A HYDRO-GEOPHYSICAL INVESTIGATION OF GROUNDWATER POTENTIAL

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PROJECT REPORT

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KERALA, INDIA

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DECLARATION

We hereby declare that this project report entitled **'A HYDRO-GEOPHYSICAL INVESTIGATION OF GROUNDWATER POTENTIAL"** is a bonafide record of project work done by us during the course of project and that the report has not previously formed the basis for the award to us of any degree, diploma, associate-ship, fellowship or other similar title of another University or Society.

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CERTIFICATE

Certified that this project work entitled **“A HYDRO-GEOPHYSICAL INVESTIGATION OF GROUNDWATER POTENTIAL”** is a record of project work done jointly by Ritu Prem, Shazna, K. and Sheeja, P.S. under my guidance and supervision and it has not previously formed the basis for the award of any degree, diploma, fellowship or associate-ship or other similar title of another University or Society.

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Ritu Prem

Shazna K

Sheeja P S

DEDICATED TO OUR ALMA MATER

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SYMBOLS AND ABBREVIATIONS

ρ_a	apparent resistivity
ρ_{strip}	strip resistivity
ΔV	Potential difference
a	electrode separation
AB	Current electrode spacing
AH	Ampere Hour
C1	Current terminal 1
C2	Current terminal 2
DC	Direct current
ECa	Apparent conductivity
ERI	Electrical resistivity imaging
h/p	Ratio of thickness to resistivity
I	Current
IGIS	Integrated geo-instruments and services
KCAET	Kelappaji College of Agricultural Engineering And Technology
KFU	King Faisal University
MN	Potential electrode separation
MSL	Mean sea level
N	Number of stacked reading
NIT	National Institute of Technology
O	Center point
PC	Personal computer

P1	Potential terminal 1
P2	Potential terminal 2
R	Resistance
SAS	Signal averaging system
TDS	Total dissolved saults
VES	Vertical electrical sounding
VLF-EM	Very low frequency-electromagnetic
Wn	Soil water content

INTRODUCTION

Groundwater is water that exists in the pore spaces and fractures in rocks and sediments beneath the Earth’s surface. It originates as rainfall or snow, and then moves through the soil and rock into the groundwater system, where it eventually makes its way back to the surface streams, lakes, or oceans. Most of the water on Earth is present in the oceans. Groundwater makes up about 1% of the water on the Earth but it makes up to 35 times the amount of water in lakes and streams. It occurs everywhere beneath the Earth’s surface, but is usually restricted to depth less than about 750 meters. The volume of groundwater is equivalent to a 55-meter thick layer, spread out over the entire surface of the Earth.

Groundwater scientists typically restrict the use of the term “groundwater” to underground water that can flow freely into a well, tunnel, spring, etc. This definition excludes under-ground water in the unsaturated zone. The unsaturated zone is the area between the land surface and the top of the groundwater system. The unsaturated zone is made up of earth materials and open spaces that contain some moisture but, for the most part, this zone is not saturated with water. Groundwater is found beneath the unsaturated zone where all the open spaces between sedimentary materials or in fractured rocks is filled with water. This water has a pressure greater than atmospheric pressure. To understand the occurrence of groundwater, the following properties of soil and water are of great importance namely porosity, saturated and unsaturated zones, permeability, storage coefficient etc.

The origin of groundwater can be in many ways. Groundwater derived from rainfall and infiltration within the normal hydrological cycle is called meteoric water. This water is said to have recent contact with atmosphere. Groundwater found at great depths in sedimentary rocks as a result of water having been trapped in marine sediments at the time of their deposition. This type of groundwater is referred to as connate waters. These waters are normally saline. It is accepted that connate water is derived mainly or entirely from entrapped sea water as original sea water has moved from its original place. Some trapped water may be brackish. Fossil water if fresh may be originated from the fact of climate change phenomenon, i.e., some areas used to have wet weather and the aquifers of that area were recharged and then the weather of that area becomes dry.

The hydrological cycle is the most fundamental principle of groundwater hydrology. The driving force of the circulation is derived from the radiant energy received from the sun. Water evaporates and travels into the air and becomes part of a cloud. It falls down to earth as precipitation. Then it evaporates again. This happens repeatedly in a never-ending cycle. This hydrologic cycle never stops. Water keeps moving and changing from a solid to a liquid to a gas, repeatedly.

Precipitation creates runoff that travels over the ground surface and helps to fill lakes and rivers. It also percolates or moves downward through openings in the soil and rock to replenish aquifers under the ground. Some places receive more precipitation than others do with an overview balance. These areas are usually close to oceans or large bodies of water that allow more water to evaporate and form clouds. Other areas receive less; often these areas are far from seawater or near mountains. As clouds move up and over the mountains, the water vapour condenses to form precipitation and freezes. Snow falls on the peaks is resulted in this way.

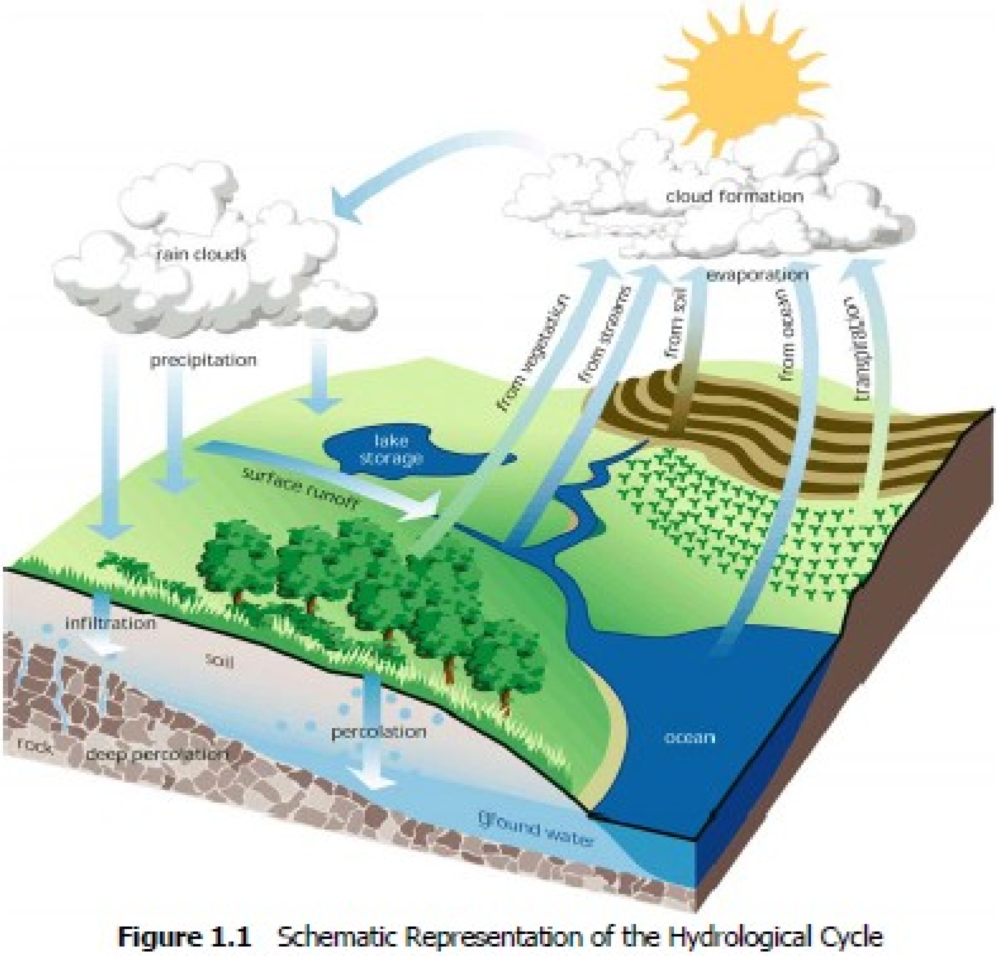


Figure 1.1 Schematic Representation of the Hydrological Cycle

Geological formations may be of four types namely aquifers, aquitard, aquiclude and aquifuge. An aquifer is a ground-water reservoir composed of geologic units that are saturated with water and sufficiently permeable to yield water in a usable quantity to wells and springs. Sand and gravel deposits, sandstone, limestone, and fractured, crystalline rocks are examples of geological units that form aquifers. Aquifers transmit ground water from areas of recharge to areas of discharge and provide a storage medium for useable quantities of ground water.

Aquifers may be classified as unconfined or confined, depending on the presence or absence of a water table, while a leaky aquifer represents a combination of the two types. An unconfined aquifer is one in which a water table varies in undulating form and in slope, depending on areas of recharge and discharge, pumpage from wells, and permeability. Rises and falls in the water table correspond to changes in the volume of water in storage within an aquifer. A special case of an unconfined aquifer involves perched water bodies. This occurs wherever a groundwater body is separated from the main groundwater by a relatively impermeable stratum of small areal extent and by the zone of aeration above the main body of groundwater.

Confined aquifers occur where groundwater is confined under pressure greater than atmospheric by overlying relatively impermeable strata. They are also known as artesian or pressure aquifers. In a well penetrating such an aquifer, the water level will rise above the bottom of the confining bed. A region supplying water to a confined area is known as a recharge area; water may also enter by leakage through a confining bed. Rises and falls of water in wells penetrating confined aquifers result primarily from changes in pressure rather than changes in storage volumes. Hence, confined aquifers display only small changes in storage and serve primarily as conduits for conveying water from recharge areas to locations of natural or artificial discharge.

Aquifers that are completely confined or unconfined occur less frequently than do leaky, or semi-confined, aquifers. These are a common feature in alluvial valleys, plains, or former lake basins where a permeable stratum is overlain or underlain by a semi-pervious aquitard or semi- confining layer. Pumping from a well in a leaky aquifer removes water in two ways: by horizontal flow within the aquifer and by vertical flow through the aquitard into the aquifer.

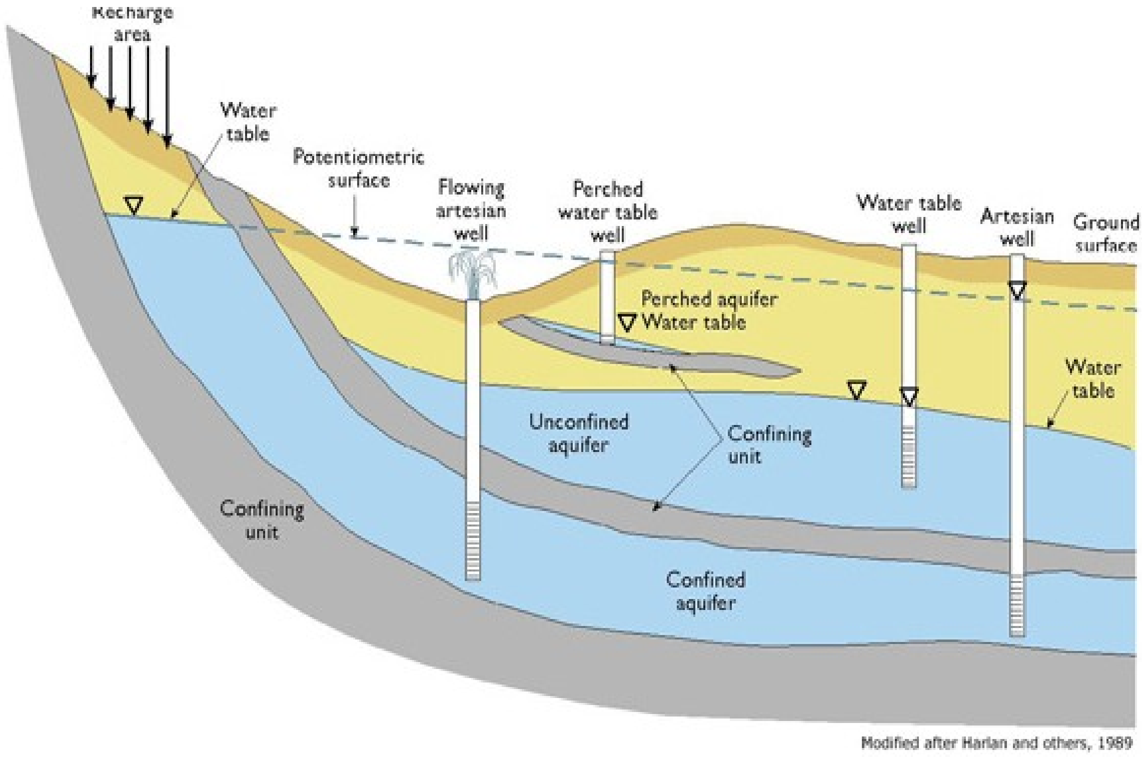


Figure 1.2 Schematic Cross-sections of Aquifer Types

Groundwater contains various types of dissolved salts in it which are ionically conductive and this enables electric currents to flow into the ground. The presence of water can be identified by measuring the ground resistivity. Electrical resistivity method is one of the geophysical techniques to investigate the nature of subsurface formations, by studying the variations in the electrical properties of the formations. Resistivity is a physical property of a substance defined as the resistance by a unit length of a substance of a unit area to the flow of electric current, when the voltage is applied at the opposite faces. If the resistivity in the ground is uniform, then the measured resistivity will be constant and independent of electrode spacing and surface location. If the resistivity in the ground is not homogeneous, then the measured resistivity will vary with relative and absolute location of the electrodes. In this case, the measured resistivity is an apparent resistivity (ρa), which depends on the shape and size of anomalous regions, layering and relative values of resistivities in these regions.

The Electrical Resistivity method has been used for the geophysical investigation of groundwater in KCAET campus. The present project has been undertaken, keeping in mind the following objectives;

1. To study the procedure for hydro-geophysical investigation of groundwater potential in KCAET campus
2. To obtain aquifer distribution within the study area
3. To delineate possible sites for drilling tube wells for sustainable water supply.

REVIEW OF LITERATURE

2.1 Surface investigation for groundwater

The naturally occurring water resource below the earth's surface is called Groundwater. Priti (2009) studied about the surface investigations for groundwater and cited that it occurs in the saturated zone of viable thickness and depth, below the surface, within the soil pore spaces and the fractures of lithologic formations. An aquifer can be defined as the water bearing formations which can yield a usable quantity of water. The depth at which the pore spaces become completely saturated with water is called water table. This source of water i.e. groundwater, cannot be seen above the earth surface. So in order to determine the condition and properties of the groundwater, many techniques are employed. Surface investigations allow us in deciding the information about type, porosity, water content and the density of subsurface creation. It is usually done with the help of electrical and seismic characteristics of the earth and without any drilling on the ground. The data supplied by this technique are partly reliable and it is less expensive. It gives only indirect sign of groundwater so that the underground hydrologic records must be inferred from the surface investigations. Right interpretation requires additional data from the sub surface investigations to confirm surface findings. It is generally achieved by geophysical methods viz. electrical resistivity and seismic refraction method.

Each and every material has got its own resistance. Similarly resistivity values of each layer of the earth also vary. Resistivity values of some commonly seen earth materials are as shown in table 1.

Table 1: Resistivity values of earth materials

COMPOSITION	RESISTIVITY (Ohm-m)
Top soil	5-50
Peat and clay	8-50
Clay sand and gravel mixture	90-250
Saturated sand and gravel	40-100
Moist to dry sand and gravel	100-3000
Mud stone and shale	8-100
Sandstone and limestone	100-1000
Crystalline rock	200-10000
Quartz	100
Calcite	500
Dense granite	1000000

Metamorphic rock	100-100000000
Unconsolidated sedimentary rock	10-10000
Gravel and sand with water	100
Fresh water	100
Shale and clay	10
Brine	0.05

Based on these resistivity values it is possible to distinguish water bearing materials from the others. Resistivity values of different types of water also differ from each other. Some of these values are shown in table 2.

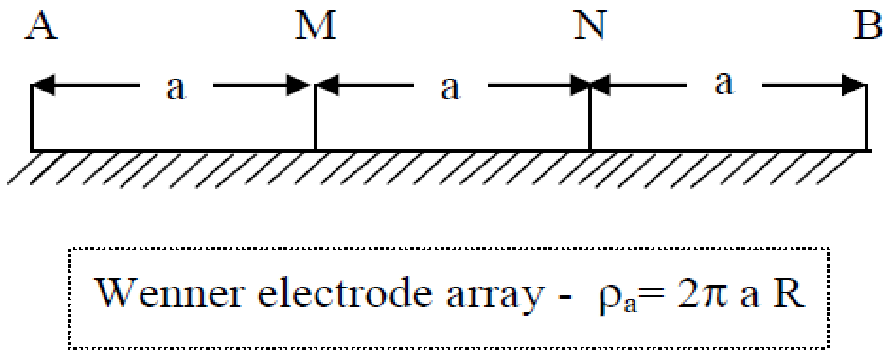
Table 2: resistivity values of different types of water

DIFFERENT TYPES OF WATER	RESISTIVITY(Ohm-m)
Meteoric water (derived from precipitation)	30-1000
Surface water (in districts of sedimentary rocks)	10-100
Groundwater (in areas of igneous rocks)	30-150
Sea water	0.2
Groundwater (in areas of sedimentary rocks)	More than 1

The relative values of electrical resistivity are interpreted in terms of the general geology of the subsurface to limited depths. In electrical resistivity survey the resistivity values are measured with linearly placed four electrodes. Electric current is applied to the ground through two of the electrodes and the potential drop across other two is noted. The potential electrodes are placed in between current electrodes and are symmetric with respect to the centre of the configuration. The most common electrode spacing is the Wenner and Schlumberger arrangements. In Wenner configuration, both current and potential electrode spacing are kept equal. On the other hand the Schlumberger configuration, the current electrode separation is varied, while keeping potential electrode separation constant.

2.2ELECTRICAL RESISTIVITY METHODS

Electrical Resistivity Method is one of the Geophysical techniques used to investigate the nature of the subsurface formations. In Electrical Resistivity method, current is sent into the ground through a pair of electrodes, called current electrodes, and resulting potential



difference across the ground is measured with the help of another pair of electrodes, called potential electrodes.

Apparent Resistance:The ratio between the potential difference (ΔV) and the current (I) is called apparent resistance.It depends on the electrode arrangement and on the resistivities of the subsurface formations.

2.2.1 Arrangement of Electrodes

There are several types of electrode arrangements (configurations) of which the most popular and commonly used are;

1. Wenner Configuration
2. Schlumberger Configurations

2.2.1.1 Wenner Configuration

In this configuration, all the four electrodes are kept along a line at equal distances called electrode separation 'a'. For each measurement, all the electrodes are moved simultaneously keeping the inter-electrode spacing the same. The current is sent normally through outer current electrodes and potential difference is measured across the inner potential electrodes.

The resistance is multiplied by the configuration factor 2 πa, to get the value of apparent resistivity (ρ_{aw})

$\rho_a = 2\pi a R$,where $R= \Delta V/ I$

Fig. 3 Wenner electrode array

2.2.1.2 Schlumberger Configuration

In this type of arrangement, electrodes are positioned same as in Wenner configuration. The only difference is that the outer electrode spacing is kept large compared to the inner electrode spacing, usually more than 5 times. For each measurement, only the current electrodes are moved, keeping the potential electrodes at the same locations. The potential electrodes are moved only when the signal becomes too weak to be measured.

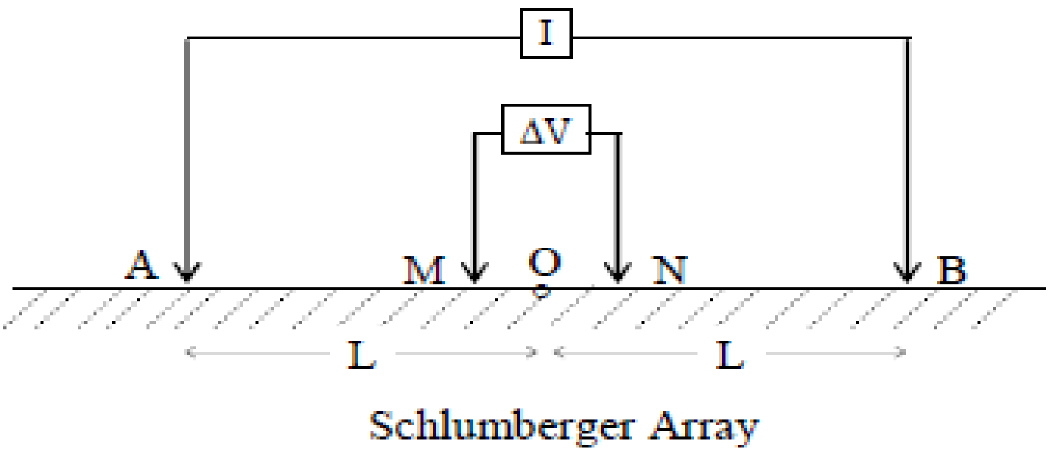


Fig. 4 Schlumberger array

The apparent resistivity for this configuration is computed with the formula;

$$\rho_{as} = \frac{\pi\,[(AB/2)^2 - (MN/2)^2]R}{MN}$$

2.2.2 Resistivity Observation Methods

There are two types of procedures for making resistivity observations. They are;

1. Resistivity Sounding / Vertical Electrical Sounding(VES)
2. Resistivity Profiling / Horizontal Electrical Profiling

2.2.2.1 Vertical Electrical Sounding (VES):

The Vertical Electrical Sounding is used to estimate the resistivities and thickness of various subsurface layers at a given location and is mainly employed in groundwater exploration to determine the disposition of the aquifers. In this approach, the centre of the configuration is kept fixed and the measurements are made by successively increasing electrode spacing. The apparent resistivity values obtained with increasing values of electrode separations are used to estimate the thicknesses and resistivities of the subsurface formations.

2.2.2.2 Horizontal Electrical Profiling:

Resistivity profiling is employed to determine the lateral variations in the resistivities thereby establishing the existence of vertical bodies like dykes, fracture zones, geological contacts etc.

Conventional approach of Data Acquisition and Data Processing:

Analysis of thickness and resistivities of the subsurface layers are done by making a plot on double logarithmic scale.

1. In case of Wenner configuration a plot is made between apparent resistivity and electrode spacing (a).
2. In Schlumberger configuration apparent resistivity is plotted against half of the current electrode spacing (AB/2).

The data density is between 6-8 logs per cycle of electrode separation. Even if the data density is higher than that it would not give any additional advantage because of logarithmic plotting.

The field curve is first compared with the theoretical curves for obtaining a preliminary model and this model is modified and refined with computer inversion programs, incorporating the geological information of the area.

Disadvantages of VES

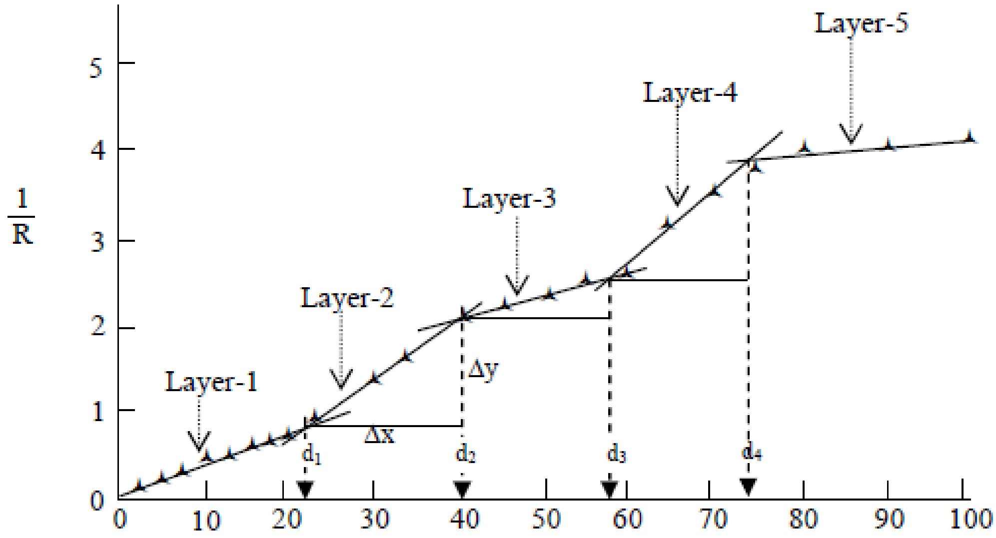
The resistivity sounding technique has the following inherent disadvantages:

1. The resolving power of this method is poor and is particularly true for deeper boundaries.
2. Due to the principle of suppression, a middle layer with resistivity intermediate between enclosing beds will have practically no influence on the resistivity curve as long as its thickness is small in comparison to its depth. Hence the layers with small thickness cannot be recognized.
3. Due to principle of equivalence:
   (i) a conductive layer sandwiched between two layers of higher resistivities will have the same influence on the curve as long as the ratio of its thickness to resistivity (h/p) remains the same and similarly
   (ii) a resistive layer sandwiched between two conducting layers will have the same influence on the curve as long as the product of its resistivity and thickness. Hence the thicknesses and resistivities of sandwiched layers of small thickness cannot be determined uniquely.

2.2.3 Inverse Slope method

An innovative approach to interpret the vertical electrical sounding data with Wenner configuration was suggested by Chary(1967). According to this approach, the inverse of resistance measured (1/R) is plotted against the Wenner electrode separation 'a' on a linear graph. The data points are plotted and these points align themselves on discrete line segments. The segments are then joined by straight lines. Each line segment represents a layer and the intersections of the line segments correspond to the depths to the particular layers. The resistivities of the layers are obtained by the inverse slope of the particular line segment multiplied with '2π.

A schematic example of the Inverse Slope method of interpretation of resistivity sounding data is given below:



Electrode spacing (meters)

Fig. 5 Inverse Slope method of interpretation

Slope of line segment = Δy/ Δx = (1/R) / a

Inverse Slope = a / (1/R) = a * R

Resistivity of the layer = '2π' * (Inverse Slope) = 2π * (a * R) = 2π a R

A small improvement of this is to plot (a/ρ_a) on the Y-axis instead of (1 / R). Then the Inverse Slope directly gives the resistivity of the layer (No need to multiply the inverse slope with '2π').

The Inverse Slope method was proposed for interpretation of Wenner sounding data, actually. However, this method can also be used for Schlumberger data with a minor modification. For Schlumberger sounding the linear plot has to be prepared between (AB/2) on X-axis and {(AB/2)/ ρa} on Y-axis. Inverse of resistance (1/R) cannot be used for plotting since R depends on both AB/2 and MN/2. While the inverse slope of the line segments directly gives the true resistivity of the layers, the intersections of the line segments have to be multiplied with (2/3) to get the depths to the interfaces. The procedure of interpretation for both these soundings is described in table 3.

Table 3: Procedure of interpretation of Wenner and Schlumberger sounding

Step	Wenner sounding	Schlumberger sounding
1	Calculate (1/2πR) or (a/ρ_a) depending upon which value is available for each observation.	Calculate the value ((AB/2)/ρ_a) for each observation.
2	Plot the values (1/2πR) or (a/ρ_a) on Y-axis against the electrode separation 'a' on the X-axis on a linear graph sheet.	Plot ((AB/2)/ρ_a) values (on Y-axis) against 'AB/2' (on X-axis) on a linear graph.
3	Join the plotted points with best fitting lines such that a minimum of 3 points fall on each line.	Join the plotted points with best fitting straight lines such that a minimum of 3 points fall on each line.
4	All the points are generally covered by straight-line segments each of which represents one subsurface geo-electric layer.	Some points may not be covered by any line segment due to shift in potential electrodes. Each segment represents one subsurface geo-electric layer.
5	Take any point on a segment. Read its coordinates—X coordinate represents value of 'a' and Y coordinate represents (1/2πR) or (a/ρ_a) depending upon which value was used.	Take any point on a segment. Read its coordinates—X coordinate represents value of 'AB/2' and Y coordinate represents ((AB/2)/ρ_a).
6	Calculate the Inverse Slope of each line segment. Y-coordinate value divided by X-coordinate value. This value directly gives the true resistivity of the subsurface layer represented by the line segment.	Calculate the Inverse Slope of each line segment. Y-coordinate value divided by X-coordinate value. This value directly gives the true resistivity of the subsurface layer represented by the line segment.
7	Read the X-coordinate values of all the intersection points of the line segments. These values represent the depths to the interfaces.	Read the X-coordinate values of all the intersection points of the line segments (t1, t2, t3…etc.). Multiply each't' value with (2/3). These multiplied values (t1 x 2/3, t2 x 2/3, t3 x 2/3 etc.) represent the depth to the interfaces 1, 2, 3 resp.

Two very important things to keep in mind:

1. The detectability of thin layers at deeper levels depends on density of data. More the data densitybetter is the detectability.
2. More the resolution of the resistivity meter better is the possibility of detecting thin layers at depths.

2.3 Various resistivity meters

There are many different types of resistivity meters used for electrical resistivity survey. Details of a few resistivity meters commonly used are mentioned below in brief.

2.3.1 Earth Resistivity Meter 16GL-N:

Tagel (2008) conducted a geophysical investigation for groundwater potential assessment using 16GL-N earth resistivity meter and found that it's a high resolution, high sensitivity instrument managed by multiprocessor. It has got a light and compact structure in a weatherproof case. Continuous readout of current or voltage can be made out and an acquisition memory of 18000 readings can be made without direct data downloading. It can be used for subsoil groundwater prospecting at shallow, medium and great depth, geological stratigraphy, studies of salt water contamination in fresh water layers, landslide monitoring, mineral exploration and archaeological research.

2.3.2 IGIS Signal Stacking Resistivity Meter Model SSR-MP-ATS;

Ahilan*et al* (2011) used Schlumberger configuration using Microprocessor based signal stacking digital resistivity meter of IGIS. In the presence of random (non-coherent) earth noises, the signal to noise ratio can be enhanced by $\sqrt{N}$ where N is the number of stacked readings. SSR-MP-ATS is a microprocessor based signal stacking resistivity meter in which running averages of measurements [1, (1+2)/2, (1+2+3)/3, ...(1+2+....+16)/16] up to the chosen stacks are displayed and the final average is stored automatically in memory utilizing the principle of stacking to achieve the benefit of high signal to noise ratio. Hence SSR-MP-ATS can be used for resistivity investigations up to about 600 m deep or more under favorable geological conditions.

The SSR-MP-ATS is operated through user-friendly menu. The special feature in SSR-MP-ATS is that, it can store the data up to 20,000 measurements (or data of about 100 Soundings) in its FLASH memory. It has provision to transfer the entire data (or any particular data) directly to the computer through USB port for further analysis. The Data can also be viewed through (20 x 4) alpha-numeric LCD.

Applications of this device are mainly in the areas of ground water exploration, bed rock investigations, delineation of geological structures, sand and gravel deposit identification, mineral investigations and geophysical field training.

2.3.3SYSCAL type resistivity meter:

Mohamed *et al* (2012) used SYSCAL type resistivity meter for geo-electrical resistivity survey in Al-Quway'yia area in Saudi Arabia. They used this instrument because of the following features. These are fully automatic resistivity-meters designed for intensive exploration of groundwater by DC electrical methods. They allow study of variations in resistivity with respect to the depth (vertical electrical sounding) together with variations along a profile (electrical profiling). Chargeability (Induced Polarization) of the ground can also be computed. Intensive field measurements can be carried out efficiently, as these equipments are very compact. It consists of two internal batteries, one for the circuitry supplying and the other for generation of injection current. The resistivity-meter uses its internal converter to generate current into the ground.

2.3.4 TL-5 earth resistance meter:

K'Orowe*et al* (2012) used TL-5 earth resistance meter and cited that it is a digital instrument controlled by a microprocessor which has been designed to take earth resistance and resistivity measurements, using Wenner method. The TL-5 unit is fully automatic and easy to use. Before taking a reading, the unit controls the installation conditions to check that they are within the adequate limits. Then it notifies the user of any abnormal situation (very high interference voltages, very low intensity of the test current, etc.). It can be used to select two frequencies to generate the test current (270 Hz or1470 Hz).The instrument has 4 ranges to measure resistances, covering the range that goes from 0.01 Ω to 20 kΩ.

2.4 Electrical resistivity surveys

The studies about ground water exploration using electrical resistivity meter at different parts of the world have been critically reviewed with respect to the following objectives of study;

1) Groundwater exploration
   a) In hard rock areas
   b) In basement terrains
2) Lithology and groundwater quality
3) Groundwater recharge estimation
4) Aquifer properties

2.4.1 Groundwater exploration studies

Mohammad (1975) conducted a feasibility study to locate groundwater sourcesusing vertical electrical resistivity soundings. The study discusses the occurrence of ground water in the Coastal Plain region of southeastern Virginia and northeastern North Carolina. 45 vertical resistivity soundings (VES) were taken with the Schlumberger array. A maximum separation of 8,000 feet between the current electrodes was provided. VES data was interpreted through an automatic computer interpretation program, and by the curve-matching method. The results reported here suggest that, in the area west of the town of Suffolk, the depth to the basement complex can be determined with reasonable confidence. Eastwards from Suffolk, an "electric basement" of high resistivity was detected at depths which usually exceeded 1,000 feet. The correlation between some VES interpretations and resistivity logs of wells in their vicinities reveals high degrees of similarities.

Dahlin and Owen (1998) cited that 2D geo-electric methods are very effective at measuring sections down to 10m with some recent results shown from deeper penetration. Results for electrical surveys are usually presented as geo-electric, conductivity or resistivity sections, line profiles or maps and volumes. Groundwater exploration was carried out using 2Dresistivity surveys with an ABEM Lund Imaging System, together with a ground penetrating radar in shallow alluvial aquifers in Zimbabwe. The results were used to build conceptual geological/hydro-geological models of the aquifers as a basis for guiding the drilling programme. Olayinkaand Barker (1990) used similar micro-processor controlled resistivity traversing techniques for siting boreholes in Nigeria.

Ayolabi*et al.* (2000) carried out groundwater investigation at Igbogbo, Lagos, using seismic refraction and electrical resistivity techniques. They correlated the results from each method and delineated aquifer zones.

Rhett (2000) made a study on electrical resistivity in geophysics. This paper presents the electrical resistivity component of an undergraduate geophysics course at Radford University. The final results are given in a form that, the practicing geophysicists may use it in the field. A method is presented for constructing an inexpensive apparatus for measuring electrical resistivity in both a tabletop laboratory setting and in the field.

Basudeo*et al*. (2005), carried out a study to evaluate the groundwater prospective zones by using remote sensing and geo-electrical methods in Jharia and Raniganj coalfields, Dhanbad district, Jharkhand state. Twenty-six Vertical Electrical Soundings (VES) have been carried out by using Schlumberger electrode configuration. The results shown to have brought out 3 to 7 layered sub-surface layers. The resistivity of water-bearing weathered/fractured rocks was found to vary from 120–150 ohm-m. The integrated studies have revealed the most promising for groundwater exploration and dug wells may be dug up to depths of30 ± 5m.

Priti (2009) conducted a project on groundwater exploration using electrical resistivity method. Ashida soil resistivity meter was used for the survey. It is a vital, sophisticated electronic tool to explore the mysteries of the sub-surface world. It is very easy to operate the instrument if the instructions are followed step-by-step and correctly, then the readings can be easily interpreted. The lowest resistance spot was marked i.e. 55 ohms and it was considered to be the best spot in a given area, for maximum amount of ground water yielding and the water zone is at a depth 14 meter and 30 meter.

Oseji and Ujuanbi (2009) conducted a research on hydrogeophysical investigation of groundwater potential in Emu kingdom, Ndokwa land of Delta State, Nigeria. A study of 10 vertical electrical soundings from different quarters of Emu kingdom using Schlumberger array were undertaken. This was an attempt to obtain useful information on the aquifer distribution within the area and hence delineate possible site where boreholes could be drilled for potable and sustainable water supply. Based on the geo-electric section which is in agreement with the driller’s log, the best environments for sustainable water supply were identified. This coincides with the third layer of the aquifer in Emu kingdom and consists of medium-grained sand formation. The average depth to this aquifer was found to be 45 m whose thickness is not defined at Obiogo since it is the last layer. In other parts of Emu-Kingdom, the thickness ranges from 45 m in Ikosa quarter to 95 m in Etevie quarter. The resistivities of these layers vary from 1000–3000 ohm-m. The aquifer system of Emu

Kingdom has an overlying confining bed without an underlying confining layer; hence it is leaky or semi-confined.

Bozkurt*et al*. (2009) studied the relationships between soil apparent conductivity (ECa) and soil water content (Wn), with respect to salinity, porosity, pH, and clay content in two engineered covers located in the Umuttepe and Alikahya Regions. The study was done to understand the different properties of soil apparent conductivity. At the same time soil samples were collected to a depth of 0.3 m from each site of measuring points in both engineered covers to determine the soil properties. pH values were measured at each of the measuring point in-situ. Soil ECa readings were correlated with Wn, salinity, porosity, pH, and clay content.

Ameloko and Rotimi (2010) did a study which was designed to produce appropriate images of the Kubbani river basin with the aim of investigating and delineating appropriate location for underground water exploitation.A modern field system, Terrameter (Signal Averaging System) SAS 4000/1000, was used to accomplish the task of exploring groundwater in the basin. 23 image lines were measured at different strategic locations of the study area based on the fractured map of the area and previous information obtained from the area. The measured apparent resistivities were used to construct a vertical contoured section displaying the variation of resistivity both laterally and vertically over the section. Interpretation of the data acquired using this equipment revealed the suitability of the Southern part of the study area for location of boreholes.

Naveen (2010) conducted a project on exploration of ground water using electrical resistivity method. The project report underlines the survey work carried in order to tap ground water so as to cater the need of increasing demand for water by the NIT Rourkela. Based on the survey results drilling operations were carried out at proposed point incorporating Rotary percussion method and measurement of discharge was done. The survey work was carried out with the help of Ashida electrical resistivity method and the results obtained through the survey work were coherent with the actual findings obtained through drilling operations.

Ezomo and Akujieze (2010) carried out a geophysical investigation in Oluku village and its environs of Edo state, Nigeria. This was done in order to investigate possible sources of groundwater. Vertical electrical sounding techniques (VES) technique was used with Schlumberger array. The current electrode spacing ranged from 1-632m. This study revealed the existence of unconfined aquifer in the area which can be exploited to meet the basic need of the community. Ten (10) fairly distributed VES in Oluku Village and its environs was carried out to justify the field operation of geophysical survey. The results of the interpretation identified an unconfined aquifer as a source of ground water. It belonged to the Benin formation at depth of 10 m to 125 m below the sea level. The resistivities of the detected unconfined aquifer varied from 700 ohm-m to 10,000 ohm-m while its thickness varied from 5m to 65m. Area of probable groundwater sources have been detected for future drilling operation.

Mahmoudi*et al.* (2011) conducted a study to map aquifers in King Faisl University (KFU) campus. The aim of this paper is to map the underlying aquifers systems at the study area. This study helped to choose the best locations for the proposed site wells, in the most potential areas.

Ashvin (2011) had done B.tech project on exploration of groundwater using electrical resistivity method.The project mainly deals with the tapping of Ground water in NIT Rourkela by doing a survey work for fulfillment of needs. Based on results, measurement of discharge was done. Drilling operations were carried out at proposed point with the help of Rotary percussion method. Whole of the survey work has been done with Ashida electrical resistivity method. Coherency was found between the survey work done and actual findings which was done through drilling operations.

Anomohanran (2011) carried out a geophysical investigation in Oleh, Nigeria to determine the groundwater potential and the geological structure of the area. The method employed in this study was the Vertical Electrical Sounding (VES) using the Schlumberger configuration. The data obtained were interpreted by computer iteration process and results were compared with lithologic log from existing boreholes. This comparison indicated a four layered formation. The first aquifer identified in this study was located along the second layer with resistivity ranging from 347.4 to 1137 Ωm and depth ranging between 2.0 and 3.7 m. Analysis of this layer showed that this aquifer is unconfined and prone to pollution since it underlies a thin, loose and clayey sand formation. The second aquifer was found to be a viable potable water formation with resistivity range of 416.7 to 1459.2 Ωm and a thickness range of 12.0 to 14.9 m. The depth of the aquifer ranges from 21.8 to 29.7 m. Boreholes for potable groundwater were therefore recommended within the forth layer.

Rosli*et al.* (2012) conducted a study in areas which have a geology record of thick alluvium, using 2-D electrical tomography. The results show that groundwater will lower the resistivity value and silt also will bring down the resistivity value lower than groundwater effect.

Massing *et al.* (2012) conducted a research on groundwater exploration in the basement of Lake-Iro, District-Chad, using electrical resistivity imaging approach. The measurements were performed with the Syscal Junior R1-Switch-48 multi-electrode systems (Iris Instruments). Interpretation of the processed electrical images has revealed the utility of this technique in the selection of boreholes sites in difficult terrains. The ERI method has produced significant pseudo-sections with high quality in terms of structural resolution. Significantly defined layering of different lithological units, depth to bedrock and weathering profiles and identification of structures such as fractures at the subsurface were possible. The aquifer has been found to be heterogeneous, anisotropic and discontinuous. The relationships between the weathered thicknesses/operating flow rate and lithology were compared with hydrodynamic parameters. This has made it possible to highlight the groundwater potentiality in the basement. They concluded that borehole drillings have confirmed a success rate of 65.22% and the groundwater is generally exploitable in the granitic formations.

Mohamed *et al*. (2012) conducted a research on groundwater exploration using geo-electrical resistivity technique at Al-Quwy'yia area in central Saudi Arabia. This was done to map the aquifer and estimate the groundwater potentiality. The acquired vertical electrical sounding (VES) data sets have been collected along three longitudinal profiles trending East-West, perpendicular to the basement/sedimentary contact. The data sets were analyzed using 1D to obtain the resistivity layers along the areas. Information from two boreholes was combined during the processing to enhance the results and constrain the resistivity models with geological layers. The results revealed mainly two geo-electric layers represent mainly the basement and sedimentary rocks.

Selvam (2012) carried out a groundwater investigation in Panchipenta Mandal using vertical electrical resistivity survey. This study was done with an aim of demonstrating the application of VES method of investigation in exploration of groundwater. The area of probable groundwater sources have been detected for future drilling operation. VES have proved to be very reliable for underground water studies.

2.4.1.1 Groundwater exploration in hard rock areas

Stephen and Gabriel (2009) conducted a case study in Fidiwo/Ajebo areas of Southwestern Nigeria in order to study the role of Electrical Resistivity Method for groundwater exploration in hard rock areas. About 28 stations were probed in the study area using Vertical Electrical Sounding (VES) with Schlumberger electrode configuration. The result was interpreted by both Partial Curve Matching Technique and Computer Iteration Program. By this electrical method, the common aquifer was found out to be a typical Basement Complex which constitutes weathered and fractured bedrock. From the depth of few hand dug wells in the study area, it was discovered that they only tap their water resources from the regolith and this lead to the dryness of these well at the peak of Harmattan season in Nigeria.

2.4.1.2 Groundwater exploration in basement terrains

Olorunfemi and Oloruniwo (1987) used the electrical resistivity method for groundwater investigation in parts of the Basement terrain in Southwest Nigeria and concluded that the weathered layer and the fractured Basement constitute the aquifer zones.

Abdelatif (2000) conducted a case study on Exploration of Ground Water in a Basement Area Using Electrical and Electromagnetic Surveys, at El Sunut, North Kordofan State. Geophysical surveys were applied in combination with geological and hydro-geological investigations in the study area. The study showed that the thickness of weathered basement is about 77m and it may reach up to 135m. The interpretation of vertical electrical sounding shows that the superficial deposits overlying the weathered basement are composed of sand, quartz or basement fragments. Drilled boreholes in the area showed yield more than 2000 g/h in some localities. From drilled boreholes data and geophysical interpretation results, it was concluded that the valley in the area is an old buried channel.

Anudu*et al*. (2011) conducted a geo-electric sounding for groundwater exploration in the crystalline basement terrain around Onipe and adjoining areas in southwestern Nigeria. Sixteen geo-electric soundings (VES) using the Schlumberger array were conducted across the area. Field data acquired were interpreted using partial curve matching approach and iterative resistivity sounding interpretation software, IPI2Win Version 3.0.1. The results show three to four geo-electric layers and the best points for siting wells or boreholes in the area were located.

Ushie and Nwankwala (2011) carried out a geo-electrical survey in Yalla, Southern Benue Trough, South-East Nigeria to assess the occurrence of groundwater. Results from resistivity survey show that there are atleast four geo-electric layers of various thicknesses. These layers were found to have different electrical resistivities, which indeed reflected their water content.

Bayewu*et al*. (2012) focused on the use of Very Low Frequency-Electromagnetic (VLF-EM) and Electrical Resistivity- Vertical Electrical Sounding (VES) methods of geophysical survey in a typical crystalline basement complex terrain. The aim of this work therefore was to delineate fracture zones for groundwater exploration within the subsurface of the permanent site of Olabisi Onabanjo University, Ago-Iwoye, south-western Nigeria so as to improve the water supply situation on the campus. The work shows the effectiveness of the combination of VLF-EM and VES survey in accurately delineating an area for groundwater occurrence and exploitation.

Aweto (2012) conducted a dc-electrical resistivity investigation of Oke-Ila area with a view of delineating fractured zones within the crystalline basement rocks, using ABEM SAS 1000 Terrameter. The results of the investigation revealed three distinct geo-electric layers: top soil, weathered layer and fractured/fresh crystalline basement rocks. The study revealed that the fractured zones which constitute the productive water bearing zones are discontinuous (localized) and they occur at an average depth of 37.5m.

2.4.2Lithology and groundwater quality

Abdelatif and Sulaiman (2000) used resistivity survey to evaluate groundwater quality at Seri Pataling landfill located in the state of Selanger, Malaysia. They used OYO McOhm Resistivity Meter. From the VES curves obtained they concluded that the groundwater in this landfill is unfit for domestic consumption because of the presence of high amount of total dissolved solids (TDS) along the survey line.

Arshad*et al*. (2007) used Electrical resistivity survey for the determination of groundwater quality and lithology of lower Rechna Doab aquifer in the central part of the Punjab. VES measured at nine locations with Schlumberger array. The interpreted VES curves revealed the presence of fresh groundwater in the aquifer consisting of surface layer (top soil), alluvium layer and saturated (bottom soil) layer and the depth, thickness and type of all layers were identified**.**

Girish (2009) conducted an integrated hydro-geological study of the Muvattupuzha river basin, Kerala. The present study deals with the different hydro-geological characteristics of a central Kerala river basin i.e. to evaluate the aquifer parameters, to determine the seasonal variations in groundwater quality and to demarcate the groundwater potential zones. Measurements are taken with Schlumberger configuration of electrodes. From the interpreted resistivity curve some properties of aquifer were obtained. Resistivity analysis indicates that the Muvattupuzha basin is having good groundwater phreatic potential zone and certain promising zones for medium and deep bore wells in the entire basin.

Amarachi and Ako (2012) conducted a geophysical investigation involving the seismic refraction and the vertical electrical sounding (VES) electrical resistivity methods was carried out around Ajebandele quarters, Ile-Ife, Osun State, Southwest Nigeria. The study was carried out with a view to determine the subsurface layer parameters (velocities, resistivities, and thicknesses) and use same to categorize the ground-water potential of the area. Six vertical electrical soundings were located and measurements are taken with Schlumberger electrode configuration. The curves are interpreted based on the geo-electric characteristics and determination of percentage of each group. On the basis of lithologic log available,the VES curves were interpreted in terms of lithology.

2.4.3 Groundwater recharge estimation

Donald and Doak (1967) conducted a technical project on estimation of ground-water configuration near Pahala, Hawaii using electrical resistivity techniques. The survey attempted to determine the extent of this high-head water and define the nature of its occurrence. 32 electrical soundings were completed; some of the soundings indicated the limits of reservoir. The high head ground water encountered at the Pahala well has been found to extend at least 3500 feet northeast of a well in Pahala.

Israil*et al*. (2003) conducted groundwater-recharge estimation using a surface electrical resistivity method in the Himalayan foothill region, India. In the study area, 32 VES measurements were taken. The interpreted result shows a well-defined empirical relationship between unsaturated zone resistivity and recharge per cent. The method suggests a new application of surface electrical resistivity data in determining recharge per cent due to infiltration. They concluded the obtained relationship is useful in groundwater recharge estimation and evaluation and the surface electrical resistivity survey is efficient, economic and less time consuming.

2.4.4 Aquifer properties

Owen *et al*. (2003) conducted a multi-electrode resistivity survey over meta-sedimentary strata and meta-volcanics in the Harare Greenstone belt in northeastern Zimbabwe as part of groundwater resources investigation. Meta-basalt, meta-arenite, granodiorite and banded iron formation can be identified by resistivity data, based principally on depth of weathering but also partly on relative resistivity values.

Ariyo and Adeyemi (2009) made a study to determine the geo-electrical and hydro-geological characteristics of the aquifer present in Fidiwo/Ajebo areas of Southwestern Nigeria. About 28 VES locations were probed with Schlumberger configuration and the interpreted result gives an overview of aquifer characteristics.

HadiandGholam (2010) conducted a geophysical survey using VES techniques to investigate the sub-surface layering in Shooroo basin, Southwest of Zahedan in order to determine the nature, characteristics and spatial extent of the components of the aquifer underlying the region. The VES measurements are taken for Schlumberger arrangement. The filed curves are plotted. The field data was interpreted using the Russian software IPI7.6.3. The results showed the characteristics of basin.

Metwaly*et al.* (2012) carried out Geo-electrical resistivity surveys in Al Quwy'yia area located in the central part of Saudi Arabia, to map the aquifer and estimate the groundwater potentiality in promising area close to Riyadh. VES are obtained with Syscal R_2 acquisition system, operating with the Schlumberger electrode configuration. The acquired resistivity data curves give certain properties of geologic environment.

MATERIALS AND METHODS

3.1Groundwater exploration study in KCAET campus

Groundwater is a dependable source of water for our needs such as irrigational requirements, domestic purposes and all other necessities. Its occurrence can be studied with the help of various geophysical techniques. Since electrical methods are most commonly used and are comparatively economical, we conducted a study using Electrical Resistivity method for exploring the groundwater at various locations, in our own campus.

The basic principle of this method is that groundwater contains various dissolved salts. These salts are ionically conductive and enable currents to flow into the ground. We can identify the presence of groundwater by measuring the ground resistivity through surface investigations.

Surface investigations can be done either vertically or laterally. It involves measurement of ground resistivity. In this method, primarily we have four electrodes: two potential electrodes and two current electrodes. A current has to be transmitted through the two currentelectrodes. The potential created on the surface by the circulation of this current into the ground is measured with potential electrodes. Progressively increasing the distance between the transmitting and the receiving electrodes permits to increase the depth of investigation. Translating the four electrodes together permits to detect lateral change of resistivity, this is called lateral investigation or profiling.

The resistivity measured in the ground is predominantly controlled by the amount of moisture and water within the soil and rock and the concentration of dissolved solids in that water. Theactual current flow is highly influenced by conductive layers, the value measured is known as the “apparent resistivity”. Itrepresents an average resistivity value of all the different materials within the volume of materials being measured. Most modern resistivity meters calculate apparent resistivity once the geometric parameters are given as input.

3.2. General description

Kelappaji College of Agricultural Engineering and Technology is located at Tavanur, Kuttipuram. The place is situated at 10^0 51' 23'' N and 75^0 59'13'' E, at an elevation of about 28.3 meters above MSL. The campus spreads over 100 acres of land along the banks of Bharathapuzha. The objectives of the study were to familiarize with the procedure for hydro-geophysical investigation of groundwater potential, to identify aquifer distribution within the study area and to delineate possible sites for drilling tube wells for sustainable water supply.

To start with, the various locations in the campus were selected for the purpose of groundwater exploration study. Electrical resistivity method was adopted. The instrument used for the purpose was IGIS Signal Stacking Resistivity Meter Model SSR-MP-ATS. It is a high-quality data acquisition system with so many new features.Electrical resistivity method can be done in quite large flat locations, where measurements can be taken up to 100 meters horizontally straight. Our first task was to select such locations.

3.2.1 Locations for study

Areas with low irregularities and where a stretch of about 100 meters can be obtained for carrying out the resistivity survey were selected. These locations were then marked on the map of the campus. Areas lying so close to the river Bharathapuzha were avoided.

The map given below gives us the overall view of KCAET campus. The sites selected for study, are clearly depicted in the map. The sites chosen are named as follows;

- Ground
- Farm road
- Near canteen
- Near men's hostel
- Near staff quarters
- Workshop

All the selected areas were easily accessible. The instrument could be used without any threats to its functioning.

The electrical resistivity survey was carried out on fair weather days. Rains can alter the resistivity values i.e. the values will be deviating from the actual values. So readings were taken only on favourable days.

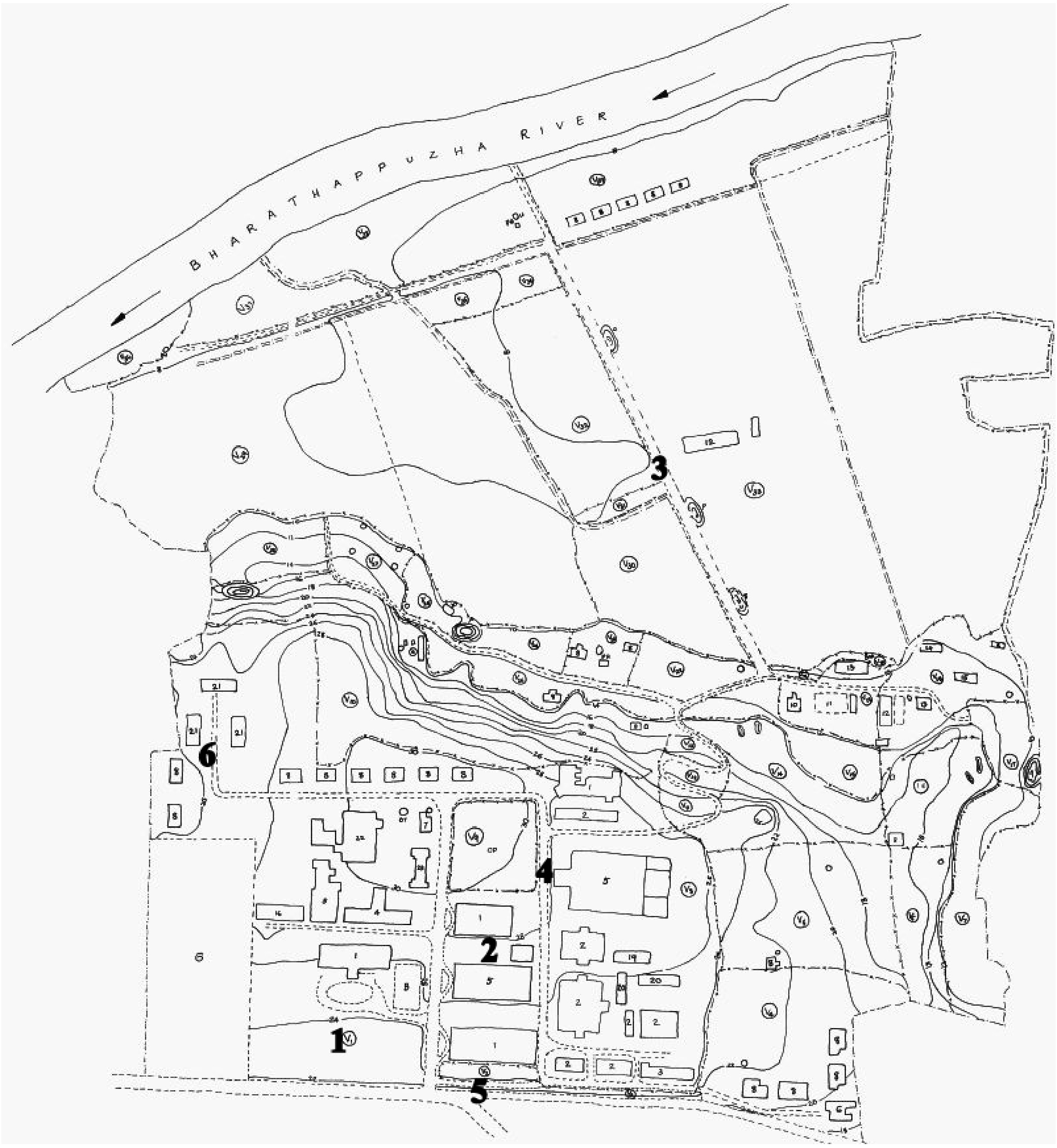


Fig.6 Map of KCAET campus with the locations of study clearly marked

3.3 Componentsof resistivity meter model: SSR-MP-ATS

The IGIS Signal Stacking Resistivity Meter Model SSR-MP-ATS is a high quality data acquisition system incorporating several innovative features**.** The SSR-MP-ATS is operated through user-friendly menu. The special feature in SSR-MP-ATS is that, it can store the data up to 20,000 measurements (or data of about 100 Soundings) in its FLASH memory. It has provision to transfer the entire data (or any particular data) directly to the computer through USB port for further analysis. The SSR-MP-ATS measures DV & current (I). It calculates the Resistance (R = DV / I), Apparent resistivity ρ_a& Strip Resistivity ρ_{strip}. It has a resolution of 10-5 ohms.

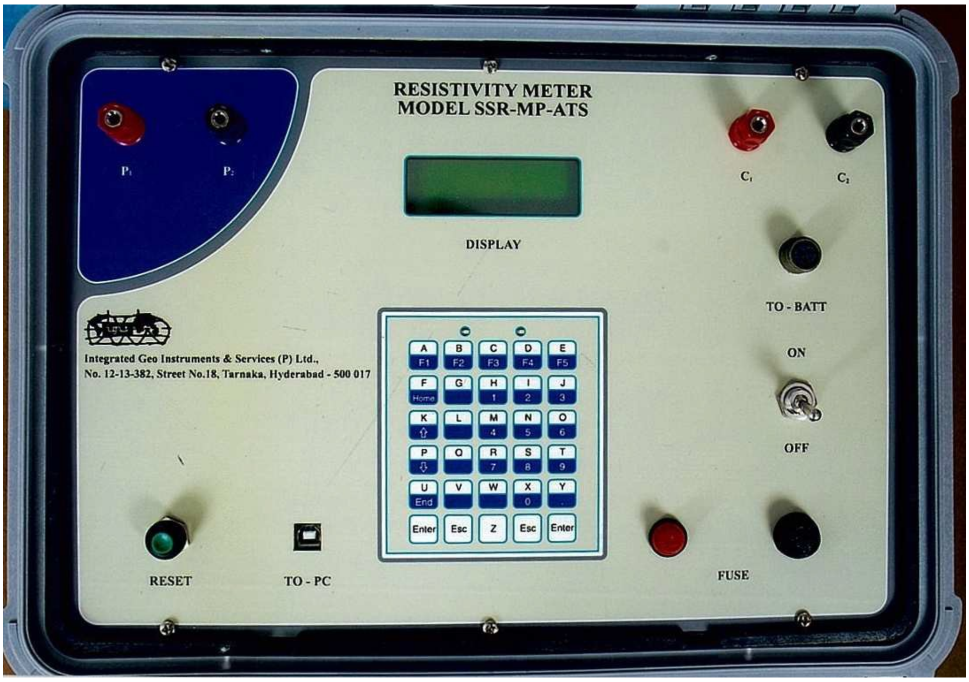


Plate 1: IGIS Signal Stacking Resistivity Meter Model SSR-MP-ATS

3.3.1 Terminals

P1 and C1 are of red colour and P2 and C2 are of black colour. C1 and C2 are terminals for connecting current electrodes through which current is injected to the ground. P1 and P2 are terminals for connecting potential electrodes through which the potential created by injecting the current through the current probes is measured. There is no current setting. Current input depends on the contact resistance at the current electrodes. Maximum current can go up to 2A and voltage settings of 100-300V can be done.

3.3.2 On-Off switch

With this switch the main battery supply to instrument is disconnected. This is used to switch on and off power. Input Impedance is 1 Mega Ohm and Resistance Range it can measure is 0.00001-19.99 K Ohms. The device includes selectable stacking cycles up to 16 for data averaging.

3.3.3 Display

This is a Liquid Crystal Alphanumeric Display to show the menu and measured values. By the help of this display it is easy to operate the instrument. Stack No. /stack selected, current in mA, running average resistance during measurement and final display of average resistance, apparent resistivity and strip resistivity are displayed.

3.3.4 To-batt

This is a 3-Pin Connector to connect the battery unit. This will be connected throughout the operation of the main instrument.

3.3.5 Fuse

Function of fuse is protection of Input & Output circuits in the device against circuit loads.

3.3.6 Key pad

It has got a user-friendly menu operation with 6x5 feather touch key pad. Key pad is to interact with the system and to input data like electrode spacing, number of stack etc.

3.3.7 To-PC

This is a connector to interface the computer. Computer downloads measurements from the resistivity meter by connecting the connector to the computer. In the device it can be store the data of about 100 Soundings (~ 20,000 readings). The data can be transferred directly to IBM Compatible PC through USB port for further analysis and interpretation

3.3.8 Reset

This key is used to switch ON the measuring unit from stand-by mode. After each reading is taken the instrument is reset to take another reading. There are error signals for discontinuity in current lines and low signals.

Plate 2: Winch

Plate 3: ElectrodesPlate 4: Battery box

3.3.9 Battery box

This is a compartment with 2x12 7 AH batteries. This battery supplies charge to the main instrument while taking the measurements.

3.3.10 Socket

This is to enable connection between the batteries and the measuring unit.

3.3.11 Winches

There are four winches .Each winch has a wire winded on it which has a different colour end. The open end of wires has a pin connected to it which in turn is to be attached to the respective probes. The other end of the wires is concluded on the banana socket located at the reverse side of handle of the winch. At this end the corresponding wires from instrument terminals are connected.

3.3.12 Probes

There are four stainless steel probes which are of the appropriate sizes and they are supplied along with. Each probe has a pointed end. This facilitates to hammer the probe in ground. The probes are hammered in the ground in such a way that the firm electrical contact is established. To these electrodes the corresponding wire ends are connected.

3.4 Methodology

3.4.1 Setting up of instrument

Electrical resistivity survey was first carried out at 'ground 1'. The measurements were taken in a straight line of about 100 meter. First of all this straight line was decided on the site and the centre of the site was marked and named 'O'. At this point the device was placed and the points at which the electrodes are to be placed were marked on the basis of electrode spacing which ranges from two meters for the first reading and gradually increased by two meters for further readings. The two electrodes i.e. potential electrodes were hammered at the marked points 'M' and 'N' which are at one meter distance from the centre point 'O' so that the electrode separation is two meters. The other two electrodes i.e. current electrodes were hammered at corresponding points which are two meters away from the potential electrodes

‘A’ and ‘B’ i.e. three meters away from the centre point ‘O’. The potential electrodes were connected to the potential terminals and the current electrodes were connected to the current terminals in the device with the help of interconnecting cables and winches. These winches can be extended up to the respective electrodes. The device was connected to the battery unit by using a three-pin connector.

Plate 5: Setting up of instrument in the field

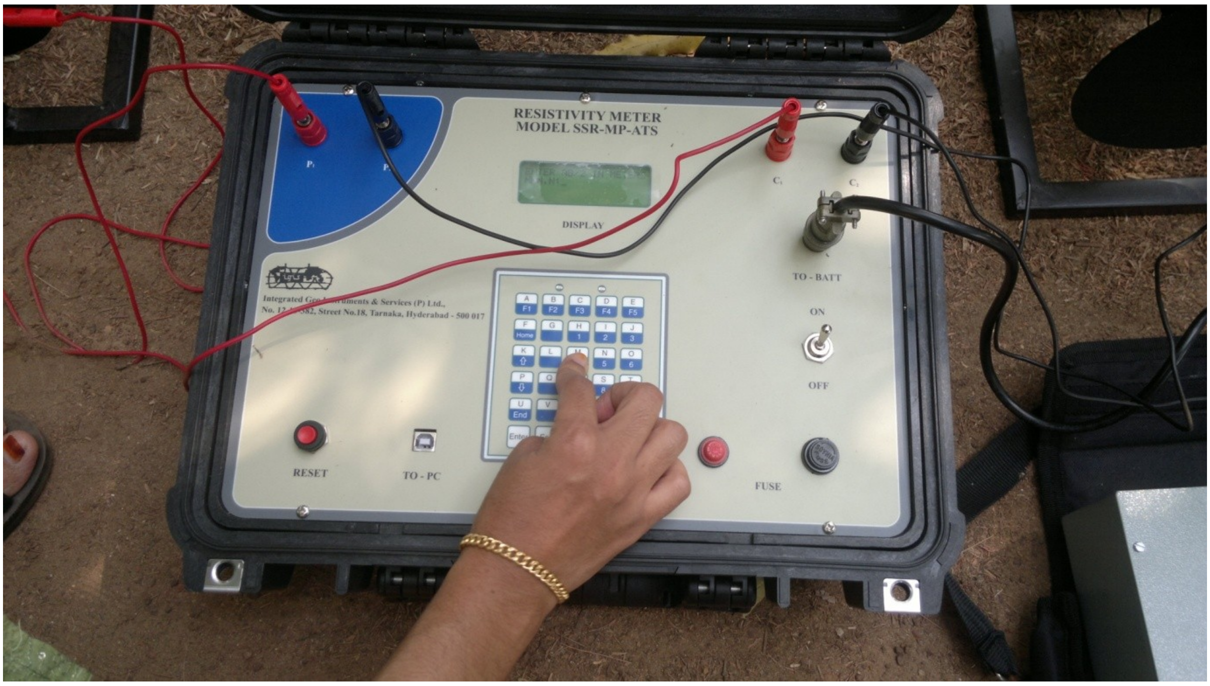


Plate 6: Measurement of resistivity

3.4.2 Measurement of resistivity

The connections made were checked for any possible defaults. The SSR- MP-ATS model resistivity meter was switched on and the reset button was pressed. We get the display as follows:

I.G.I.S [P] Ltd. RESISTIVITY METER MODEL SSR-MP-ATS

And the Display goes to the following main functions

F1: SET FUNCTIONS F2: MEASUREMENT F3: MEMORY OUT F4: DIRECT R VALUE

From the displayed options F1 was selected for entering the details of the location. The Display changes to

F1: VES F2: SET TIME

F3: CLEAR MEMORY

Again F1 was selected. When the following display was shown, the name of the location was typed in and ENT button was pressed. The display shows:

VES NUMBER: 001…….
PRESS ENT. TO CONT.

The VES number is displayed as 001 by default when the instrument is used for the first time or when the memory is cleared. The VES number is automatically incremented for the subsequent VESs. The ENT button was pressed then display shows:

ENTER AB/2 IN METERS
NNN.N:

Half of the distance between the current electrodes was entered as AB/2 and ENT button was pressed. For the first reading AB/2 was taken as three meters.

ENTER MN/2 IN METERS
NNN.N:

When the above display appeared, MN/2 i.e. half of the distance between the potential electrodes (one meter for first reading) was entered. As the ENT button was pressed the number of stacks for the measurement had to be entered.

NO. OF STACKS
NN:

Number of stacks can be taken up to a maximum of 16, so we selected four and ENT button was pressed. To confirm all the entered values, 'Y' for yes or 'N' for no had to be entered when the following display appeared.

CONFIRM Y/N

As ENT or Y key was pressed, the instrument goes to ‘measurement on’ mode.For any wrong entry of the above three parameters AB/2, MN/2 or number of stacks, ‘N’ has to be pressed so that the instrument goes back to AB/2 entry level. Enter the correct parameters and confirm the correctness by pressing ‘Y’. Then display shows:

MEASUREMENT ON

The display changes to;

¼ I = 100.32 mA
R = 12.32324 Ohms

First line in the above display indicates the current flowing in to the ground during First Stack (1/4) out the 4 stacks set. Second line shows the resistance in ohms.This display goes for the subsequent stacks (2/4, 3/4 and 4/4) till the maximum stacks set and each R value is the average of previous R value and present R value.

And after completing all the stacks, instrument finally shows R for resistance, RHOa for resistivity, d for depth of sounding and STRIP for strip resistivity. Depth referred here is equal to AB/3.

R = 12.32324
RHOa =
DEPTH =
STRIP =

Here, if the record is satisfactory ENT button was pressed to store the values in memory for further processing. Or else ESC was pressed when the instrument switches off automatically. Same procedure was followed for various electrode configurations with electrode spacing of 4m, 6m, 8m etc.

The whole data was transferred to PC by connecting the instrument to the computer through the USB cable. To transfer the complete data, the function for full data transfer is used and if only selected data is to be transferred, the alternative option called selective data transfer can be employed.

The data can be viewed on the Instrument's LCD or the data can also be transferred to PC installed with Inverse Slope Software (AT 3.0) for interpretation of VES. The data transferred to the computer is then studied and interpreted using VES Interpretation Software. The various types of lithologic formations can be identified on the basis of the obtained readings. These results have been discussed in detail in the following chapter.

3.5 Water table readings in wells

Water table readings of the open wells in the campus were also noted. The sites where the hydro-geophysical investigations were carried out were not so near to the open wells considered. The well readings were taken with an objective to correlate the values with the results obtained from the investigation. Readings were taken from five wells at various locations. The wells considered are located near KVK, farm office, the temple, dairy farm and well located near the road leading away from the temple. The well readings on different dates are furnished below:

Table 4: Well readings near KVK

DATE	READINGS
29-11-12	15.44
3-12-12	15.67
4-12-12	15.67
5-12-12	15.65
23-1-13	16.91

Table 5: Well readings near farm office

DATE	READINGS
29-11-12	4.05
3-12-12	4.05
4-12-12	4.1
5-12-12	4.67
23-1-13	4.08

Table 6: Well readings near dairy farm

DATE	READINGS
29-11-12	3.85
3-12-12	3.8
4-12-12	3.8
5-12-12	3.81

23-1-13	4.03

Table 7: Well readings near temple

DATE	READINGS
29-11-12	
3-12-12	3.64
4-12-12	3.63
5-12-12	3.64
23-1-13	4.25

Table 8: Well readings near the temple road

DATE	READINGS
29-11-12	
3-12-12	5.8
4-12-12	5.85
5-12-12	5.93
23-1-13	

RESULTS AND DISCUSSIONS

The present project has been undertaken with the following objectives;

1. To study the procedure for hydro-geophysical investigation of groundwater potential in KCAET campus
2. To obtain aquifer distribution within the study area
3. To delineate possible sites for drilling tube wells for sustainable water supply.

4.1 Hydro-geophysical investigation of groundwater potential

The geophysical observations were taken from 6 locations spread over the campus. The sites were identified on the basis of field observationsand chances of the occurrence of water. As the campus is mostly of lateritic terrain, chances for the occurrence of a phreatic water surface are minimum. However, certain points may be located where there is a chance for occurrence of ground water and feasibility for digging bore wells. Vertical electrical sounding using SSR-MP-ATS meter was conducted. Inverse slope curves were plotted using the VES Interpretation Software. Different types of formations were distinguished from the curve.

4.2 Aquifer distribution

Vertical electrical soundings were done at various locations in the campus. The sites where the investigations were carried are ground are given in the table below along with their respective geographical locations and elevations.

Table 4: Geographical locations and elevations of the sites

Site	Geographical location	Elevation (m)
Near volleyball court	10°51’07.81”N 75°59’09.67”E	24.7
Near workshop	10°51’06.87”N 75°59’13.75”E	23.8
Near canteen	10°51”09.94”N 75°59’12.21”E	27.4
Near flat	10°51’14.15”N 75°59’05.59”E	26.8
MH road	10°51’11.48”N 75°59’13.27”E	28.6
Farm road	10°51’21.48”N 75°59’15.76”E	8.54

The graph representing inverse slope curve are drawn with VES interpretation software for all the locations.

The soundings were done at the location near to the volleyball court. The inferred geo-electric sections and the layer details of the point are presented in the inverse slope curve shown in graph 1. The electric soundings to a depth of 32 meters were done. From the graph a three layered formation is found to have been present. The resistivity value for the first layer of thickness 8 meters was found to be 1200 ohm-m. Below that a layer of non- significant depth and of resistivity 9999 ohm-m was found to exist. The layer beneath extend to a depth of 8 meters with resistivity 261 ohm-m. Below that a layer was found to have a formation of 123 ohm-m resistivity. The upper three layers were identified as crystalline rock formations whereas the bottom layer was identified as weathered form. Since the profile is distinctly four layered and the bottom layer was to found have been extending to a depth of 16 meters, this layer may be identified as a confined aquifer. The formation is fractured and the chance of availability of water is high.

The inverse slope curve for the point near to the canteen was obtained. The graph showed crystalline rock formations of varying resistivity values. The resistivity values of the formation up to the initial depth of 14m were, 811 ohm-m up to 4 meters depth, 1364ohm-m to a depth of 4 to 6m, 750 ohm-m to a depth of 6 to 8 m, 492ohm-m to a depth of 8 to 12m, 270 ohm-m to a depth of 12 to 14m and weathered formation of resistivity 1270 ohm-m exists below 14 meter depth. This may yield a satisfactory discharge from the weathered formation which was found to be confined. The fractures present may make the aquifer suitable for ground water extraction.

The next VES was carried out and the inverse slope curve was obtained for the road connecting Bharathapuzha and the farm office. The initial geological formations were found to be loose soil with not much variation in resistivity values. The resistivity value for the upper 4 meter layer was 44 ohm-m whereas the layer beneath extending from 4 to 6 meters was 15 ohm-m. There exists a layer of un-significant depth with resistivity value of 34ohm-m at 4m depth. This may be a clay layer which may act as a confined layer. A 14 meters thick weathered formation with a resistivity value of 77 ohm-m was found to occur below this clay layer. So there is a good chance for obtaining groundwater by drilling tube wells. Below the weathered formation, a layer of sedimentary rock with resistivity 9999 ohm-m was found to occur.

The formations at the point near MH road were found to be basically a combination of crystalline and sedimentary rock formations extending up to 17m. The formations are fractured at depths of 11m, 12m, 14m, 16m and 18m. The weathered formation occurs between depths of 18m and 24m. Two layers of weathered formations were found: 18-20m, layer with resistivity 129 ohm-m and 20-24m with resistivity value 61 ohm-m. The formation beneath 24m was found to be crystalline rock of resistivity 2182 ohm-m. Since the weathered formation was found below the layers of crystalline and sedimentary formations, this may be considered as a confined aquifer. The aquifer thickness being 6 meters, it is thought to yield medium or appreciable discharges.

Near workshop, the electrical sounding could identify a 3-layered profile with crystalline rock formation extending to initial 4m depth. A weathered formation was found to exist at a depth of 4 to 18m. The formation below 18 meters was found to be sedimentary rock formation of very high resistivity values. The weathered formations may serve as a good confined aquifer. The thickness of the aquifer was 14 meters. The chances for getting appreciable discharges were high.

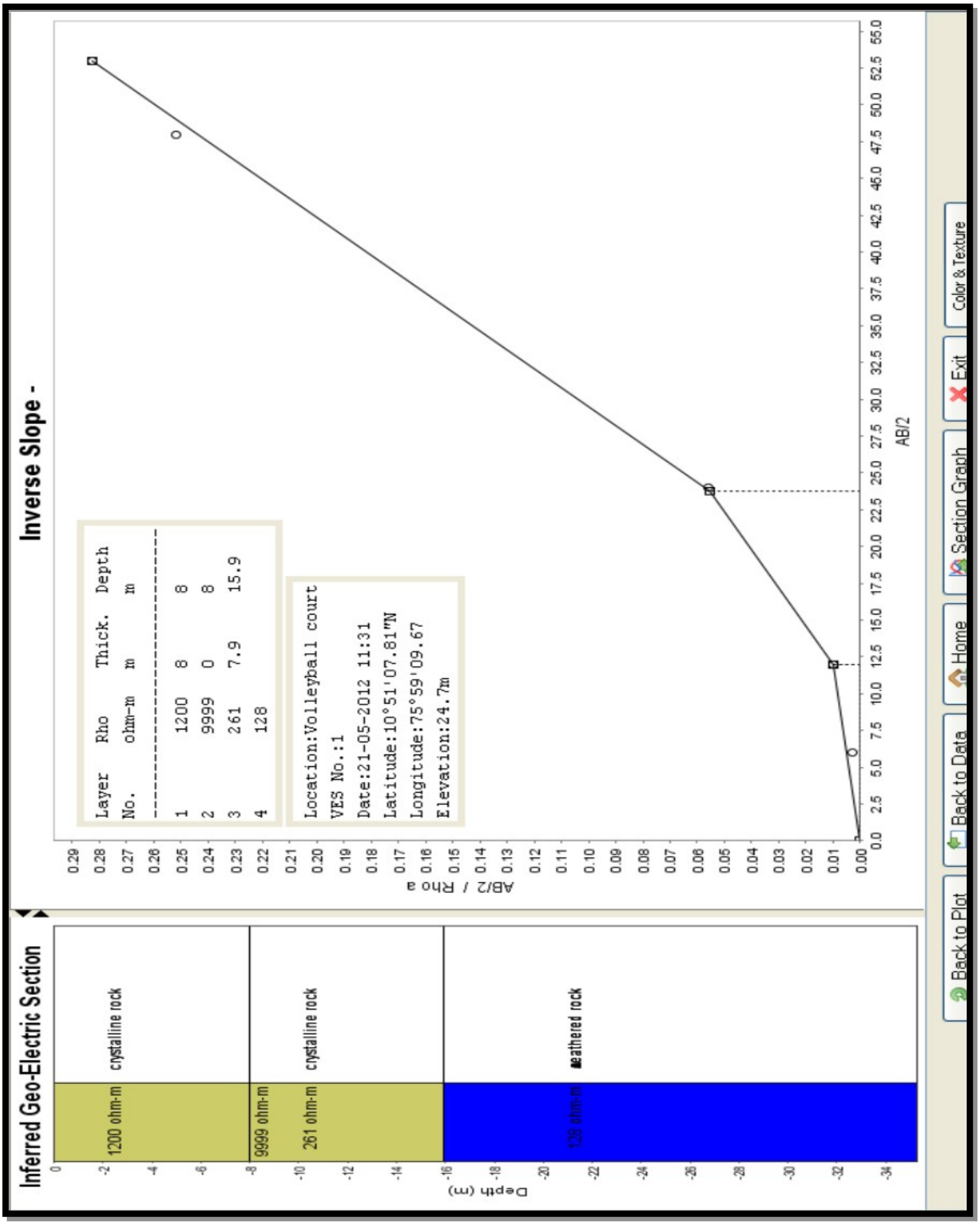
The area near to the flats was identified as high crystalline rock area. Even though a fracture occurs at a depth of 12.5 meters, the formations does not show any good change in quality. The area may not be suitable for wells.

4.3 Potential sites for drilling tube wells

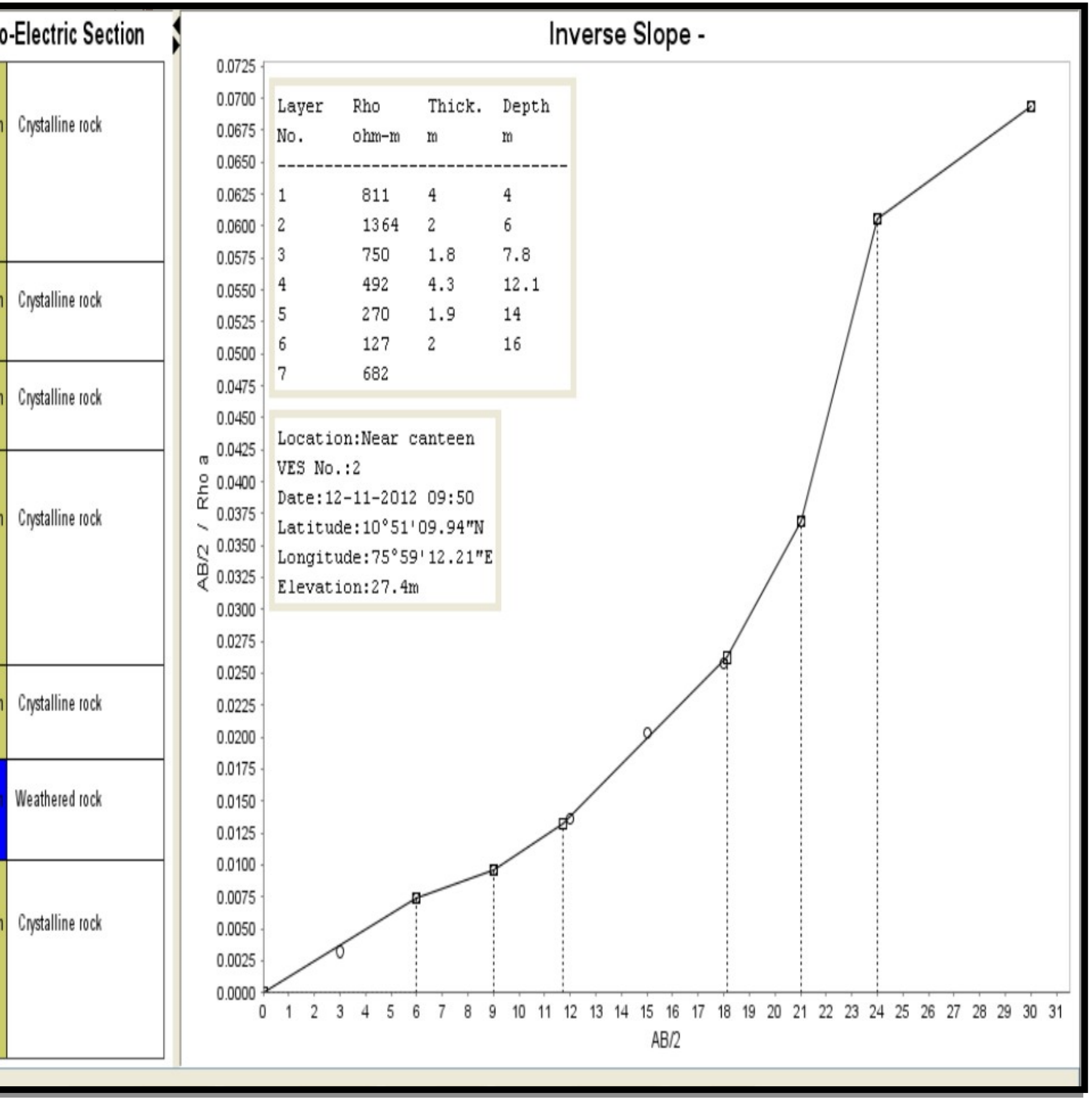
The hydro-geophysical survey conducted on the campus revealed that the formations were basically rocky. Appreciable amount of fracture and weathered formations could be found near to the workshop, near to the volleyball ground and near to the canteen. So the study reveals that there are three potential areas for drilling tube wells.

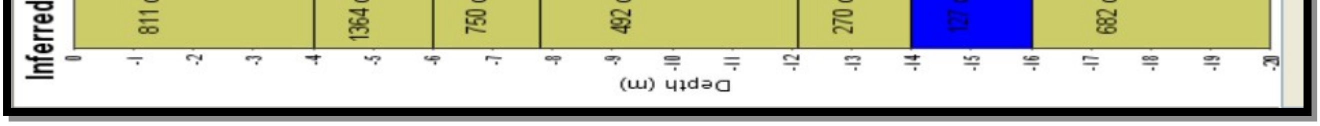
4.4 Correlation with the well readings

The well readings near KVK were compared with the results obtained from the hydo-geophysical investigation carried near men’s hostel. The water table from the well is found to lie at around a depth of 16 meters below ground surface. The result from the investigation shows that the weathered formation lies between the depths 18-20 meters. The well considered is almost 1.5-2 meters above the area where the investigation was done. So the results can be said to be converging to a common result.

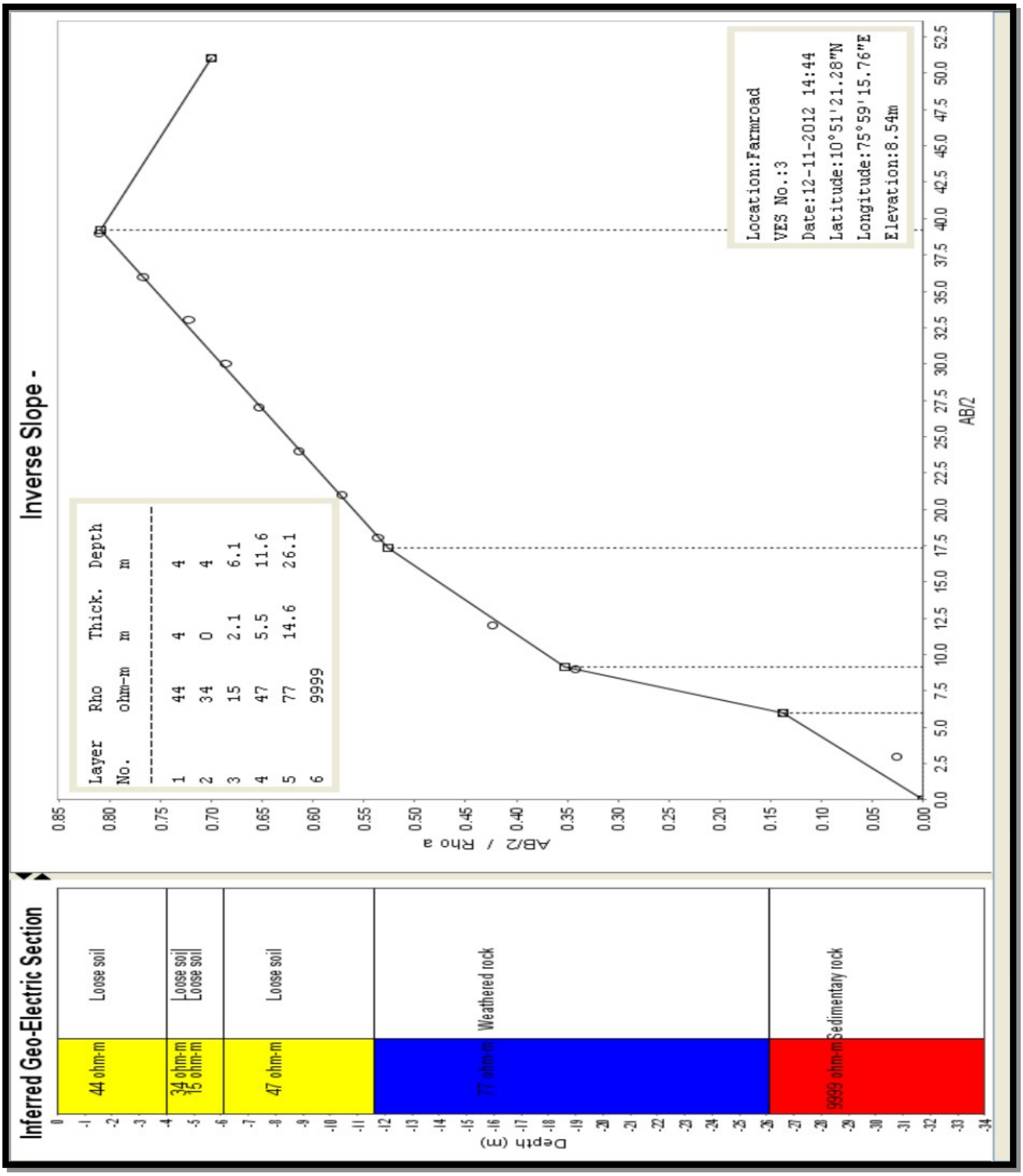


Graph 1: inverse slope curve (near volleyball court)

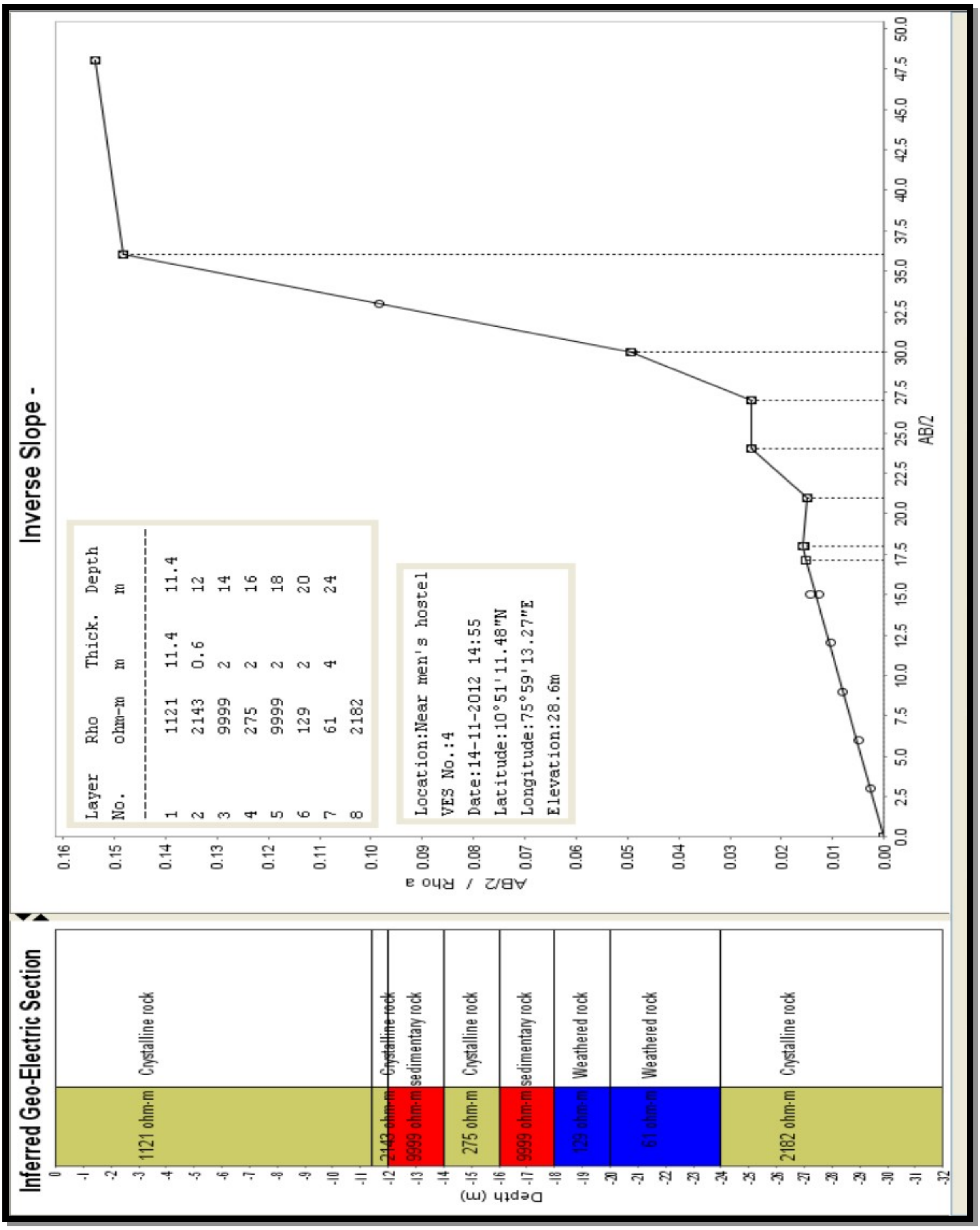

o-Electric Section
Crystalline rock
Crystalline rock
Crystalline rock
Crystalline rock
Crystalline rock
Weathered rock
Crystalline rock
Inverse Slope -
Layer No. | Rho ohm-m | Thick. m | Depth m
1 811 4 4
2 1364 2 6
3 750 1.8 7.8
4 492 4.3 12.1
5 270 1.9 14
6 127 2 16
7 682
Location:Near canteen
VES No.:2
Date:12-11-2012 09:50
Latitude:10°51'09.94"N
Longitude:75°59'12.21"E
Elevation:27.4m
AB/2 / Rho a
AB/2



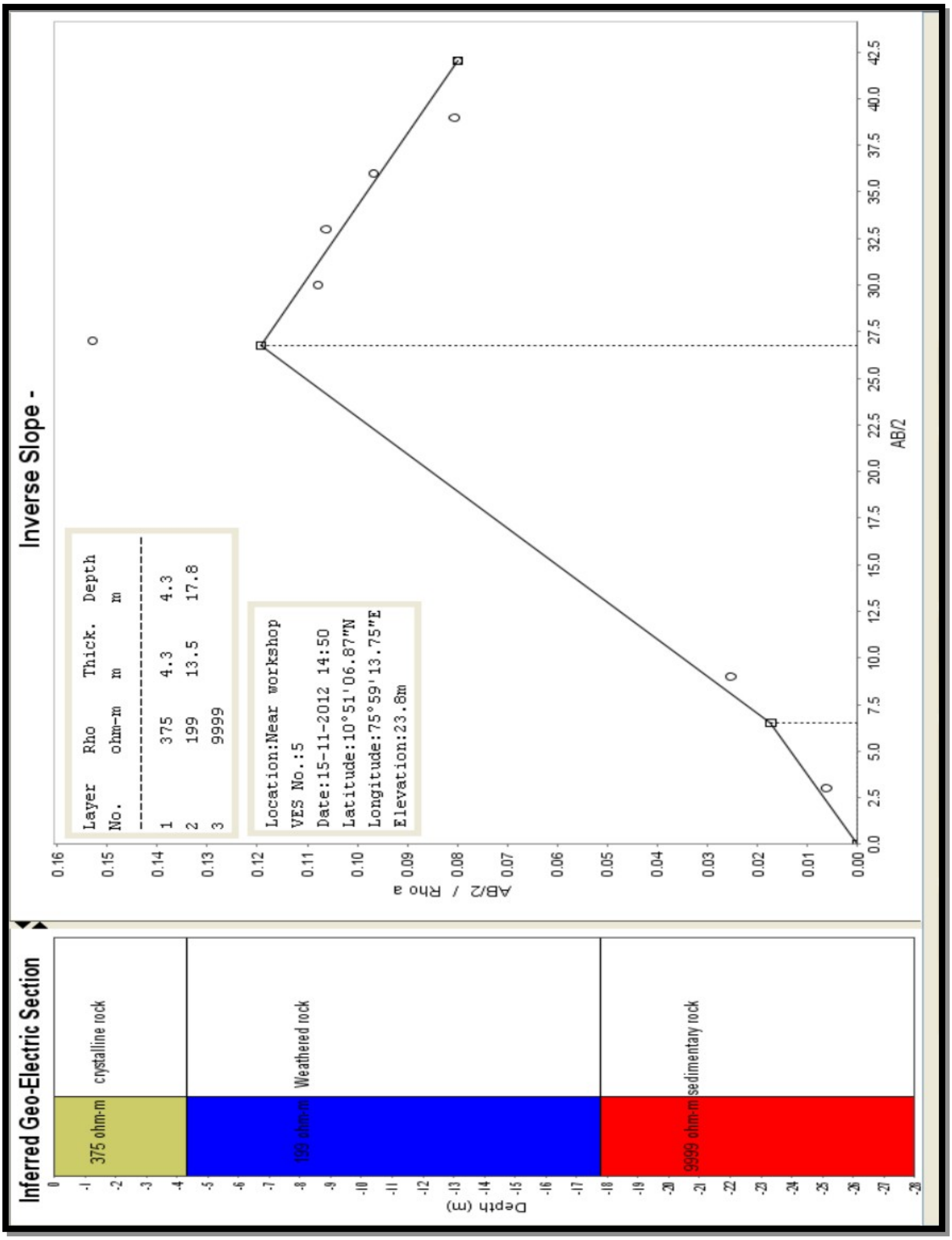
Graph 2: Inverse slope curve (near canteen)



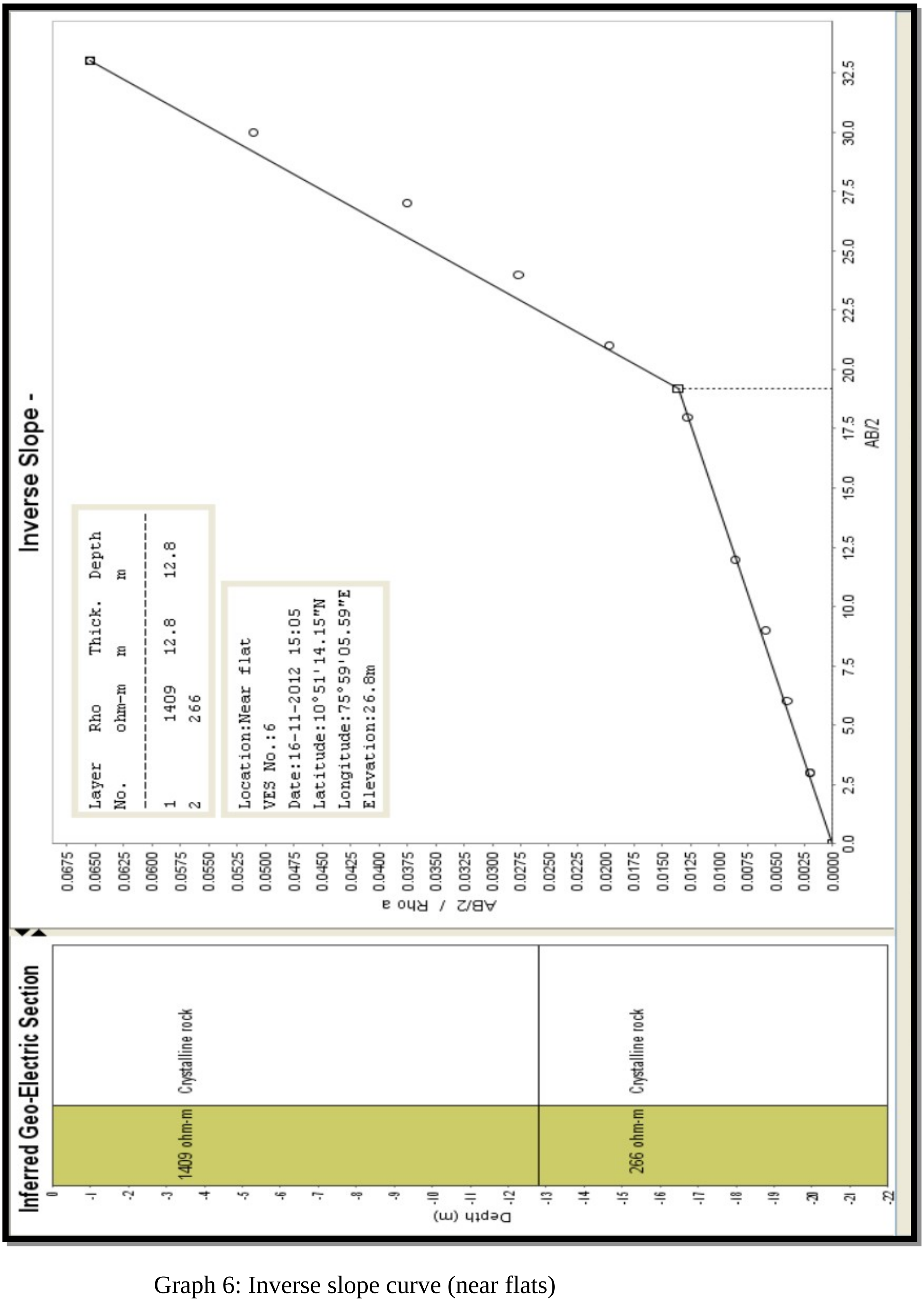
Graph 3: Inverse slope curve (near farm road)



Graph 4: Inverse slope curve (near men's hostel)



Graph 5: Inverse slope curve (near workshop)



Graph 6: Inverse slope curve (near flats)

SUMMARY AND CONCLUSION

The Electrical Resistivity method was used for the hydro-geophysical investigation of groundwater resources in KCAET campus so as to discover a sustainable source of water, to cater the various requirements of the campus. The main objectives of the present project were to study the procedure for hydro-geophysical investigation of groundwater potential in the campus; to obtain the aquifer distribution and to delineate all the sites where there is a scope for drilling tube wells. By this study, all possible sites in the campus were explored for the presence of ground water. The project could come to a positive conclusion, whereby potential areas for sustainable water supply were delineated. From the six locations under consideration, three of the locations revealed potential groundwater reserves which could be a good source of water to be explored. In one site, near to the Bharathapuzha River filter-point wells may be a possibility. The sites where appreciable discharge can be expected and where tube wells can be installed for groundwater extraction are namely: near to the workshop, near to the volleyball court and near to the canteen. So the present project has succeeded in fulfilling its primary objectives. Therefore, drilling of tube wells is suggested in the potential sites located.

The water table readings taken could be successfully correlated with the results of the hydro-geophysical investigation. And both the results could come to a single conclusion. So the investigation is thought to be accurate, as far as our knowledge is concerned.

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ABSTRACT

The electrical resistivity method is being employed for hydro geophysical investigation of groundwater. This technique will provide an insight into the nature of subsurface formations. Wenner configuration of electrode arrangement is mostly practiced the resistivity observations. Resistivity observations were taken with vertical electrical sounding (VES). An estimate of the resistivity and thickness of various subsurface layers at a location could be obtained by successively increasing electrode spacing. The inverse of the resistance measured 1/R was plotted against Wenner electrode separation on a linear graph. Even thin layers at deeper layers could be detected. IGIS signal stacking resistivity meter model SSR-MP-ATS was used to obtain the pattern of aquifer distribution in KCAET campus and to delineate possible sites for drilling tube wells. The subsurface formations in the campus were found to be basically rocky. But certain areas like near the volley ball court (location), near the carpentry workshop, near canteen, near men's hostel, confined aquifers of weathered rock formation could be seen. A confined aquifer with a thickness of 13 meters and resistivity 199 ohm-m extending from 4 to 17meters was observed near the carpentry workshop. Weathered formations of resistivity 123 ohm-m was obtained at a depth of 16m near volleyball court. The area near the farm office was found as potential sites for filter point tube wells. No water bearing formations could be identified along the western boundary of the campus were the residential buildings are located. The water scarcity in the campus can thus be overcome by utilizing the ground water available at the potential areas identified in this work.