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Application of Electrical Resistivity in Ground Water Detection – A Case Study

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ABSTRACT

Electrical resistivity of the soil is considered as a proxy for the spatial and temporal variability for other soil physical properties (i.e. structure, water content, or fluid composition). Because the method is non-destructive and very sensitive, it becomes an important application for describing the subsurface properties of the soil and the rocks without digging.

The importance of groundwater cannot be over - emphasized. For this reason, the exploration for water is a vital aspect in Geophysics. The technique is employed together with drilling, for determination of resistivity value of both - the alluvium and the groundwater. The study will be conducted in areas which have a geology record of thick alluvium. The results show that groundwater will lower the resistivity value and silt also will bring down the resistivity value lower than groundwater. Groundwater reservoirs are found in saturated sand, saturated sandy clay and saturated silt, clay and sand.

The resistivity method of surveying was carried out for the delineation of ground water aquifers NES in vicinity of JNNCE, Navule, Shivamogga city, Karnataka, India. Data's were acquired using the Schlumberger electrode arrangements. The vertical electrical sounding was also performed to obtain readings for resistance of the and the apparent resistivities.

Keywords: Electrical Resistivity, Ground water exploration, Geophysics.

INTRODUCTION

Electrical resistivity surveys are usually very useful and convenient while exploring for groundwater and in the exploration of minerals. It provides information about the subsurface nature when potential measurements are taken at the surface.

The electrical resistivity method is used as a tool for geophysical exploration, and is based on the fact that the underlying rock materials can impose resistance to the flow of current and as such ohm's law could be applied to them if the earth is homogenous, the resistivity measured is called true resistivity otherwise, the term apparent resistivity is used and this is a weighted average of the resistivity's of the various formation.

The usual practice in resistivity survey is to introduce current into the ground by means of two current electrodes and a potential drop is measured through a second pair of potential electrodes. The flow of current within the earth is affected by subsurface formation and hence the distribution of electric potential.

Conduction of electricity in the ground occurs through the interstitial water present in the rock and contains some dissolved salts invariably. Low resistivity usually indicates the presence of water (clay) in the formation, this is therefore as important as water salinity in establishing the true resistivity of a medium.

Data of groundwater potential zone, groundwater direction and velocity is very important data, that on should possess if there is any chance to build a radioactive waste repository facility. Before a repository facility built in that area, the groundwater contamination study has to be done in order to get the groundwater contamination plumes direction and to identify the groundwater monitoring area.

ELECTRICAL RESISTIVITY

In the electrical resistivity method, the electrical resistance is determined by applying an electric current (I) to metal stakes (outer electrodes- a.c. type) driven into the ground and measuring the apparent potential difference (V) between two inner electrodes (non-polarisingd.c. type) buried or driven into the ground shows the electrodes arrangement for electrical resistivity method.

Changing the spacing of electrodes changes the depth of penetration of the current and the apparent electrical resistivity pa obtained at different depths by measuring the resistance

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R= V/I, apparent resistivity is plotted on a semi-log or log-log paper against depth (Field curves). By proper interpretation of the resistivity data from the field curves obtained and matching them with standard curves (Mooney and Wetzel, master curves), it is possible to identify the water bearing formations and accordingly and limit the depth of well drilling.

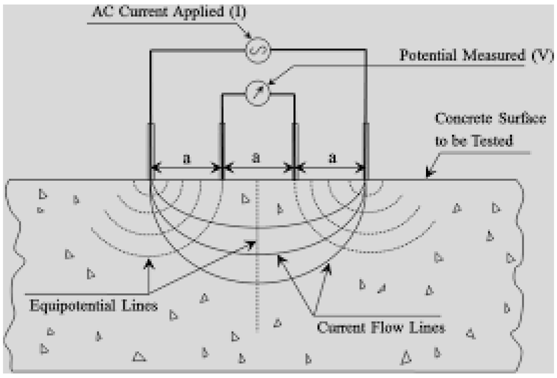
There are two common systems of electrode arrangements:

Wenner Electrode arrangement system and Schlumberger Electrode arrangement system

WENNER ELECTRODE SYSTEM:

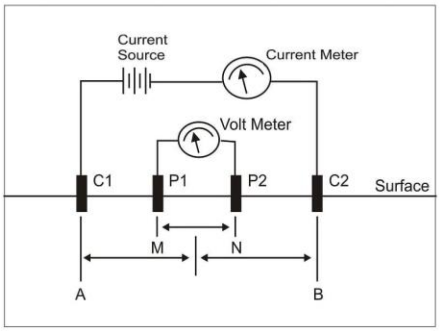
In this system, the electrodes are space at equal distances, a, Fig. and the apparent resistivity ρa for a measured resistance is given by,ρ a = 2 π aR

The field curve is plotted on a semi-log paper "ρa versus a", ρa being in ohms-meter in logarithmic scale and a in meter in arithmetic scale.



SCHLUMBERGER ELECTRODE ARRANGEMENT SYSTEM: In this system, the distance between the two inner potential electrodes is kept constant for some time and the distance between the current electrodes is varied. The apparent resistivity ρa for a measured resistance is given by

$$\rho_a = \frac{\left(\frac{AB}{2}\right)^2 - \left(\frac{MN}{2}\right)^2}{MN} \pi \left(\frac{V}{I}\right)$$



Where,
ρa =Apparent resistivity in Ohm meter
V = Voltage
I = Current in ampere
A,B = Current electrode
M,N = Potential electrode

Resistivity values of common rocks and soil materials

Material	Resistivity (Ohm)
Alluvium	10-800
Sand	60-1000

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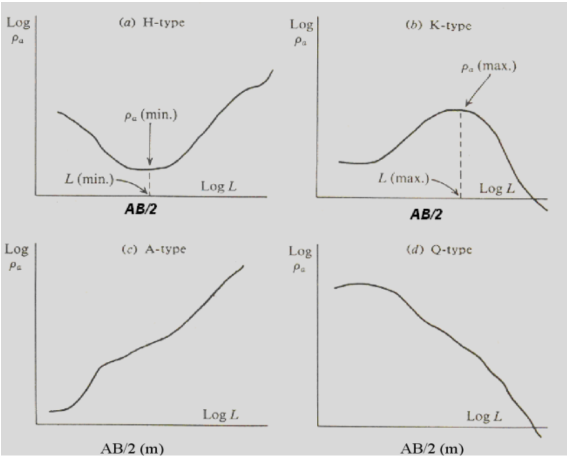
Clay	1-100
Groundwater	10-100
Sandstone	8-4x10^3
Shale	20-2x10^3
Limestone	50-4x10^3
Granite	5000-1000000



Graph of apparent resistivity vs distance.

Apparent-resistivity curves are often plotted on logarithmic paper and compared with type curves (normalized theoretical curves) for interpreting the resistivity, thickness, and depth of subsurface layers.

Logρa – apparent resistivity

ρa (max) - resistivity maximum

ρa (min) - resistivity minimum

Aim and objectives: The main aim of the present study is to delineate the ground water potentiality of the area by locating the suitable aquifers present in NES layout near JNNCE College, Shivamogga, with the following Objectives:

- To determine the soil resistivity of the area.
- To determine the ground water potential zones in the area.
- To determine the type of soil and its influence on groundwater characteristics.

STUDY AREA

Location	13.967174°N ,75.582156° E
Total area	3 sq.km
Area	Madhuvana Colony A-Block, NES layout
District	Shivamogga
Pin code	577204

RESULTS and DISCUSSIONS

The results obtained are plotted in the graph. Most of the values obtained are well within 500 Ohm – m. But only in 1 stretch the value has gone beyond 700 ohm m. The area is mainly composed of rocks from late ArcheanShimoga schist belt like - Granite Migmatites and Granodioritic to Tonolitic gneisses, Amphibolitesand Peliticschist's.The area is mainly composed ofclayey soil and in some areas gravel can also be noted. The values and the corresponding graph are tabulated below.

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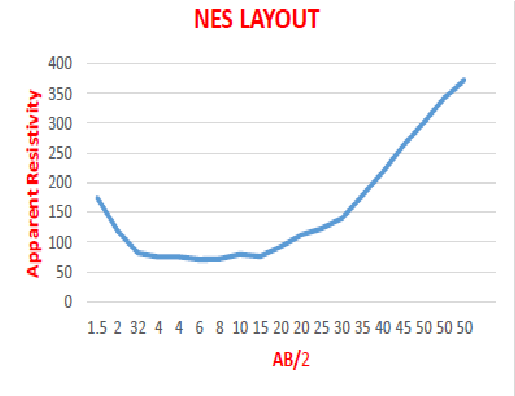
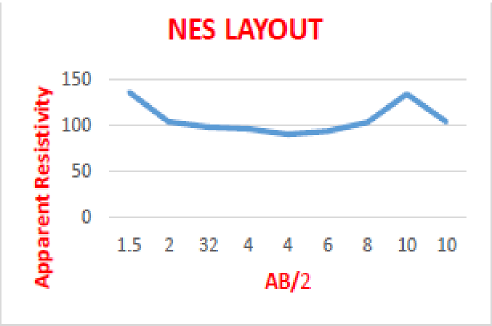
STRETCH-1

MN/2	AB/2	R(ohm)	K=π*((AB/2)*2-(MN/2)*2)/MN	Rho=K*R(Ohm-m)
0.5	1.5	27.91	6.28	175.27
0.5	2	10.08	11.75	118.69
0.5	32	2.97	27.475	81.6
0.5	4	1.52	49.455	75.17
1	4	3.16	23.55	74.41
1	6	1.28	54.95	70.336
1	8	0.72	98.91	71.21
1	10	0.51	155.43	79.26
2	15	1	75.36	75.58
2	20	0.53	173.485	91.94
2	20	0.36	310.86	111.9
5	25	1.04	117.75	122.46
5	30	0.74	188.4	139.41
5	35	0.65	274.75	178.58
5	40	0.58	376.8	218.54
5	45	0.53	494.55	262.11
5	50	0.48	628	301.44
5	50	0.44	777.15	341.94
10	50	0.99	376.8	373.03



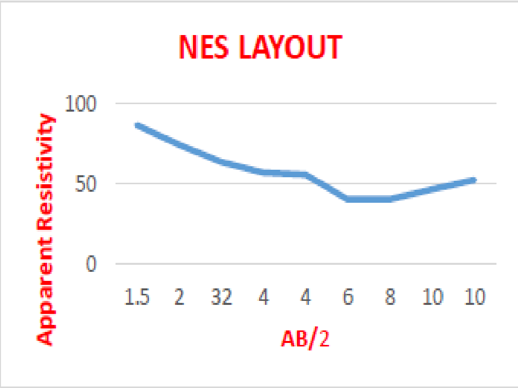
STRETCH-2

MN/2	AB/2	R(ohm)	K=π*((AB/2)*2-(MN/2)*2)/MN	Rho=K*R(Ohm-m)
0.5	1.5	21.56	6.28	135.39
0.5	2	8.8	11.75	103.62
0.5	32	3.56	27.475	97.81
0.5	4	1.94	49.455	95.94
1	4	3.82	23.55	89.96
1	6	1.7	54.95	93.41
1	8	1.04	98.91	102.86
1	10	0.86	155.43	133.66
2	10	1.37	75.36	103.24
2	15	0.59	173.485	102.35



STRETCH-3

MN/2	AB/2	R(ohm)	K=π*((AB/2)*2-(MN/2)*2)/MN	Rho=K*R(Ohm-m)
0.5	1.5	33.24	6.28	86.97
0.5	2	13.36	11.75	74.88
0.5	32	4.31	27.475	63.74
0.5	4	2.14	49.455	57.4
1	4	4.73	23.55	56.04
1	6	1.37	54.95	40.66
1	8	0.71	98.91	40.55
1	10	0.52	155.43	46.62
2	10	1.1	75.36	52.75
2	15	0.55	173.485	95.416



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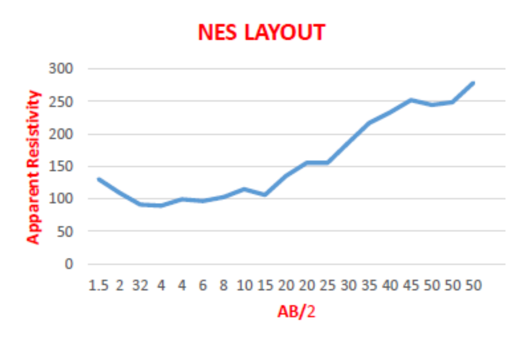
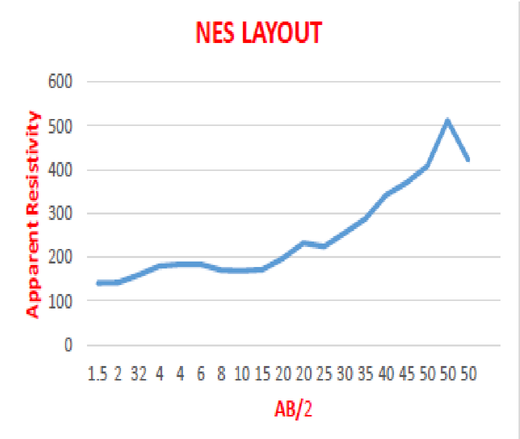
STRETCH-4

MN/2	AB/2	R(ohm)	K=π*((AB/2)*2-(MN/2)*2)/MN	Rho=K*R(Ohm-m)
0.5	1.5	20.76	6.28	130.37
0.5	2	9.32	11.75	109.743
0.5	32	3.32	27.475	91.217
0.5	4	1.81	49.455	89.513
1	4	4.22	23.55	99.381
1	6	1.76	54.95	96.712
1	8	1.04	98.91	102.866
1	10	0.74	155.43	115.01
2	15	1.41	75.36	106.25
2	20	0.78	173.485	135.318
2	20	0.5	310.86	155.43
5	25	1.32	117.75	155.43
5	30	0.99	188.4	186.576
5	35	0.79	274.75	217.052
5	40	0.62	376.8	233.616
5	45	0.51	494.55	252.22
5	50	0.39	628	244.92
5	50	0.32	777.15	248.688
10	50	0.74	376.8	278.832



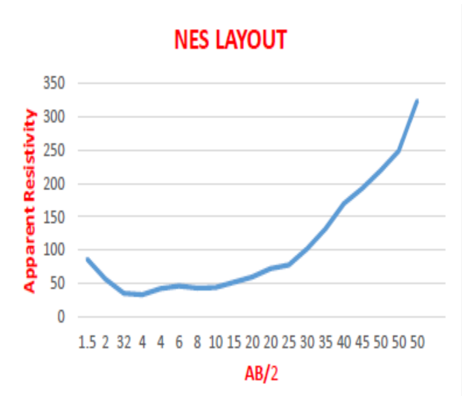
STRETCH-5

MN/2	AB/2	R(ohm)	K=π*((AB/2)*2-(MN/2)*2)/MN	Rho=K*R(Ohm-m)
0.5	1.5	22.44	6.28	140.92
0.5	2	12.01	11.75	141.41
0.5	32	5.83	27.475	160.17
0.5	4	3.63	49.455	179.52
1	4	7.8	23.55	183.69
1	6	3.36	54.95	184.63
1	8	1.73	98.91	171.114
1	10	1.09	155.43	169.41
2	15	2.28	75.36	171.82
2	20	1.14	173.485	197.77
2	20	0.75	310.86	233.14
5	25	1.91	117.75	224.9
5	30	1.36	188.4	256.224
5	35	1.05	274.75	288.48
5	40	0.91	376.8	342.88
5	45	0.75	494.55	370.91
5	50	0.65	628	408.2
5	50	0.66	777.15	512.91
10	50	1.12	376.8	422.016



STRETCH-6

MN/2	AB/2	R(ohm)	K=π*((AB/2)*2-(MN/2)*2)/MN	Rho=K*R(Ohm-m)
0.5	1.5	13.68	6.28	85.91
0.5	2	4.74	11.75	55.81
0.5	32	1.27	27.475	34.89
0.5	4	0.66	49.455	32.64
1	4	1.77	23.55	41.68
1	6	0.84	54.95	46.15
1	8	0.43	98.91	42.53
1	10	0.29	155.43	43.07
2	15	0.68	75.36	51.24
2	20	0.34	173.485	58.98
2	20	0.23	310.86	71.49
5	25	0.66	117.75	77.71
5	30	0.54	188.4	101.73
5	35	0.48	274.75	131.88
5	40	0.45	376.8	169.56
5	45	0.39	494.55	192.87
5	50	0.35	628	219.8
5	50	0.32	777.15	248.68
10	50	0.86	376.8	324.04



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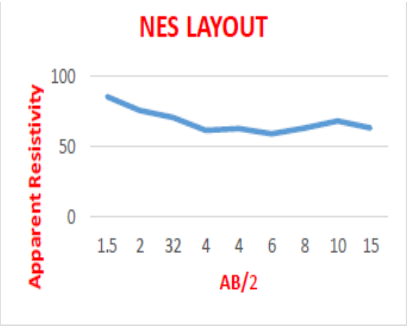
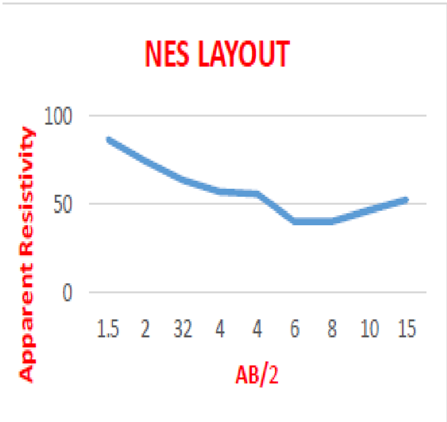
STRETCH-7

MN/2	AB/2	R(ohm)	K=π*((AB/2)*2-(MN/2)*2)/MN	Rho=K*R(Ohm-m)
0.5	1.5	13.67	6.28	85.85
0.5	2	6.44	11.75	75.83
0.5	32	2.58	27.475	70.88
0.5	4	1.25	49.455	61.81
1	4	2.67	23.55	62.87
1	6	1.08	54.95	59.34
1	8	0.64	98.91	63.3
1	10	0.44	155.43	68.38
2	15	0.84	75.36	63.3



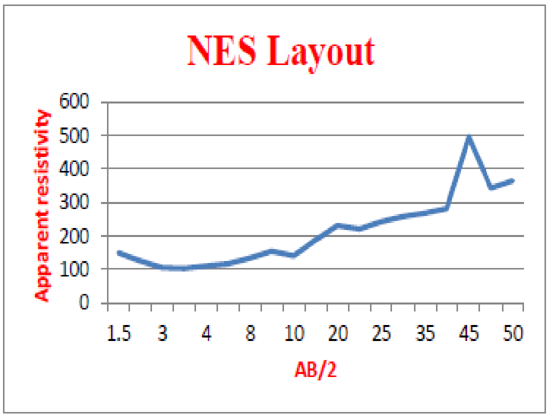
STRETCH-8

MN/2	AB/2	R(ohm)	K=π*((AB/2)*2-(MN/2)*2)/MN	Rho=K*R(Ohm-m)
0.5	1.5	13.85	6.28	86.97
0.5	2	6.36	11.75	74.88
0.5	32	2.32	27.475	63.74
0.5	4	1.1	49.455	57.4
1	4	2.38	23.55	56.04
1	6	0.74	54.95	40.66
1	8	0.41	98.91	40.55
1	10	0.3	155.43	46.62
2	15	0.7	75.36	52.75



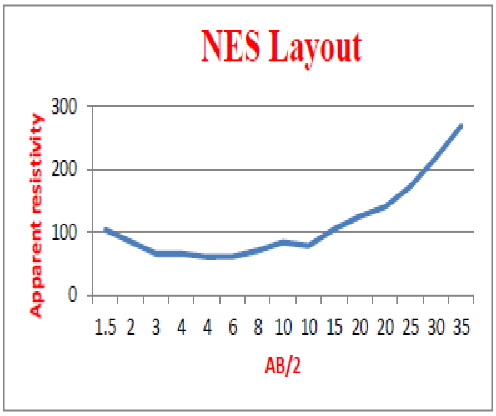
STRETCH-9

MN/2	AB/2	R(ohm)	K=π*((AB/2)2-(MN/2)2)/MN	Rho=K*R(ohm-m)
0.5	1.5	23.82	6.28	149.58
0.5	2	10.62	11.775	125.05
0.5	3	3.84	27.475	105.5
0.5	4	2.09	49.455	103.35
1	4	4.72	23.55	111.35
1	6	2.13	54.95	117.04
1	8	1.36	98.91	134.51
1	10	0.99	155.43	153.87
2	10	1.88	75.36	141.67
2	15	1.09	173.485	189.09
2	20	0.79	310.86	230.03
5	20	1.87	117.75	220.19
5	25	1.29	188.4	243.03
5	30	0.92	274.75	257.77
5	35	0.71	376.8	267.528
5	40	0.57	494.55	281.89
5	45	0.49	628	496.12
5	50	0.44	777.15	341.94
10	50	0.969	376.8	365.119



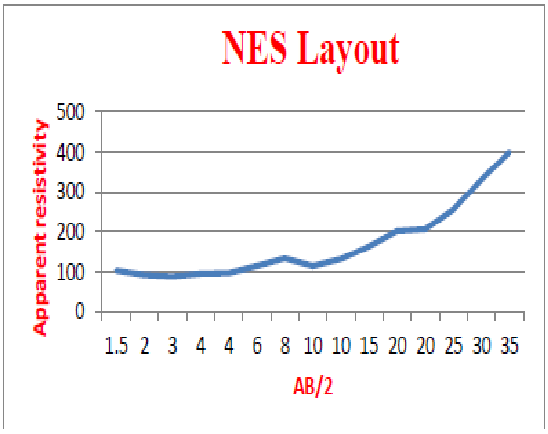
STRETCH-10

MN/2	AB/2	R(ohm)	K=π*((AB/2)2-(MN/2)2)/MN	Rho=K*R(ohm-m)
0.5	1.5	16.58	6.28	104.15
0.5	2	7.24	11.775	85.3
0.5	3	2.38	27.475	65.58
0.5	4	1.32	49.455	65.52
1	4	2.57	23.55	60.68
1	6	1.11	54.95	61.26
1	8	0.71	98.91	70.62
1	10	0.54	155.43	83.93
2	10	1.03	75.36	78.07
2	15	0.6	173.485	104.78
2	20	0.4	310.86	125.27
5	20	1.19	117.75	140.24
5	25	0.91	188.4	172.76
5	30	0.79	274.75	218.15
5	35	0.71	376.8	269.03



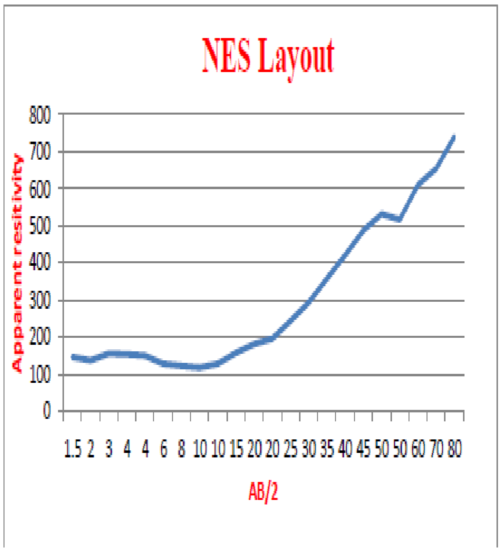
STRETCH-11

MN/2	AB/2	R(ohm)	K=π*((AB/2)2-(MN/2)2)/MN	Rho=K*R(ohm-m)
0.5	1.5	16.53	6.28	103.8
0.5	2	7.85	11.775	92.43
0.5	3	3.22	27.475	88.46
0.5	4	1.93	49.455	95.44
1	4	4.14	23.55	97.49
1	6	2.09	54.95	114.84
1	8	1.35	98.91	133.82
1	10	0.73	155.43	114.39
2	10	1.74	75.36	131.65
2	15	0.94	173.485	163.42
2	20	0.64	310.86	201.74
5	20	1.76	117.75	207.24
5	25	1.36	188.4	256.22
5	30	1.2	274.75	330.24
5	35	1.06	376.8	399.4



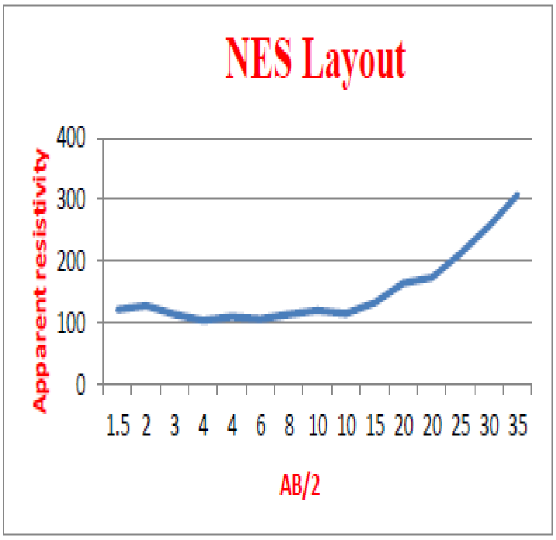
STRETCH-12

MN/2	AB/2	R(ohm)	K=π*((AB/2)2-(MN/2)2)/MN	Rho=K*R(ohm-m)
0.5	1.5	19.27	6.28	121.02
0.5	2	10.78	11.775	127.01
0.5	3	4.11	27.475	113
0.5	4	2.09	49.455	103.36
1	4	4.67	23.55	110.002
1	6	1.93	54.95	106.16
1	8	1.14	98.91	112.76
1	10	0.76	155.43	119.3
2	10	1.51	75.36	114.39
2	15	0.76	173.485	132.33
2	20	0.52	310.86	163.91
5	20	1.47	117.75	173.32
5	25	1.12	188.4	212.32
5	30	0.93	274.75	256.06
5	35	0.81	376.8	307.09



STRETCH-13

MN/2	AB/2	R(ohm)	K=π*((AB/2)2-(MN/2)2)/MN	Rho=K*R(ohm-m)
0.5	1.5	23.11	6.28	145.17
0.5	2	11.51	11.775	135.55
0.5	3	5.59	27.475	153.81
0.5	4	3.07	49.455	151.96
1	4	6.3	23.55	148.43
1	6	2.31	54.95	127.39
1	8	1.22	98.91	121.39
1	10	0.75	155.43	116.72
2	10	1.68	75.36	126.65
2	15	0.9	173.485	156.6
2	20	0.58	310.86	180.92
5	20	1.66	117.75	195.53
5	25	1.28	188.4	242.45
5	30	1.06	274.75	292.08
5	35	0.94	376.8	356.64
5	40	0.84	494.55	419.72
5	45	0.77	628	487.45
5	50	0.68	777.15	531.18
10	50	1.37	376.8	516.51
10	60	1.11	549.5	610.65
10	70	0.86	753.6	654.42
10	80	0.74	989.1	739.15



CONCLUSION

Electrical resistivityis an important method for soil characterization. Contrary to classical soil science measurements and observations which perturb the soil by random or byregular drilling and sampling, electrical resistivity is non-destructive, and can provide continuousmeasurements over a large range of scales. In this way, temporal variables such as water and plant nutrient, depending on the internal soil structure, are monitored and quantified withoutaltering the soil structure. The applications are numerous: (i) determination of soil horizonand specific heterogeneities, (ii) follow-up of the transport phenomena, (iii) monitoring of solute plume contamination in a saline or waste context. It enables the improvement of our understanding of the soil structure and it's functioning in varying fields such as agronomy, pedology, geology, archaeology and civil engineering. Concerning agronomy, applications are present in precision farming surveys. Nevertheless, electrical measurements do not give a direct access to soil characteristics that interest the agronomist. Preliminary laboratory calibration and qualitative or quantitative data (i.e. after inversion) interpretations have to be done to link the electrical resistivity measurements with the soil characteristics and function.

From the current study we can conclude that the electrical resistivity method was used for the detection of soil characteristics and delineation of potential areas for ground water in the area. Geologically the area is mainly composed of rocks from late ArcheanShimogaschist belt like -Granite Migmatites and Granodioritic to Tonolitic gneisses, Amphibolites and Peliticschist's.The soil in the area is mainly composed ofsand and gravel with silt as it is noted from the observed resistivity values. From the above survey, the level of Ground Water is found to be very deep and the Ground Water seems to be in the form of Confined and Perched Aquifer. Further drilling in the area may lead to more insight on the level and occurrence of ground water.

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