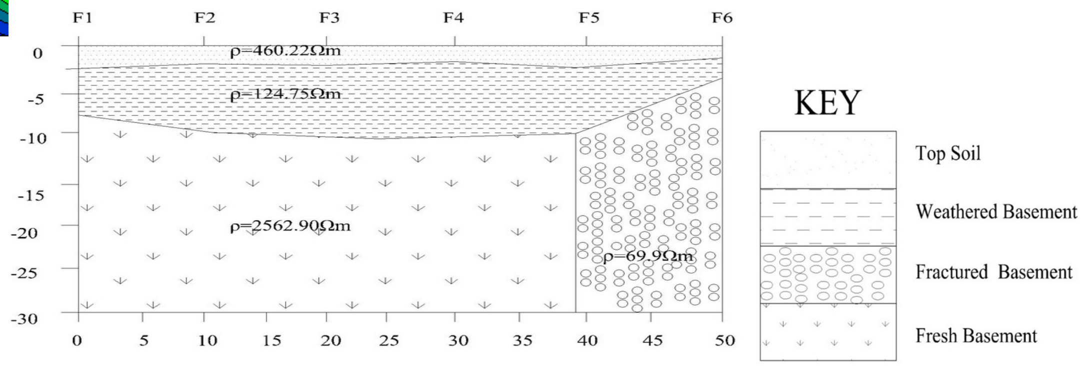


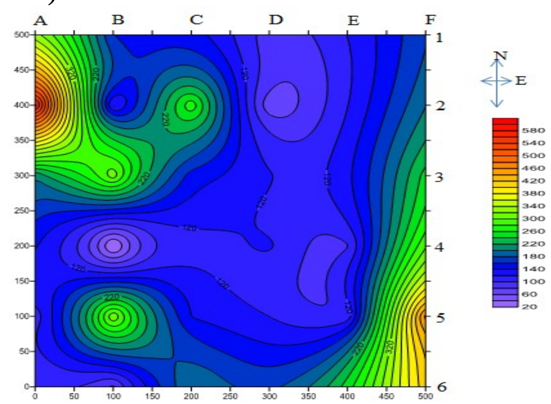
Figure 10b: Vertical Geologic Section of Profile F. Distance (m) x 10

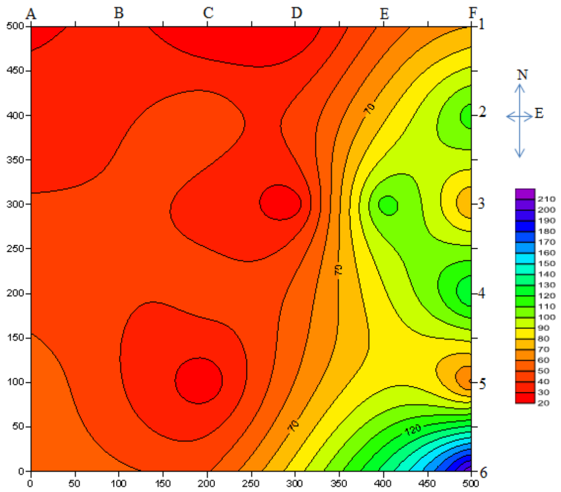
Regolith Thickness and Depth to Basement Contour Maps

The regolith thickness map indicates the range of weathered interval as well as the fractured basement with depth up to the top of fresh basement. It is the difference between the base of the weathered basement together with fractured basement and the top soil. The regolith contour map as presented in Figure 14a is a path finder to the potential aquifers. It shows the variation of the regolith materials across the study area. The thickness of the regolith in the study area ranges from 1.4 m (D2) to 15.5 m (E5). The regolith is highest at the North-eastern flank of the study area around E2, E6 and F2. It is believed that parts of the study area with relatively high regolith thickness are the major aquifers which offer the highest probability of ground water development.

Figure 11: Iso-resistivity Contour Map at Surface (Distance (m) x 10) (Contour interval is 20 Ωm)

Figure 12: Iso-resistivity contour map at 5 m depth (Distance (m) x 10) (Contour interval is 20 Ωm)





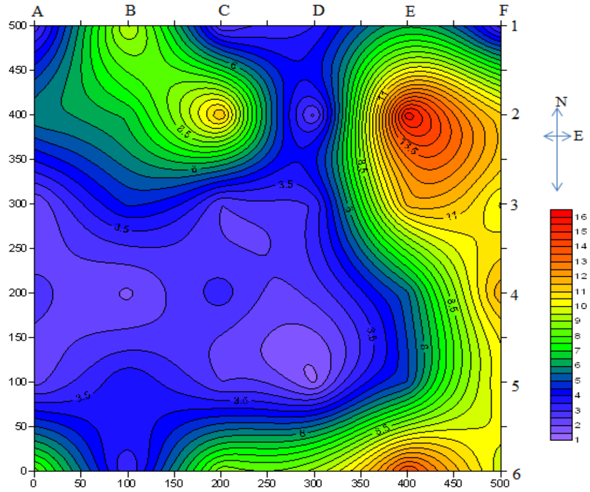
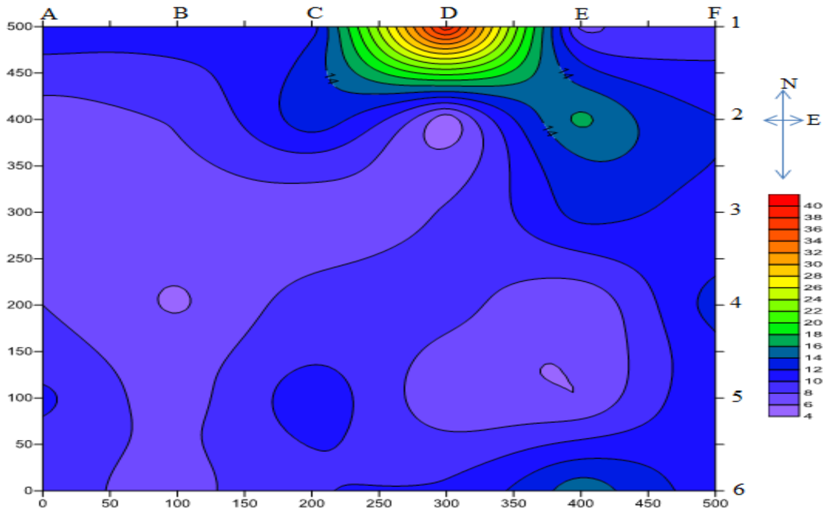


Figure 13: Iso-resistivity contour Map at 10 m depth Figure 14: Regolith thickness contour Map

(Distance (m) x 10) (Contour interval is 10 Ωm) (Distance (m) x10)(Contour interval is 0.2 Ωm)



Inter-profile distance (m)

Figure 15: Depths to Basement Contour Map (Contour Interval is 1m)

Depth to Basement Contour Map

The depth to the basement is shown by the depth to basement contour map in Figure 15. The depth values which correspond to the last layer were picked for the whole 36 VES stations. It shows that the depth to the basement increases in the north-eastern direction around D1 and E2. There is relatively shallow overburden at A1, B1, B3 and B4. This could be due to uplift of the basement. The areas which have relatively high depth values are found at the north-eastern part of the study area. The area with the highest overburden is D1. This could be where the basement suffers depression.

Generally, areas with thick overburden and less percentage of clay such as VES points D6, E4 and E5 are expected to be good potential for ground water development especially in basement complex terrain. These regions are good for ground water exploration (Olorunfemi and Okhue, 1992 and 2008; Emenike, 2001).

Conclusion and Recommendation

Electrical Resistivity Method had been used to determine area suitable for ground water exploitations in the study area. The method has shown variation in resistivity distribution in the study area. The VES method has delineated high resistivity for top soil; low resistivity values for weathered and fractured basements. The geoelectric sections produced from VES data showed that their lithologies are not uniform as depth to basement differed. Relatively low resistivity and thickness values of the weathered and fractured basement constitute the aquifer unit.

VES A1 of the second layer on Profile A has relatively high thickness value (8.3 m), while the fractured basement in VES A2 and VES

A6 of the third layer along profile A may likely be good aquifers in the study area because of the relatively high thicknesses of 8.0 m and 6.7 m respectively. There is high conductivity value in VES C1 (8.9 m) of the weathered basement. There are also high conductivity and good thickness values for the fractured basement. High conductivity and thickness values were recorded in VES D1 (9.2 m) along profile D. Relatively high thickness and conductivity values were also observed at both weathered and fractured basement of VES stations E2 (5.0 m), F1 (9.7 m), F2 (10.4 m), F4 (9.9 m) and F5 (11.1 m).
Therefore, VES stations C6, D3, D6, E4, E5, F1, F2 and F5 with relatively high regolith thickness and conductivity values should be considered for groundwater developments in the study areas.

REFERENCES