A HYDRO-GEOPHYSICAL INVESTIGATION OF GROUNDWATER BY ELECTRICAL PROFILING

by

AFTHAB SAEED P.P

FASLUDEEN N.S

PROJECT REPORT

Submitted in partial fulfillment of the requirement for the degree of

BACHELOR OF TECHNOLOGY
IN
AGRICULTURAL ENGINEERING

Faculty of Agricultural Engineering and Technology
Kerala Agricultural University

Department of Land and Water Resources & Conservation Engineering

KELAPPAJI COLLEGE OF AGRICULTURAL ENGINEERING AND TECHNOLOGY

TAVANUR- 679573, MALAPPURAM

KERALA, INDIA

January 2014

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ABSTRACT

Groundwater is water that exists in the pore spaces and fractures in rocks and sediments beneath the earth's surface. The Electrical Resistivity method was used for the hydro-geophysical investigation of groundwater resources in coconut garden of Horticulture College so as to discover a sustainable source of water, to meet the various requirements of the campus. The main objectives of the present project were to conduct hydro-geophysical investigation of groundwater potential and to obtain aquifer distribution within the study area in order to delineate possible sites for drilling tube wells for irrigation water supply. A special technique called 'Resistivity Scanning' is found to successfully delineate the fractured geometry of formation. This technique will provide an insight into the nature of subsurface formations. Wenner configuration of electrode arrangement is mostly practiced for 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.

From the eight locations under consideration, none of the locations could serve as potential groundwater sources. By the analysis of 2 -D cross-section of strip resistivity ,to identify site favourable for recharge structure, we can arrive at the conclusion that a continuous soil layer of average depth 10 m was observed at the top.Major portion of area was occupied by a continuous layer of crystalline rock formation which extended up to 80m depth. Beyond crystalline rock, there was a layer of continuous metamorphic formation which could not provide sufficient water. By this study, all possible sites in the coconut garden were explored for the presence of ground water. The project could come to a conclusion that, potential areas for sustainable water supply were not available in the coconut garden.

I. INTRODUCTION

Water is a liquid at standard ambient temperature and pressure, but it often co-exists on earth with its solid state, ice, and gaseous state, steam (water vapor). Water covers 71 % of the earth's surface, and is vital for all known forms of life. On earth, 97 % of the planet's water is found in seas and oceans, 1.7 % in groundwater, 1.7% in glaciers and the ice caps of Antarctica and Greenland, a small fraction in other large water bodies, and 0.001 % in the air as vapor, clouds (formed of solid and liquid water particles suspended in air), and precipitation. Only 3 % of the earth's water is fresh water, and 98.8 % of that water is in ice and groundwater. Less than 0.3 % of all freshwater is in rivers, lakes, and the atmosphere, and an even smaller amount of the earth's freshwater (0.003 %) is contained within biological bodies and manufactured products.

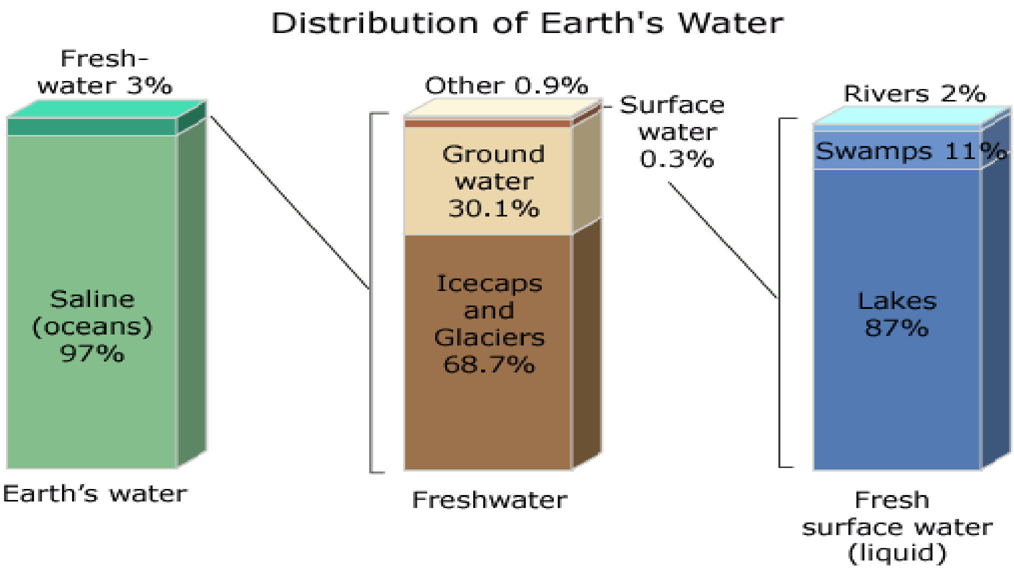


Fig.1.1 Distribution of earth's water.

The water cycle (known scientifically as the hydrologic cycle) refers to the continuous exchange of water within the hydrosphere, between the atmosphere, soil water, surface water, groundwater, and plants. Water moves perpetually through each of these regions in the water cycle consisting of following transfer processes:

1. Evaporation from oceans and other water bodies into the air.
2. Transpiration from land plants and animals into air.
3. Precipitation, from water vapor condensing from the air.
4. Runoff from the land usually reaching the sea.

Most water vapor over the oceans returns to the oceans, but winds carry water vapor over land at the same rate as runoff into the sea, about 47 Tt per year. Over land, evaporation and transpiration contribute another 72 Tt per year. Precipitation, at a rate of 119 Tt per year over land, has several forms : most commonly rain, snow, and hail, with some contribution from fog and dew. Dew is small drops of water that are condensed when a high density of water vapor meets a cool surface. Dew usually form in the morning when the temperature is the lowest, just before sunrise and when the temperature of the earth's surface starts to increase. Condensed water in the air may also refract sunlight to produce rainbows.

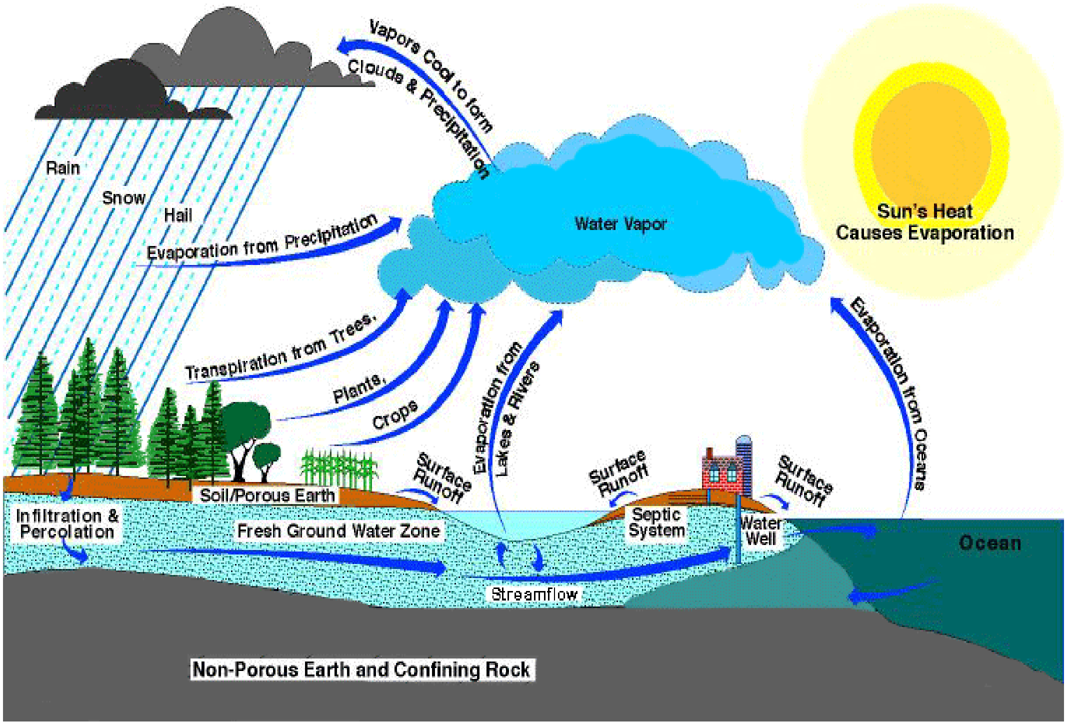


Fig.1.2 Schematic representation of hydrologic cycle.

Water runoff often collects over watersheds flowing into rivers. A mathematical model used to simulate river or stream flow and calculate water quality parameters is hydrological transport model. Some of water is diverted to irrigation for agriculture. Rivers and seas offer opportunity for travel and commerce. Through erosion, runoff shapes the environment creating river valleys and deltas which provide rich soil and level ground for the establishment of population centers.

A flood occurs when an area of land, usually low-lying, is covered with water. It is when a river overflows its banks or flood from the sea. A drought is an extended period of months or years when a region notes a deficiency in its water supply. This occurs when a region receives consistently below average precipitation.

Groundwater is the water located beneath the earth's surface in soil pore spaces and in the fractures of rock formations. A unit of rock or an unconsolidated deposit is called an aquifer when it can yield a usable quantity of water. The depth at which soil pore spaces or fractures and voids in rock become completely saturated with water is called the water table. Groundwater is recharged from, and eventually flows to, the surface naturally; natural discharge often occurs at springs and seeps, and can form oases or wetlands. Groundwater is also often withdrawn for agricultural, municipal, and industrial use by constructing and operating extraction wells. The study of the distribution and movement of groundwater is hydrogeology, also called groundwater hydrology. Groundwater makes up about twenty percent of the world's fresh water supply, which is about 0.61% of the entire world's water, including oceans and permanent ice. Global groundwater storage is roughly equal to the total amount of freshwater stored in the snow and ice pack, including the north and south poles. This makes it an important resource that can act as a natural storage that can buffer against shortages of surface water, as in during times of drought.

Groundwater is naturally replenished by surface water from precipitation, streams, and rivers when this recharge reaches the water table. Groundwater can be a long-term 'reservoir' of the natural water cycle (with residence times from days to millennia), as opposed to short-term water reservoirs like the atmosphere and fresh surface water (which have residence times from minutes to years).

Recent research has demonstrated that evaporation of groundwater can play a significant role in the local water cycle, especially in arid regions. Typically, groundwater is thought of as liquid water flowing through shallow aquifers, but, in the technical sense, it can also include soil moisture, permafrost (frozen soil), immobile water in very low permeability bedrock, and deep geothermal or oil formation water. Groundwater is hypothesized to provide lubrication that can possibly influence the movement of faults. It is likely that much of the earth's subsurface contain some water, which may be mixed with other fluids in some instances. Groundwater may not be confined only to the earth. The formation of some of the landforms observed on Mars may have been influenced by groundwater. There is also evidence that liquid water may also exist in the subsurface of Jupiter's moon Europa.

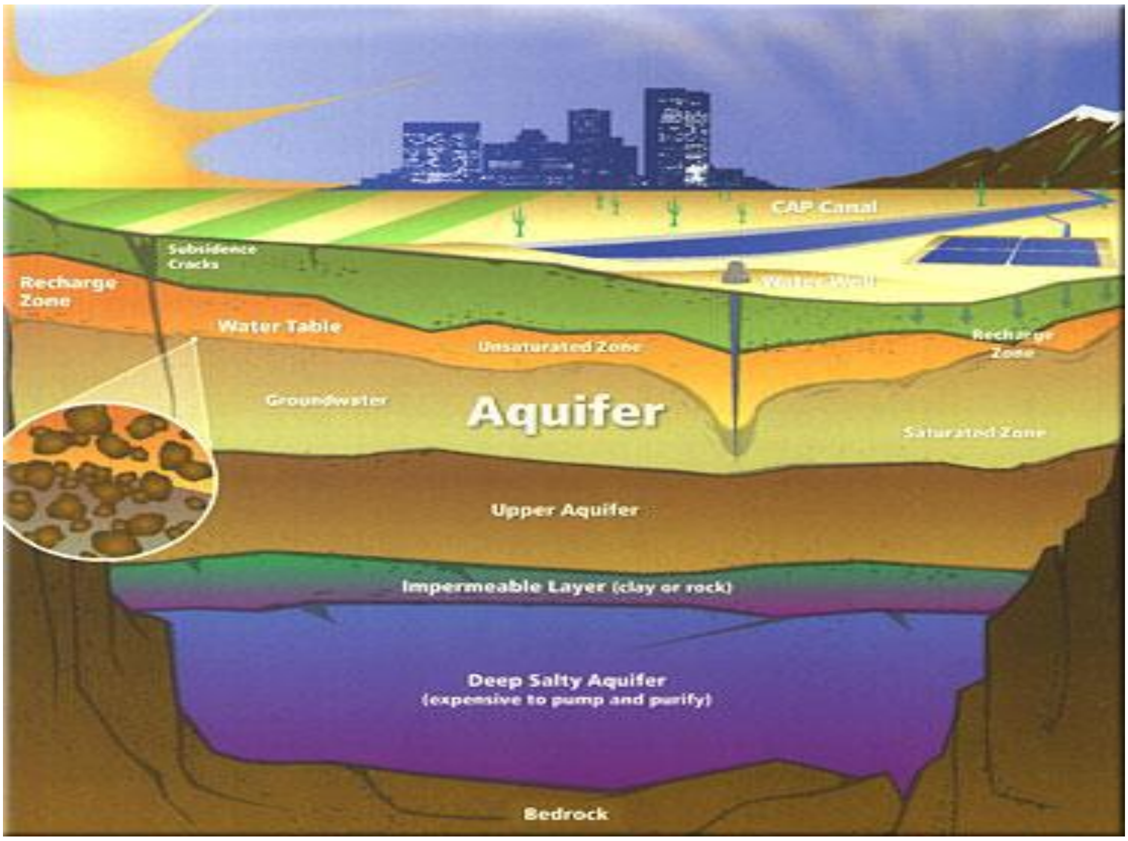


Fig.1.3 Schematic cross-sections of aquifer types.

An aquifer is a layer of porous substrate that contains and transmits groundwater. When water can flow directly between the surface and the saturated zone of an aquifer, the aquifer is unconfined. The deeper parts of unconfined aquifers are usually more saturated since gravity causes water to flow downward.

The upper level of this saturated layer of an unconfined aquifer is called the water table or phreatic surface. Below the water table, where in general all pore spaces are saturated with water, is the phreatic zone.

Substrate with low porosity that permits limited transmission of groundwater is known as an aquitard. An aquiclude is a substrate with porosity that is so low it is virtually impermeable to groundwater.

A confined aquifer is an aquifer that is overlain by a relatively impermeable layer of rock or substrate such as an aquiclude or aquitard. If a confined aquifer follows a downward grade from its recharge zone, groundwater can become pressurized as it flows. This can create artesian wells that flow freely without the need of a pump and rise to a higher elevation than the static water table at the above unconfined aquifer.

The characteristics of aquifers vary with the geology and structure of the substrate and topography in which they occur. In general, the more productive aquifers occur in sedimentary geologic formations. By comparison, weathered and fractured crystalline rocks yield smaller quantities of groundwater in many environments. Unconsolidated to poorly cemented alluvial materials that have accumulated as valley-filling sediments in major river valleys and geologically subsiding structural basins are included among the most productive sources of groundwater.

The high specific heat capacity of water and the insulating effect of soil and rock can mitigate the effects of climate and maintain groundwater at a relatively steady temperature. In some places where groundwater temperatures are maintained by this effect at about 10°C (50°F), groundwater can be used for controlling the temperature inside structures at the surface. For example, during hot weather relatively cool groundwater can be pumped through radiators in a home and then returned to the ground in another well. During cold seasons, because it is relatively warm, the water can be used in the same way as a source of heat for heat pumps that is much more efficient than using air.

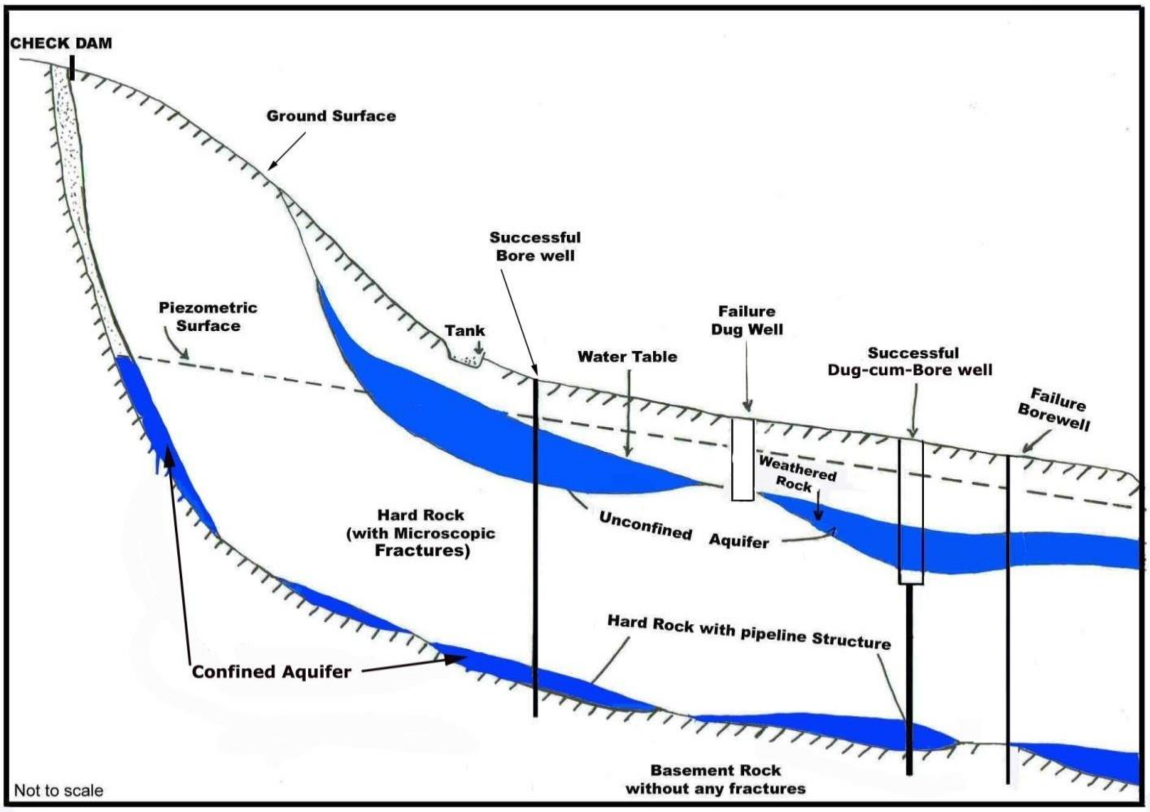


Fig.1.4 Ground water distributions.

Although groundwater cannot be seen on the earth's surface, a variety of techniques can provide information concerning its occurrence and under certain conditions even its quality. Surface investigations help us in finding the information about the type, porosity, water content and compactness of subsurface formation. It is generally done with the aid of electrical and seismic properties of earth and without any drilling on the surface. The information supplied by these techniques is partially reliable and involve less expenditure. It provided only indirect indications of groundwater so that underground hydrologic data must be inferred from surface investigations. Correct interpretations require supplementary data from sub surface investigations to substantiate surface findings. It is mainly achieved by the geophysical method viz., electrical resistivity & seismic refraction method.

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 resistivity in these regions.

1.1 SOIL COMPOSITION AND RESISITIVITY

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

Table 1. Resistivity values of earth materials, Ohm-m

COMPOSITION	RESISTIVITY
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. Similar to the earth formations, the resistivity values of different types of water also differ from each other. It shows variations according to the geologic factors and the formations in which the water exist. Some of these resistivity values are shown in Table 2.

Table 2. Resistivity values of different types of water, Ohm-m

DIFFERENT TYPES OF WATER	RESISTIVITY
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

Both porous and non porous rocks behave as insulators until they are in dry condition. Resistance decreases with increase in pore water. Unconsolidated material has more resistance than compacted material of same composition. Sedimentary rock has better conductance i.e. lesser resistance than igneous rocks. Clay has higher conductivity than sand because of presence of iron cluster on surface of the clay. Based on this knowledge from resistivity survey it is possible to distinguish between major rock group and the water bearing zones.

The Electrical Resistivity method has been used for the geophysical investigation of groundwater in coconut garden of college of horticulture, Vellanikkara. The present project has been undertaken with the following objectives;

1. To conduct hydro-geophysical investigation of groundwater potential at the coconut garden of College of Horticulture, Vellanikkara.
2. To obtain aquifer distribution within the study area.
3. To delineate possible sites for drilling tube wells for irrigation water supply.

II. REVIEW OF LITERATURE

2.1 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.

2.1.1 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 studies of salt water contamination in fresh water layers, landslide monitoring, mineral exploration and archaeological research.

2.1.2 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 □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.

2.1.3 SYSCAL 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.

2.1.4 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

2.2 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) Aquifer properties.
2) Groundwater exploration
    (i) In basement terrains
    (ii) In hard rock areas
3) Groundwater recharge estimation.
4) Lithology and groundwater quality.

2.2.1 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.

Hadi and Gholam (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.

Ayoola (2013) studied about Quantitative Use of Surface Resistivity Data for Aquifer Hydraulic Parameter Estimation .Results pointing out the presence of different physical behavior controlling the relationship between hydraulic conductivity, K, and electrical resistivity, ρ are made known. Surface resistivity data can be important quantitative estimator of aquifer hydraulic parameter and geometries when correctly used in aquifer characterization studies. It is needful when using surface resistivity data to consider: 1) the nature of the aquifer (clay content); 2) the saturation; 3) the physical basis of the correlation; 4) the possibility of false correlation.

2.2.2 Groundwater exploration studies

Mohammad (1975) conducted a feasibility study to locate groundwater sources using 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 2D resistivity 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 of 30 ± 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 hydro-geophysical 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.

Austin *et al.* (2013) conducted Geo electrical studies for the delineation of potential groundwater zones at Oduma in Enugu State, Southeastern Nigeria. This work evaluates the use of geo electrical method in the delineation of potential groundwater zones at Oduma. Thirteen (13) vertical electrical soundings (VES) were carried out within the study area. Interpretated VES data shows predominance of Q and H curve type, indicating a fracture-shale subsurface. Contour maps of iso-resistivity, depth, transverse resistance, longitudinal conductance, aquifer transmissivity and hydraulic conductivity were constructed. Computed aquifer transmissivity from VES data values indicates a low yield aquifer. The latter was used to delineate the potential groundwater zones based on Gheorge aquifer transmissivity classifications. Three potential groundwater zones were delineated; the low, very low and negligible potential zones.

Kurien *et al.* (2013) The electrical resistivity method is being employed for hydro geophysical investigation of groundwater. Wenner configuration of electrode arrangement with vertical electrical sounding (VES) is mostly practiced. IGIS signal stacking resistivity meter model SSR-MP-ATS was used to obtain the pattern of aquifer distribution in selected lateritic terrain and to delineate possible sites for locating aquifers. 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.

2.2.2.1 *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.

Kehinde Ishola *et al*. (2013) Assessed Groundwater Potential Zones in Basement Complex Terrain Using Resistivity Depth Soundings and to delineate groundwater potential zones in basement .methodology was total of forty Vertical Electrical Soundings (VES) were conducted along five traverses in Challenge and Oluyole localities in Ibadan (southwestern Nigeria) using a Schlumberger electrode array with maximum half electrode spacing of 150m. Measurements were acquired using JAK 6000 Terrameter. The field curves obtained from the soundings were interpreted using partial curve matching and iteratively by WinGlink computer software with output as one -dimensional sounding curves showing resistivity and depth of the subsurface layers. Results delineated three to four geo-electric layers. These include the surface layer topsoil , an intercalation of clay and sand, the weathered and fractured basements constituting the aquifer with thickness of about 6.9 to 11.9m and the fresh bedrock, characterized by resistivity value of 780 to 970 Ohm-m. The geo-electric sections and the iso-pach maps of the overburden revealed areas of thin and thick overburdens. The areas of thick overburden (materials above the bedrock) are priority areas for possible groundwater developments. The conclusion was the groundwater potential is relatively high for exploitation.

2.2.2.2 *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.

Anomohanran (2013) carried out geophysical investigation was carried out in Oleh, Nigeria to assess the groundwater condition of the area. The method employed in this study was the Vertical Electrical Sounding (VES) technique using the Schlumberger configuration. The data obtained were interpreted by computer iteration process and results when compared with lithologic log from existing borehole indicate a four layered formation. Analysis of this layer revealed that this aquifer is unconfined and prone to pollution since it underlay's a loose sand and very thin clayey sand formation. The second aquifer located in the forth layer is a viable portable water formation whose resistivity values ranged between 416.7 and 1459.2 Ωm. The thickness of the aquifer was found to range between 12.0 and 14.9 m while the depth was between 12.8 and 28.7 m. Boreholes for potable groundwater are therefore recommended within the forth layer.

Rai *et al* (2013) studied on Electrical resistivity tomography for groundwater exploration in a granitic terrain in NGRI campus, Hyderabad. Withdrawal of groundwater for domestic uses has increased several folds causing continuous lowering of the water table in and around the campus. Due to this changed scenario, availability of groundwater to meet the requirement of CSIR-NGRI is drastically reduced .This communication presents the results of electrical resistivity tomography (ERT) carried out in the CSIR-NGRI premises to locate potential groundwater resources as well as choose suitable sites for artificial recharging of aquifer. Groundwater potential zone identified by ERT is verified at one site by drilling a bore well.

2.2.3 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.

2.2.4 Lithology 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.

Olawepo *et al*. (2013) Evaluated Groundwater Potential and Subsurface Lithologies in Unilorin Quarters Using Resistivity Method .The Schlumberger array of the electrical resistivity method was used to sound a total of six VES points within premises of the Senior Staff-Quarters of the University of Ilorin in Ilorin, Kwara State, Nigeria. The objective was to evaluate the groundwater potential and to delineate the subsurface lithology of the area. The results obtained from the sounding were then analysed to determine the aquifers in the zone. It can be deduced from the result of the interpretation that the test site has at least four major Lithologic layers with the topmost layer (topsoil) majorly laterite, the second layer being clay/sand, the third being weathered basement and the fourth layer being fractured basement. The aquifer in the area is located mostly within the fractured basement found at a depth ranging from 16.8 m to 88.6 m. The average depth to the aquifer is 50.0 m. The protective capacity of the overburden showed that 16.67% of the study area has poor protective capacity, 50% weak protective capacity and 33.33% moderate protective capacity. This suggests that the area is a fair aquifer zone but the fractured basement containing the groundwater is not prone to surface and near-surface contaminants.

III. MATERIALS AND METHODS

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 coconut garden of College of Horticulture, Vellanikkara.

3.1 GROUNDWATER EXPLORATION STUDY

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 current electrodes. 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. The actual current flow is highly influenced by conductive layers, the value measured is known as the “apparent resistivity”. It represents 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.

Plate 1. Coconut garden.

3.2 GENERAL DESCRIPTION

Kerala Agricultural University (KAU) is the primary and the principal instrumentality of the Kerala state in providing human resources, and skills and technology, required for the sustainable development of its agriculture, defined broadly encompassing all production activities based on land and water, including crop production (agriculture), forestry through conducting, interfacing and integrating education, research and extension in these spheres of economic endeavour. It is located almost in the middle of the state at Vellanikkara in the Thrissur District at a latitude 10^0 32' N 76^0 16' E and 22.5m above MSL. The headquarters of KAU is easily accessible by road, rail and air as it is situated on the National Highway (NH47) at about 13 km from the Thrissur Railway Station and 50 km from the International Airport, Kochi.

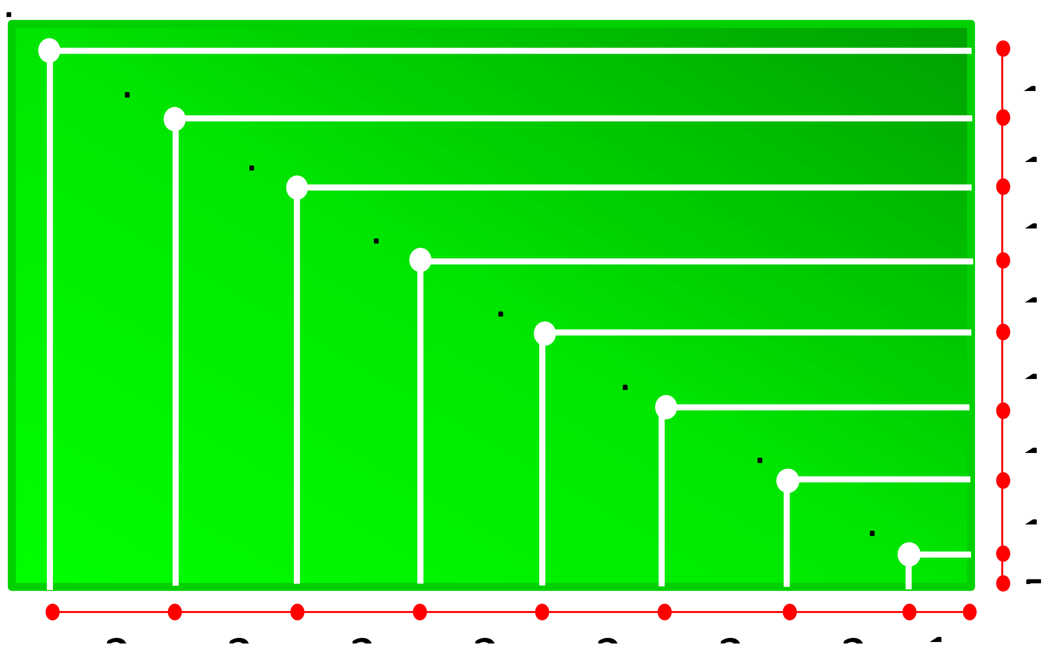
The College of Horticulture is a constituent college of Kerala Agricultural University, situated in Thrissur of Kerala state in India. The College of Horticulture imparts agricultural education at undergraduate, graduate and doctoral levels. The college has 16 departments and 7 centres undertaking the multiple activities of teaching, research and extension. The college is located in the picturesque central campus. 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.

High yielding coconut varieties of the department of plantation crops occupy an area of 15136 m^2. Continuous irrigation of the crops could not be taken up due to non availability of sufficient quantity of water. The Vellanikkara stretch of land is characterised by water scarcity, but suitable local sites could be identified for constructing tube wells. A method of electrical resistivity profiling was carried out to identify any suitable potential sites for the construction of tube wells.

To start with, the various locations in the coconut garden 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 many new features.

3.2.1 Locations for study

Fig.3.1 gives us the overall view of coconut garden of College of Horticulture, Vellanikkara. The LOCATION 1 was selected near to one of the corner of coconut garden. It was at five meters and 10 meters away from both the adjacent boundaries. Remaining locations were selected diagonally towards the opposite corner of the garden so that the LOCATION 2 remains at 15 m and 30 m away from the respective boundaries. Similarly all the remaining six locations were also identified so that the entire coconut garden could be investigated properly. The graph representing inverse slope curve were drawn with VES interpretation software for all the locations.



(All dimensions are in metres)

Fig.3.1 Site map

The sites selected for study are clearly depicted in the above map. The sites chosen were named as follows;

1. LOCATION 1
2. LOCATION 2
3. LOCATION 3
4. LOCATION 4
5. LOCATION 5
6. LOCATION 6
7. LOCATION 7
8. LOCATION 8

All the selected areas were not easily accessible. 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.

3.3 ELECTRICAL 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 is the ratio between the potential difference (ΔV) and the current (I) is called apparent resistance. It depends on the electrode arrangement and on the resistivity of the subsurface formations.

3.3.1 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

3.3.1.1 *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})

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

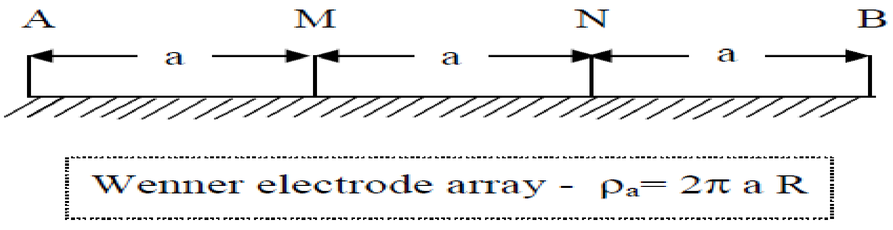
Fig.3.2 Wenner electrode arrangement.

3.3.1.2 ***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.

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

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



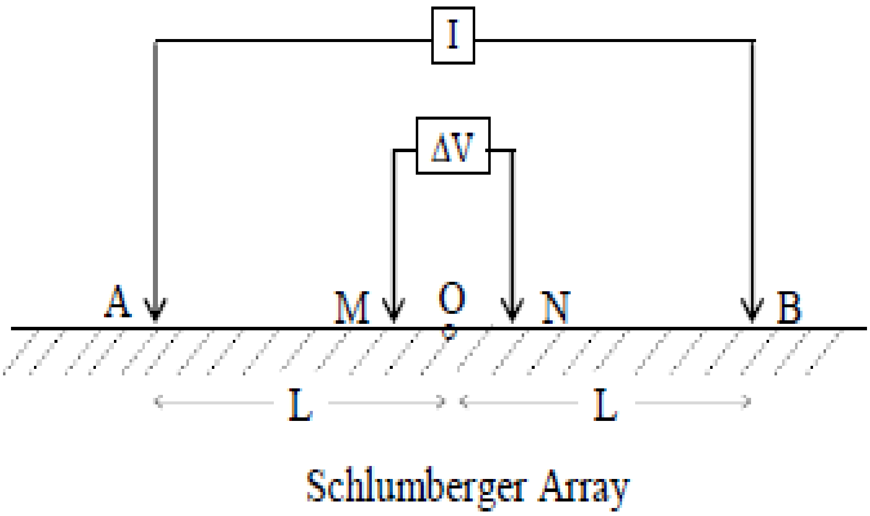


Fig.3.3 Schlumberger electrode array.

3.4 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

3.4.1 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.

3.4.2 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.

3.5 CONVENTIONAL DATA ACQUISITION AND 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.

3.6 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.

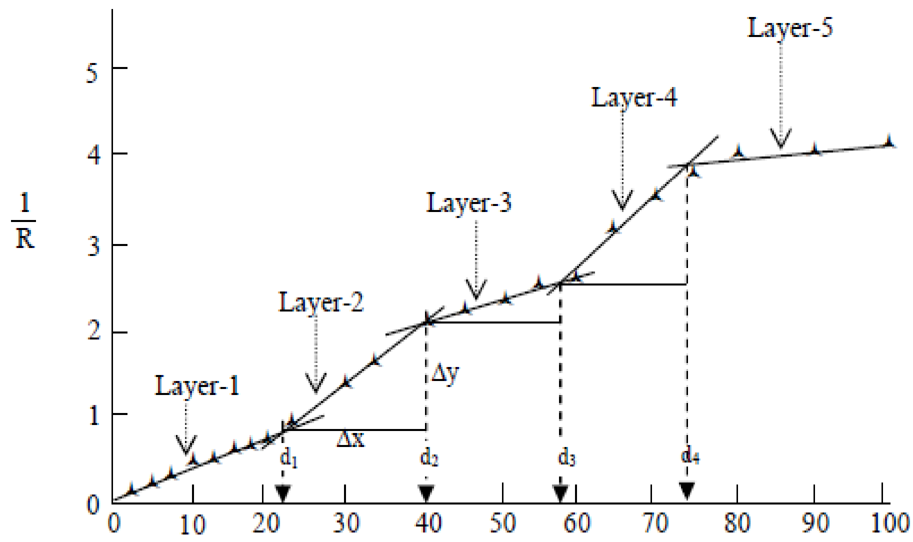
3.7 INVERSE SLOPE METHOD

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:

Slope of line segment = $\Delta y / \Delta x = (1/R) / a$

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



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

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').

Fig.3.4 Inverse slope method.

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 modifications. The procedure of interpretation for both these soundings is described in Table 3.

Table 3. Procedure for interpretation of Wenner and Schlumberger soundings.

Step	Wenner sounding	Schlumberger sounding
1	Calculate ($1/2\pi R$) or (a/ρ_a) depending upon which value is available for each observation.	Calculate the value ($(AB/2)/\rho_a$) for each observation.
2	Plot the values ($1/2\pi R$) or (a/ρ_a) on Y-axis against the electrode separation 'a' on the X-axis on a linear graph sheet.	Plot ($(AB/2)/\rho_a$) 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 ($1/2\pi R$) 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 ($(AB/2)/\rho_a$).
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 important things to be kept in mind is that;

1. The detectability of thin layers at deeper levels depends on density of data. More the data density better is the detectability.

2. More the resolution of the resistivity meter better is the possibility of detecting thin layers at depths.

3.8 RESISTIVITY SCANNING

3.8.1 Introduction

Exploration of groundwater resources in hard rock terrains is a difficult task as the thickness of water bearing fracture zones are very small and their extent is not uniform. It is quite common in hard rock terrains that two wells located a few meters away from each other give different yields, sometimes one being totally dry while the other with good yield. Small fractures, which yield most of the water to the wells in hard rock, are not detectable by conventional electrical resistivity surveys due to inherent limitations. A special technique called 'Resistivity Scanning' is found to successfully delineate such fracture geometry. The pattern and distribution of fractures in hard rocks is highly complex. Identification of fracture zones through geological and geophysical surveys is of primary importance for selecting well sites in hard rock terrains, which cover 70% of Indian subcontinent. Extreme variations of lithology and structure, coupled with highly localized water producing zones, make geological and geophysical exploration difficult in hard rock terrains. Hard rocks, in general, do not possess any primary porosity and development of secondary porosity, therefore, depends on the weathering and fracturing, which are controlled by the topography, lithology, structure and climate. Generally, hard rocks possess two distinct water bearing zones – weathered zones at shallow depths and fracture zones at deeper levels. The extent of weathering and fracturing as well as the nature of weathered products together determine the availability of ground water. The depth of weathering in majority of the rocks is confined to 10 to 15m forming shallow aquifers. Bore wells in weathered zones are, in general, considered to be failures with meagre yields due to low permeability of the weathered zones. Therefore, open wells are popular structures in these zones, which provide storage for the slow percolating groundwater. Fractured rocks yield better quantities of water to the wells. Fractures are formed during cooling of igneous, and metamorphic rocks, and also due to tectonic disturbances such as folding and faulting. Igneous and metamorphic rocks are characterized by nearly vertical or high angle fractures, but occasionally horizontal fractures (sheet joints) are not uncommon. Generally the fractures extend up to a depth of 50 to 60m in hard rocks and up to 200m depths in some cases.

3.8.2 Resistivity Scanning Technique

Normal resistivity techniques have certain limitations in detecting small fractures, which yield most of the water in hard rock. The problem will be compounded if fractures are located at deeper depths. The resistivity soundings are investigations at discrete points and hence cannot identify any fracture zones at a few meters away. Even if a sounding is conducted exactly over the fracture, its identification is practically impossible due to poor delectability of the conventional interpretational techniques through curve matching and inversion because of the logarithmic data collection and plotting schemes. Close spaced measurements at larger electrode spacing to identify thin and deep fracture zones will not reflect any changes in sounding curves, when plotted on double logarithmic scale.

Resistivity profiling techniques, though identify subsurface lateral in homogeneities, are not amenable for quantitative interpretation. To overcome the above difficulties, a new technique called ‘Resistivity Scanning’ with modified data collection and analysis schemes was developed by Ramanuja Chary of IGIS by utilizing the concept of ‘Strip Resistivity’. Its application in different geological terrains of India for identification of fracture zones is found to be highly successful.

3.8.3 Concept of Strip Resistivity:

The weighted average of the true resistivity (strip resistivity) of a slice of formation, occurring between two depths, is computed through this technique. The strip resistivity can be inferred in the same way as true resistivity. Measurements are to be made for two electrode separations - one that yields the information to the top of the target and the other to the bottom of the target layer. The depth of investigation depends mainly upon the current electrode separation.

Let us consider resistivity measurements at the same spot with two different electrode separations shown in fig.3.5.

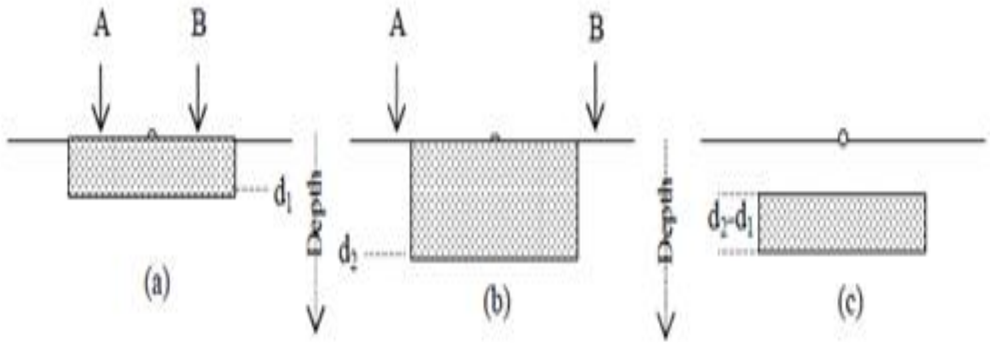


Fig.3.5 Relation between electrode seperation and depth.

In fig. 3.5 (a), the current electrode separation is small, and consequently the depth of investigation (d1) is also small. For larger AB the depth of investigation (d2) is more,
Since the current flows deeper and more subsurface material comes under the Investigation. The additional slice of the subsurface contributes to the second resistivity measurement. With help of these two apparent resistivity and the current electrode separations, it is possible to arrive at the true resistivity of the strip of the subsurface between the depth ranges (d2-d1).
The resistivity scanning technique is developed combining the principles of both profiling and sounding techniques and designed on the basis of Schlumberger AB Profiling technique (Fig.3.6). In this technique a portion of the subsurface over a length is scanned to study the variation of resistivity at required depths.

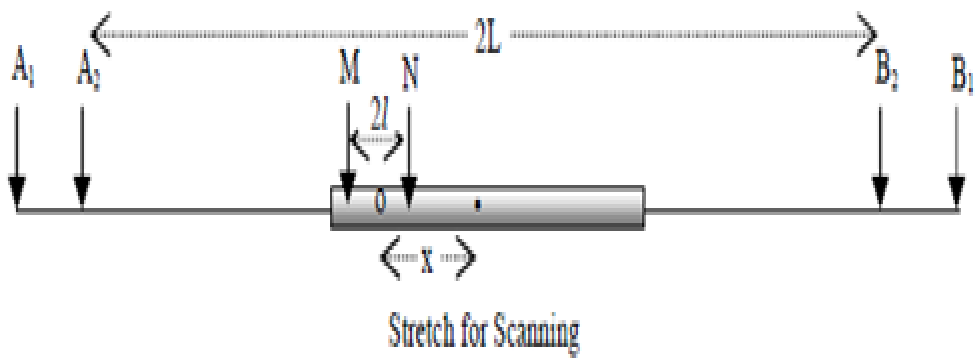


Fig.3.6 Stretch for scanning

The apparent resistivity for each electrode spacing is calculated with the formula;

$$\rho_a = \frac{\pi\ (L^2 - x^2)^2\ R}{2\ l\ (L^2 + x^2)}$$

Where ,
L is half the current electrode separation,
L is half the potential electrode spacing
X is the distance between O and o'

Strip resistivity (Rst) of the formation between these depths corresponding to
the current electrode spacing is calculated with the formula;

$$Rst = (L2 - L1)/\{(L2/ra2) - (L1/ra1)\}$$

Where **,**

L1 is half of the first current electrode spacing

L2 is half of the second current electrode spacing

ra1 is the apparent resistivity for L1

ra2 is the apparent resistivity for L2

The strip resistivity values thus obtained are marked at the centres of potential electrodes and at depths corresponding to one third of current electrode spacing. The strip resistivity values for different depths can be obtained by increasing the current electrode spacing and calculating the strip resistivity for consecutive electrodes spacing. The configuration of electrodes for scanning survey is shown in fig.3.7.

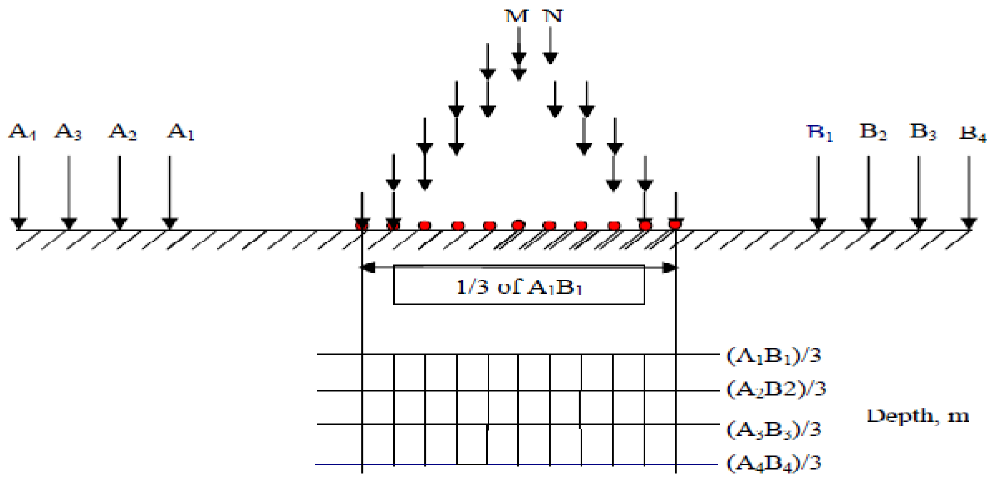


Fig.3.7 Field layout for scanning.

This consists of a number of pairs of current electrode positions A1B1, A2B2, A3B3, and A4B4etc. Depending on the requirement of depth of investigation. Further the middle one third portion of the first electrode spread i.e. A1B1 is considered for scanning and it is subdivided into 5 to 10 equal parts, called stations, with points P1, P2, P3, P4, P5, P6 etc. Initially P1 and P2 are taken as potential electrode position, i.e. station 1 and resistance measurements are made for different current electrode spacing A1B1, A2B2, A3B3, A4B4and A5B5 etc. The strip resistivity values are calculated as per the above formulae and plotted below the midpoint (o') of P1P2 at a depth corresponding to one-third electrode spacing. After completing the measurement for all current electrode pairs, the potential positions are changed to P2 and P3, i.e. to the second station. Thus the procedure is continued up to the last pair of potential electrodes. The results thus obtained represent the subsurface scanning. The maximum scan length in a scanning survey is the minimum depth of investigation. For example, if scanning information from a depth of 20 m is required, the maximum scan length on the ground surface is 20m. Due to small spacing of potential electrodes with respect to large current electrode spacing, higher currents are to be injected into the ground to generate measurable potentials. As the sampling intervals are very small a high-resolution resistivity meter is required to record such very minor variations of resistances.

3.9 ELECTRICAL PROFILING

In electrical profiling, the electrode separation is kept constant and the entire electrode array is moved as a whole with the centre of the configuration occupying successive points along a traverse in the same direction of electrode spread. This is called in-line profiling.

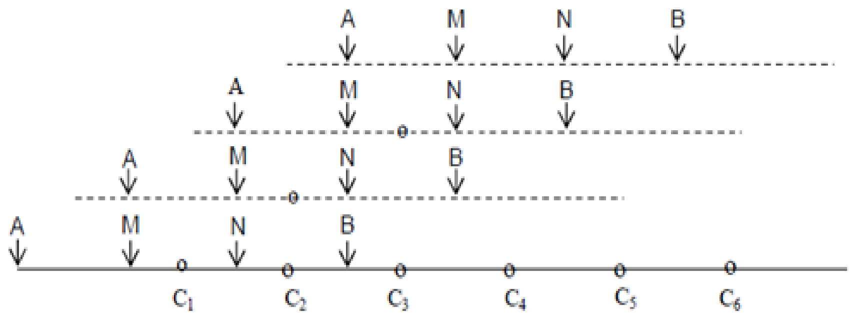


Fig.3.8 In-line profiling.

The other approach is the entire electrode setup is moved in perpendicular direction to the alignment of the electrode array. This is called the broad-side profiling (Fig.3.9).

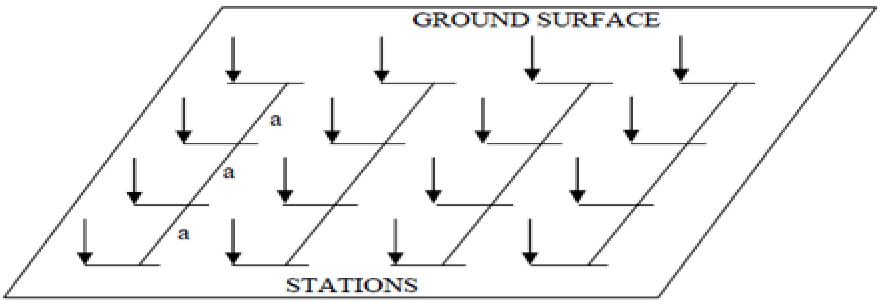


Fig.3.9 Broad-side profiling.

In profiling surveys the value of apparent resistivity is plotted generally at the centre of the electrode array. This technique is used to examine a slice of the subsurface parallel to the surface of the ground, the thickness of the slice being a function of the electrode separation.

Maximum apparent resistivity anomalies are obtained by orienting the profiles perpendicular to the geologic structure.

The data of electrical profiling may be presented as apparent resistivity contour maps if measurements are taken along a number of parallel traverses. In electrical profiling, it is advisable to take measurements at least with two electrode separations to distinguish the effects of shallow geologic structures from the effects of deeper ones Wenner and Schlumberger configurations are generally used for profiling. Other configurations are also used in special cases.

The value of apparent resistivity is plotted generally at the centre of the electrode array. This technique is used to examine a slice of the subsurface parallel to the surface of the ground, the thickness of the slice being a function of the electrode separation. Maximum apparent resistivity anomalies are obtained by orienting the profiles perpendicular to the geologic structure. The profiling technique is generally employed for studying the lateral variations in resistivity for delineating vertical structures like dykes, faults, geological contacts, limited extent bodies like buried channels, fractures, sink holes etc.

The IGIS Signal Stacking Resistivity Meter Model SSR-MP-ATS is a high quality data acquisition system incorporating several innovative features. In the presence of random (non-coherent) earth noises, the signal to noise ratio can be enhanced by ÖN 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 SSRMP- ATS can be used for resistivity investigations up to about 600 m depth or more under Favourable 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. The SSR-MP-ATS measures DV & current (I). It calculates the Resistance (R = DV / I), Apparent resistivity ra & Strip Resistivity strip. It has a resolution of 10-5 ohms.

3.10 APPLICATIONS

1. Ground Water Exploration.

2. Bed rock Investigations.
3. Delineation of Geological Structures.
4. Sand and Gravel Deposit Identification.
5. Mineral Investigations.
6. Geophysical Field Training.

3.11 SPECIFICATIONS

1. Current Settings: There is no current setting. Current input depends on the contact resistance at the current electrodes. Maximum current can go up to 2A.
2. Voltage Settings: 100 – 300 V Automatic changeover depending on the potential signal level.
3. Frequency : Greater than 0.3 Hz Square Wave
4. Power Supply: 2 X 12V rechargeable battery.
5. Input Impedance : 1 Mega Ohm.
6. Resistance Range : 0.00001-19.99 K Ohms.
7. Range Selection : Automatic.
8. Resolution : ± 1%
9. Data Averaging: Selectable stacking cycles up to 16.
10. Interaction with the system: User friendly menu operation with 6x5 Feather touch key pad and 20x4 Alphanumeric Liquid Crystal Display.
11. Display: Stack No./Stack selected, current in mA Running average Resistance during Measurement and final display of Average Resistance, Apparent Resistivity and Strip Resistivity.
12. Memory : Data of about 100 Soundings (~ 20,000 readings)
13. Output : Survey Code, Date and time [Time is (Stored Data) Automatically from built in clock], Electrode Spacing (AB/2, MN/2), Apparent Resistivity and Strip Resistivity through 20x4 Alphanumeric Liquid Crystal Display.
14. Data Transfer: The data can be transferred directly to IBM Compatible PC through USB port for further analysis and interpretation.
15. Error signals for: Discontinuity in current lines and Low signals.
16. Protection: Protected against Circuit overloads.

Controls:

1	P_1 & P_2	Terminals for connecting potential electrodes
2	C_1 & C_2	Terminals for connecting current electrodes
3	DISPLAY	Alpha numeric display to show the menu and measured values
4	TO-BATT	3-Pin Connector to connect the battery unit
5	ON-OFF	To switch ON and switch OFF power
6	FUSE	Fuses for protection of Input & Output circuits
7	KEY PAD	Key pad to interact with the system and to input data like Electrode spacings, no. of stack etc.
8	TO-PC	Connector to interface the computer
9	RESET	To switch ON the measuring unit from stand-by mode
10	BATTERY BOX	Compartment with 2 X 12 7 AH batteries
11	SOCKET	To enable connection between the batteries and the measuring unit

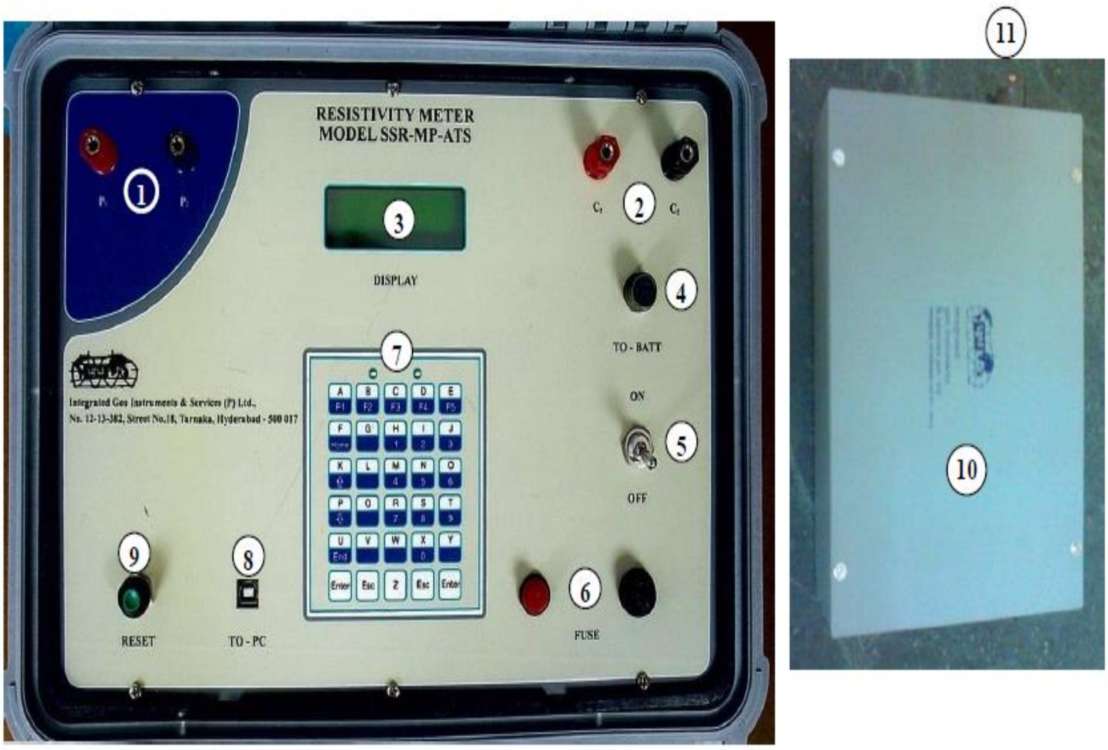


Fig.3.10 Electrical resistivity meter.

Plate 2. Winch

Plate

3. Electrodes

Plate 4. Battery box

3.11.1 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.

3.11.2 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.

3.11.3 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.

3.11.4 To-batt

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

3.11.5 Fuse

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

3.11.6 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.

3.11.7 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.

3.11.8 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.

3.11.9 Battery box

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

3.11.10 Socket

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

3.11.11 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.

3.11.12 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.

3.12 METHODOLOGY

3.12.1 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.

3.12.2 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 and 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.

Plate 5. Setting up of instrument.

IV. RESULTS AND DISCUSSIONS

The present project has been undertaken with the following objectives;

1. To conduct hydro-geophysical investigation of groundwater potential at the coconut garden of College of Horticulture, Vellanikkara.
2. To obtain aquifer distribution within the study area.
3. To delineate possible sites for drilling tube wells for irrigation water supply.

4.1 HYDRO-GEOPHYSICAL INVESTIGATION OF GROUNDWATER

The geophysical observations were taken from 8 locations spread over the plot. 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 plot. The sites where the investigations were carried out are given in the figures below along with their respective geographical locations.

The soundings were done at the LOCATION 1 and the inferred geo-electric sections and the layer details of the point are presented in the inverse slope curve shown in fig.4.1. The electric soundings to a depth of 90 meters were done and an eight layered formation was found to be present. The resistivity value for the first layer of thickness 10 meters was found to be 442 ohm-m. The layer beneath it extended to a depth of 33 meters with resistivity 230 ohm-m. Below that a layer of 5 meters depth and of resistivity 9999 ohm-m was found to exist .Below that a layer of depth 10 meters and resistivity 385 ohm-m was observed. The layer beneath it extended to a depth of five meters with resistivity 2586 ohm-m. Next layer was found to have a resistivity of 466 ohm-m and thickness of five meters. Below that a non- significant layer of resistivity 9999 ohm-m was found to exist. The upper layers were identified as moist to dry sand and gravel, crystalline rock, clay sand and gravel, metamorphic rock, moist to dry sand and gravel, sedimentary rock, moist to dry sand and gravel respectively and the bottom layer was identified as metamorphic formations.The formation is fractured and the chance of availability of water exists between depths of 20 and 50 m.

The inverse slope curve for the LOCATION 2 is given in the fig.4.2. The electric soundings were conducted up to a depth of 96 meters and a four layered formation was obtained. The graph showed rock formations of varying resistivity values. The resistivity value of the formation up to the initial 57 m depth was 537 ohm-m. Then up to 82 meters depth, 742 ohm-m was the resistivity and the formation was identified as crystalline rock. A metamorphic formation of resistivity 9999 ohm-m was found to exist below it for next five meters depth. Below that there was a crystalline rock formation of resistivity 962 ohm-m up to a depth of six meters. The fractures present may not be the aquifer suitable for ground water extraction.

The third VES was carried out and the inverse slope curve was obtained from LOCATION 3. The electric soundings were done up to a depth of 75 meters (Fig.4.3). From the graph a six layered formation was found to exist. The geological formations were found to have less variations in their resistivity values. The resistivity value for the upper 10 meters layer was 451 ohm-m whereas that of the layer beneath it, extending from 10 meters to 25 meters was 989 ohm-m. The layer below this extended up to 60 meters, with resistivity of 663 ohm-m. The layer beneath this had a thickness of five meters with a resistivity of 1364 ohm-m. Next five meters depth from 65-70 meters had a resistivity of 528 ohm-m. The layer below this extended up to 75 meters depth with resistivity of 257 ohm-m. This may be four layers of crystalline rock sandwiched between a top and a bottom layers of moist to dry sand and gravel. No significant yield could be expected from the area by drilling of tube wells.

The formations at the LOCATION 4 were found to be basically rocky, extending up to a depth of 75 meters with total four layers (Fig.4.4). The formations were found to be crystalline having resistivity values of 530 ohm-m, 843 ohm-m, 2083 ohm-m, 740 ohm-m respectively. These hard rock formations without effective fractures cannot yield reasonable amounts of discharge.

On LOCATION 5, the electrical sounding could identify a seven layered profile with hard rock formations extending up to 60 meters depth (Fig.4.5). The chances for getting appreciable discharges were low. The resistivity value for the first layer of thickness 10 meters was found to be 260 ohm-m. Below that a five meters thick layer of resistivity 460 ohm-m was found to exist. The layer beneath it extended up to a depth of 15 meters with resistivity 1291 ohm-m. A layer of depth eight meters and resistivity 815 ohm-m existed below these formations. The layer beneath it extended to a depth of seven meters with resistivity 2586 ohm-m. Next layer was found to have a resistivity of 2885 ohm-m and a thickness of seven meters extending from 40m to 47m depth. Below that a layer of depth 13 meters was found and was last layer which extended up to a depth of 60 meters and had a resistivity value of 671 ohm-m. The upper two layers were identified as moist to dry sand and gravel, followed by three layers of crystalline rock. Sixth layer was found to be sedimentary rock formation and bottom layer was identified as crystalline rock formation. The formations, being crystalline, bears only minute chance of providing appreciable yield.

Fig.4.6 shows the inverse slope curve for LOCATION 6. A four layered formation was found to be present in the profiled depth of 95 meters. The graph shown rock formations of varying resistivity values. The resistivity values of the formation up to the initial depth of 15 m was 275 ohm-m and was found to be moist to dry sand and gravel .The next 65m depth had crystalline rock formation and a metamorphic formation of resistivity 9999 ohm-m existed between the depth of 80m to 88m. Below that there was a crystalline rock formation of resistivity 297 ohm-m which extended up to 95 meters and was found to be dry sand and gravel. These geologic formations also will not yield water for extraction.

The soundings were done at the LOCATION 7 and is shown in fig.4.7. The electrical soundings up to a depth of 88 meters resulted in an eight layered formation. The resistivity value for the first ten meters was found to be 206 ohm-m. The next five meters gave a resistivity value of 429 ohm-m and the layer beneath it extended for five meters with resistivity 815 ohm-m. Below that a layer of 25 meters depth and of resistivity 9999 ohm-m was found to exist. The layer beneath it extended to a depth of five meters with resistivity 2206 ohm-m. Next layer was found to have a formation of 1242 ohm-m resistivity and 47 meters thickness. Below that a layer of eight meters thickness which extended up to 88 meter, had a non- significant depth and resistivity 9999 ohm-m. The upper layers were identified as clay sand and gravel, moist to dry sand and gravel, crystalline rock, metamorphic rock, sedimentary rock, crystalline rock formations respectively whereas the bottom layer was identified as metamorphic form. The formation was not much fractured and the chance of availability of water is less.

On LOCATION 8, the electrical sounding could identify a nine layered profile with hard rock formation extending to 93 meters depth. The chances for getting appreciable discharges were very low. The resistivity value for the first layer of thickness 10 meters was found to be 212 ohm-m. Below that a layer thickness 15 meters resistivity 513 ohm-m was found to exist. The layer beneath it extended to a depth of 25 meters with resistivity 1820 ohm-m. Below that a layer, extending from 50 m to 55 m, of resistivity 3750 ohm-m was found and next layer was found to have a depth of 15 meters and resistivity 1220 ohm-m. The layer beneath it extended to a depth of five meters with resistivity 9999 ohm-m. Next layer found to have a formation of 503 ohm-m resistivity and five meter thickness extending from 75m-80m depth. Below that a layer of depth eight meters with resistivity 9999 ohm-m was observed. The bottom most layer having depth of five meter extending from 88-93 meters had a resistivity of 2885 ohm-m. The upper layer was clay sand and gravel and the next two layers were identified as crystalline rock. Below that crystalline rock was found to exist. Bottom layer was identified as sedimentary rock. These formations also could not yield ground water at appreciable quantities.

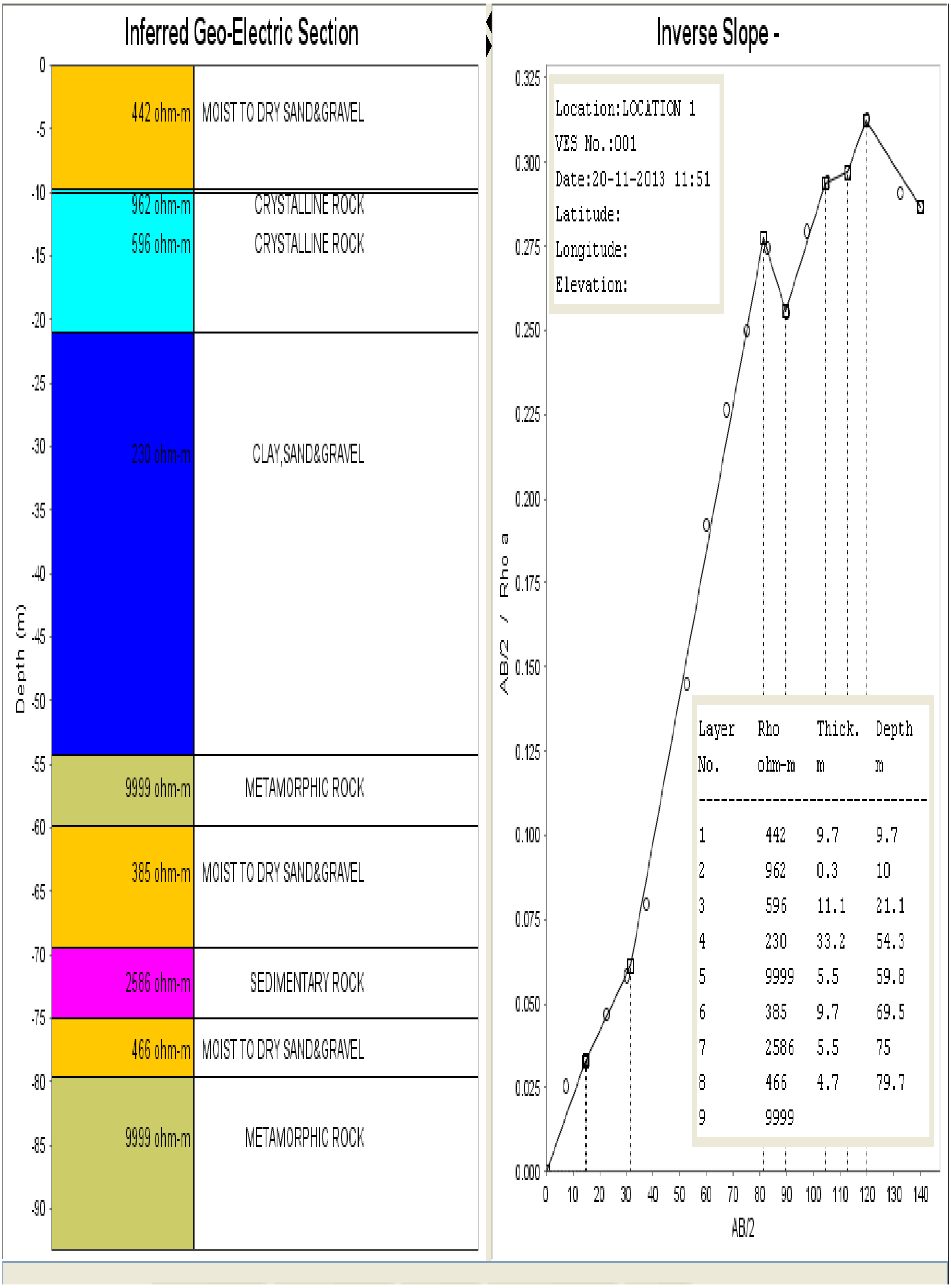


Fig.4.1: Inverse slope curve (LOCATION 1).

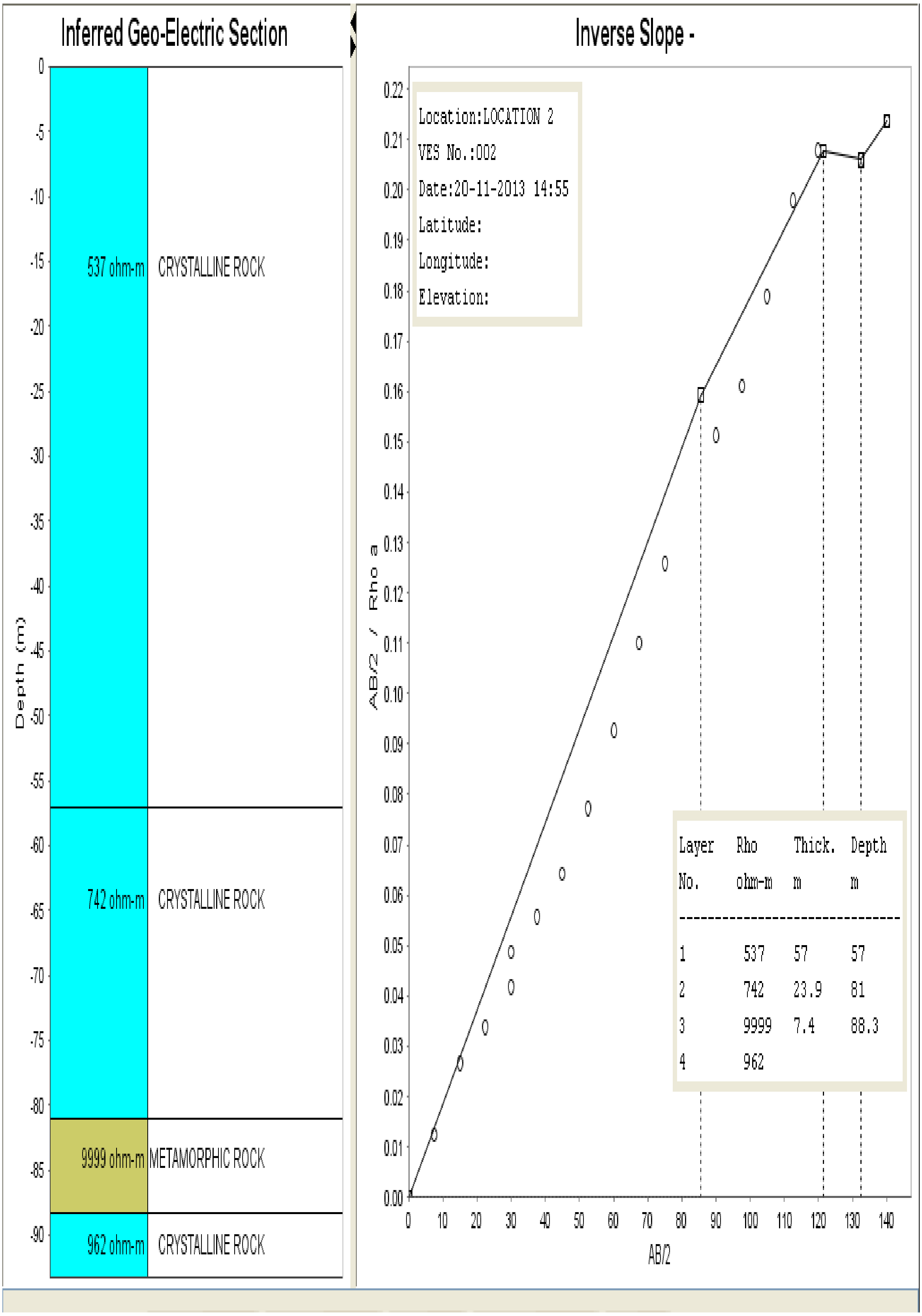


Fig.4.2 Inverse slope curve (LOCATION 2).

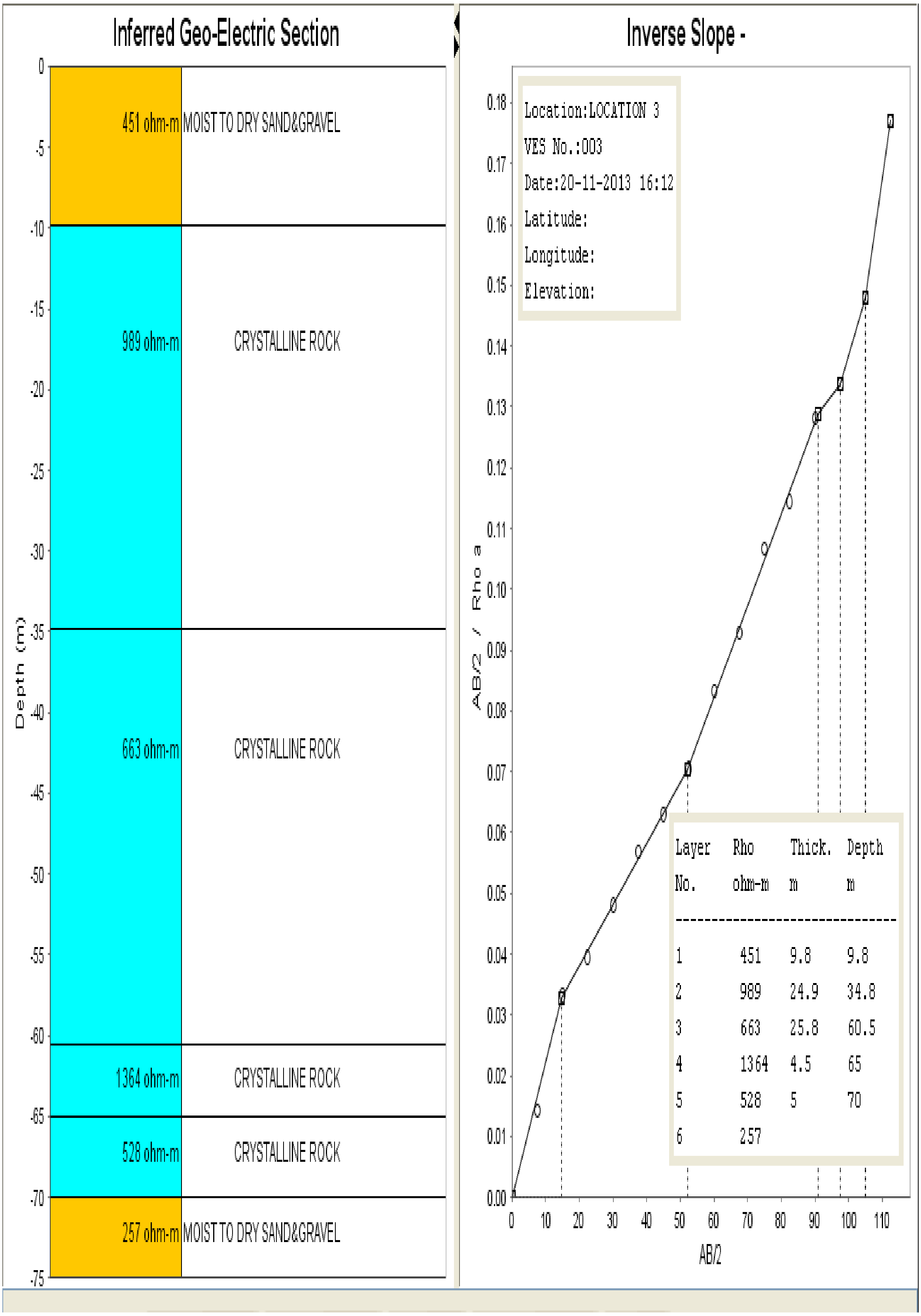


Fig.4.3 Inverse slope curve (LOCATION 3).

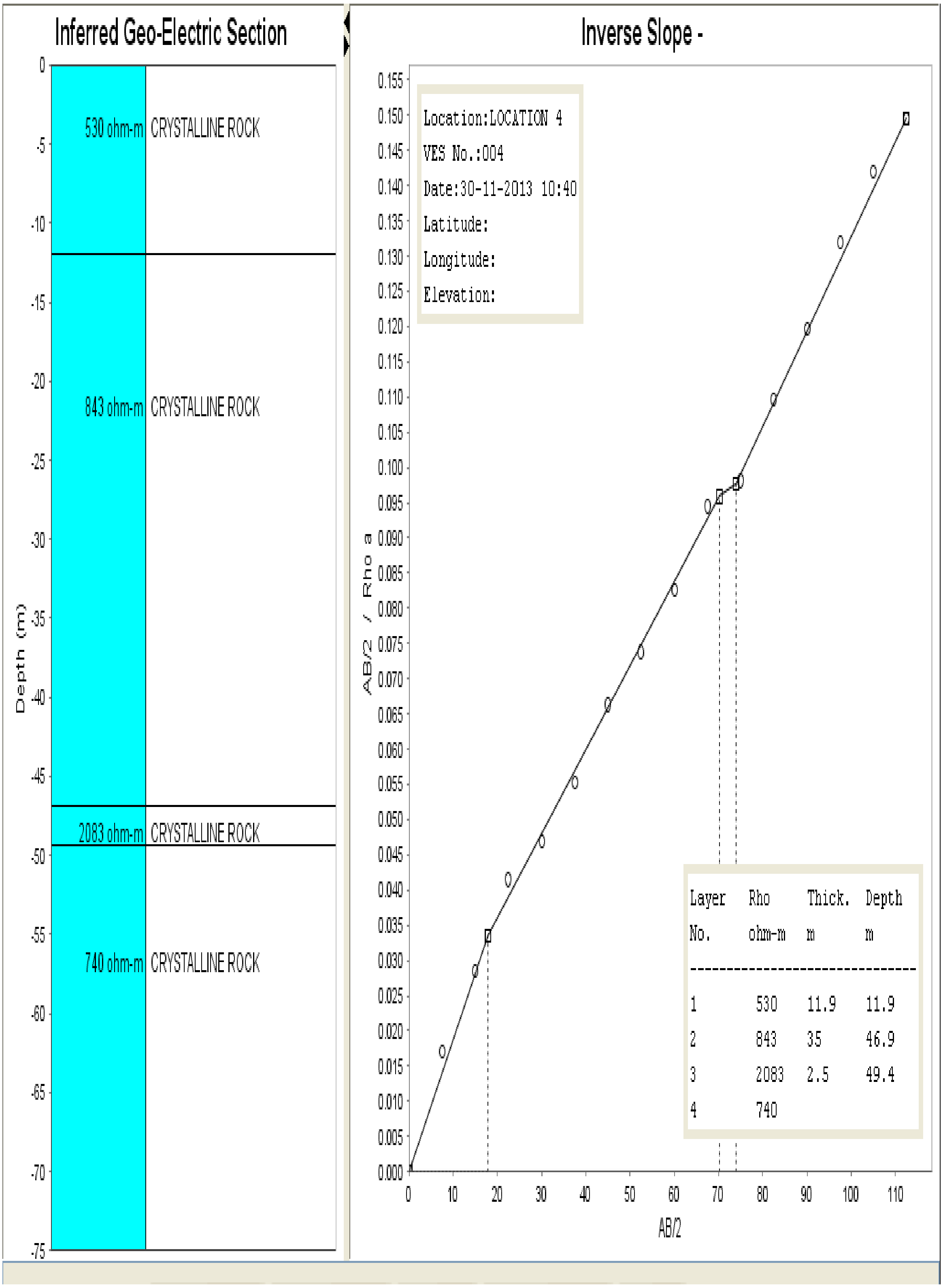


Fig.4.4 Inverse slope curve (LOCATION 4).

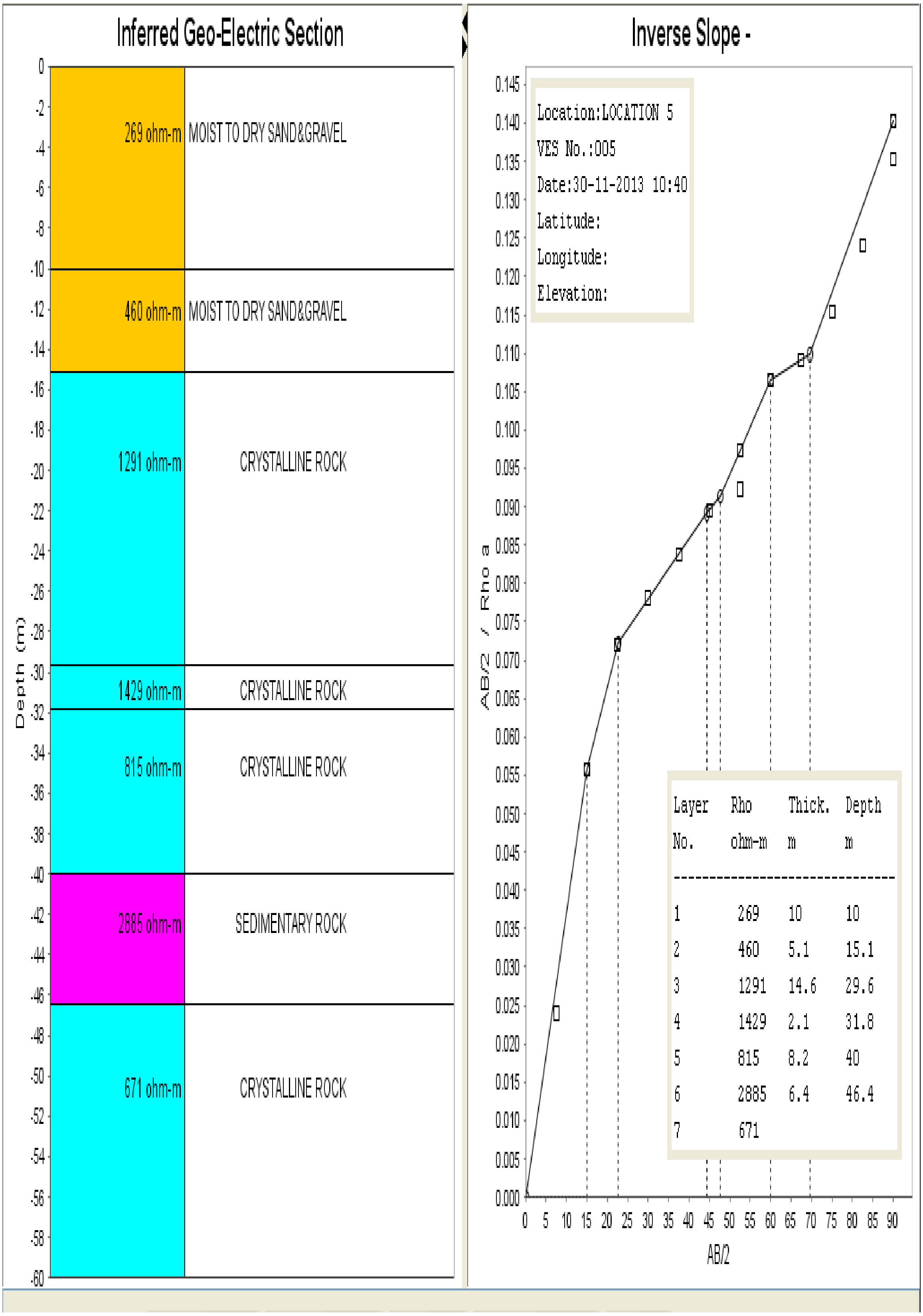


Fig.4.5 Inverse slope curve (LOCATION 5).

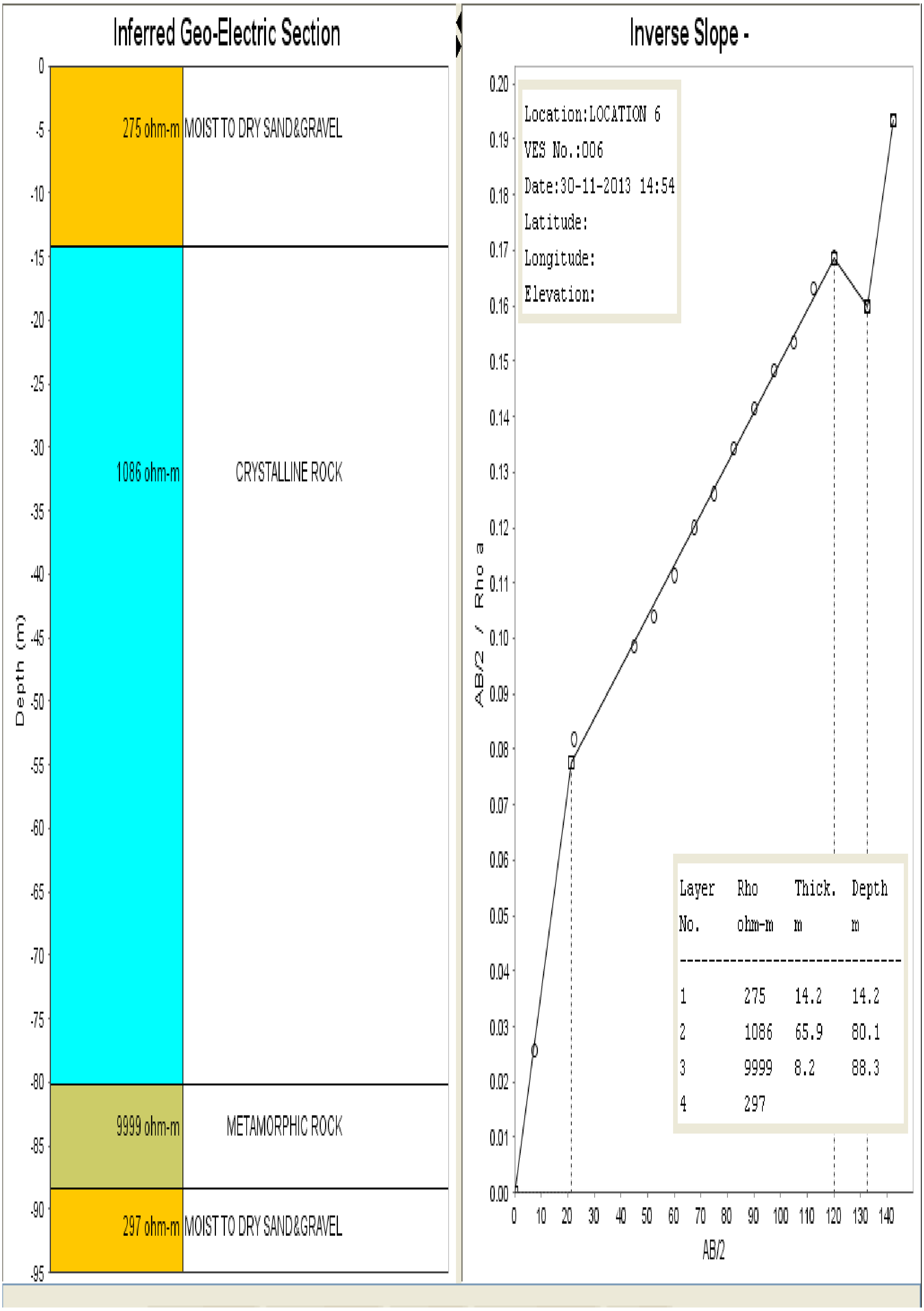


Fig.4.6 Inverse slope curve (LOCATION 6).

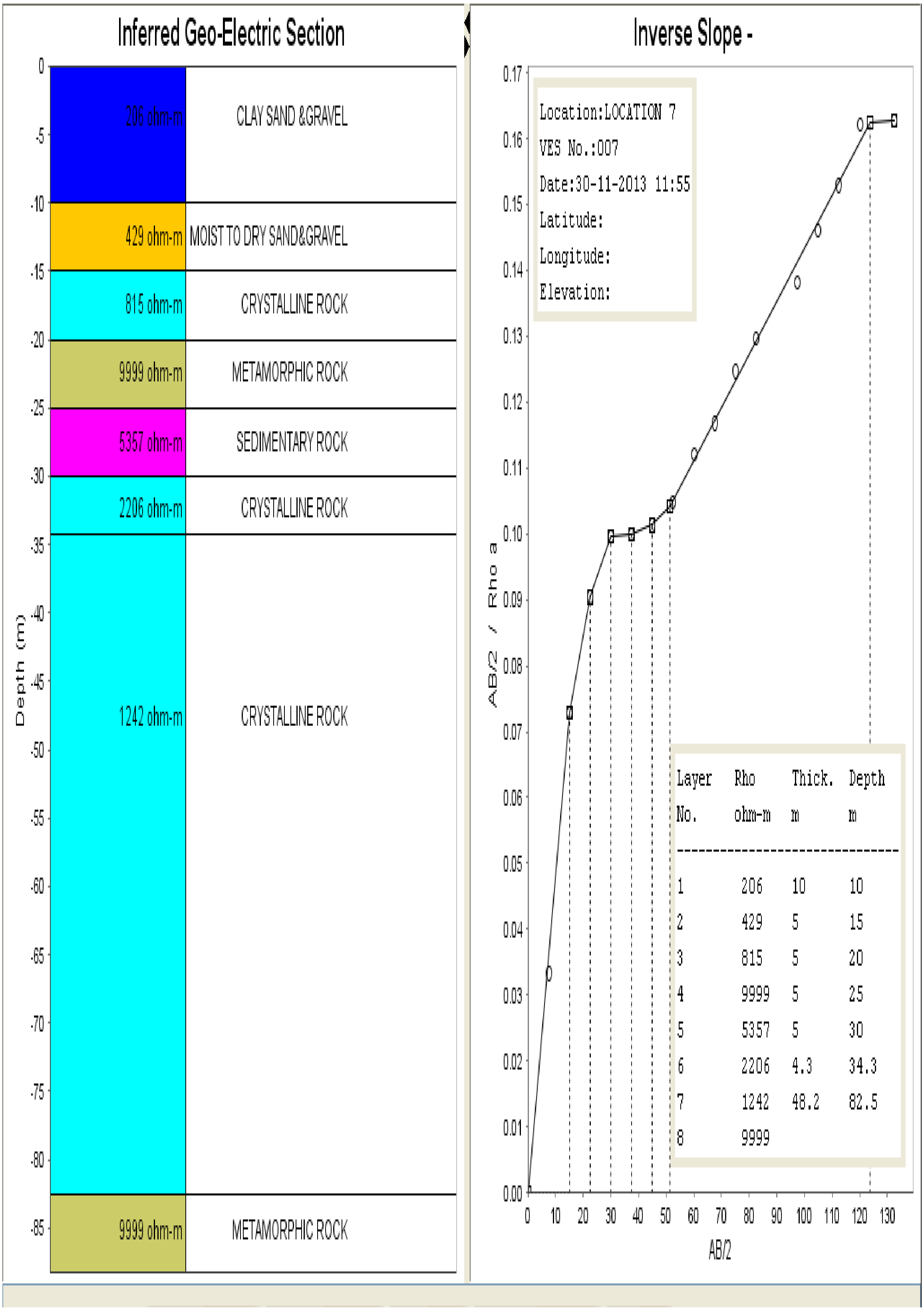
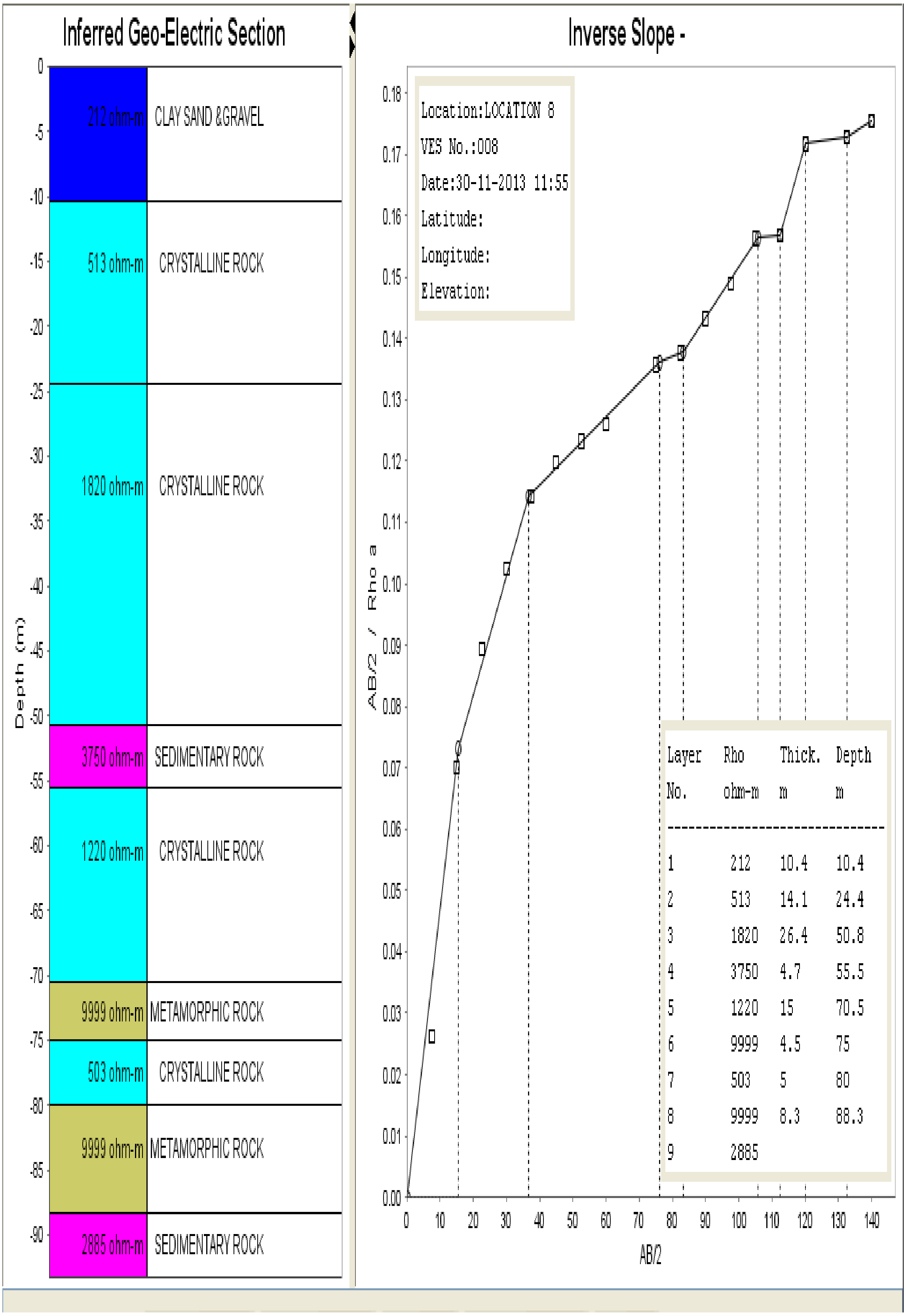


Fig.4.7 Inverse slope curve (LOCATION 7).



Layer No.	Rho ohm-m	Thick. m	Depth m
1	212	10.4	10.4
2	513	14.1	24.4
3	1820	26.4	50.8
4	3750	4.7	55.5
5	1220	15	70.5
6	9999	4.5	75
7	503	5	80
8	9999	8.3	88.3
9	2885		

Fig.4.8 Inverse slope curve (LOCATION 8).

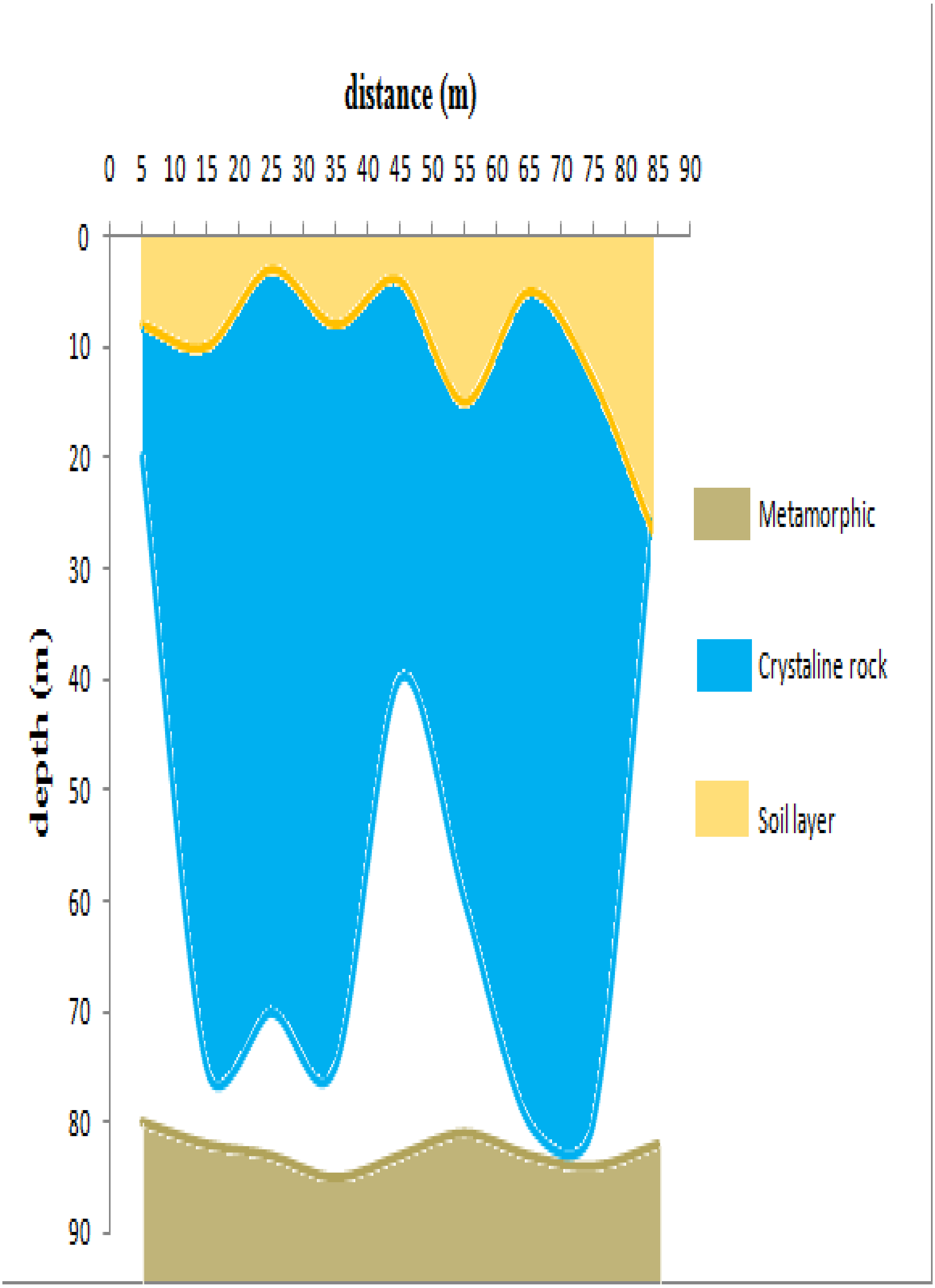


Fig.4.9 Cross-section of strip resistivity for recharge structure (2D).

4.3 POTENTIAL SITES FOR DRILLING TUBE WELLS

The hydro-geophysical survey conducted on the coconut garden revealed that the formations were basically rocky .By the analysis of 2 -D cross-section of strip resistivity to identify site favourable for recharge structure, we can arrive at the conclusion that a continuous soil layer of average depth 10 m was obtained at top. Major portion of area was occupied by a continuous formation of crystalline rocks extending up to 80m. Beyond crystalline rock, a layer of continuous metamorphic formation was found. Appreciable amount of fracture and weathered formations could not be found in the coconut garden. So the study revealed that there were no potential groundwater sources for drilling tube wells.

V. SUMMARY AND CONCLUSION

Groundwater is water that exists in the pore spaces and fractures in rocks and sediments beneath the earth’s surface. The Electrical Resistivity method was used for the hydro-geophysical investigation of groundwater resources in coconut garden of Horticulture College so as to discover a sustainable source of water, to meet the various requirements of the campus. The main objectives of the present project were to conduct hydro-geophysical investigation of groundwater potential at the coconut garden of College of Horticulture, Vellanikkara and to obtain aquifer distribution within the study area in order to delineate possible sites for drilling tube wells for irrigation water supply. A special technique called ‘Resistivity Scanning’ is found to successfully delineate the fractured geometry of formation.

From the eight locations under consideration, none of the locations could serve as potential groundwater sources. By the analysis of 2 -D cross-section of strip resistivity ,to identify site favourable for recharge structure, we can arrive at the conclusion that a continuous soil layer of average depth 10 m was observed at the top.Major portion of area was occupied by a continuous layer of crystalline rock formation which extended up to 80m depth. Beyond crystalline rock, there was a layer of continuous metamorphic formation which could not provide sufficient water. By this study, all possible sites in the coconut garden were explored for the presence of ground water. The project could come to a conclusion that, potential areas for sustainable water supply were not available in the coconut garden.

VI. REFERENCES

Abdelatif Mokhtar Ahmed and Wan Norazmin Sulaiman.2010. Evaluation of groundwater quality in a landfill using resistivity survey. Department of Environmental Sciences, University Putra Malaysia, 43400. Available: http://www.sustech.edu/staff_publications/20101216052354195.pdf.

AbdelatifMokhtar Ahmed, Abdallah E Haj Ibrahim , Abdel Rahman Ahmed Abbashar and E.A. Elzein Mohammed. 1994. Exploration of Ground Water in a Basement Area Using Electrical and Electromagnetic Surveys, Case Study: El Sunut, North Kordofan State. *University of Africa J. Sciences* 2: 1-13

Ahilan, J. and Senthil Kumar, G.R. 2011. Identification of aquifer zones by VES method: A case study fromMangalore block, Tamil Nadu, S. India. *Arch. Appl. Sci. Res.*3(2):414-421.

Ahmed, S. El Mahmoudi, Khalid, M., Al-Barrak, and Massoud A. Massoud. 2011. 2-D Electrical Tomography for Mapping of Aquifers at the New Campus of King Faisl University, Al Hassa, KSA. *International J.Water Resources and Arid Environments* 1(6): 397-410.

Ali Bozkurt, CengizKurtulus and HasanEndes. 2009. Measurements of apparent electrical conductivity and water content using a resistivity meter. *International J. Physical Sciences*. 4 (12): 784-795.

Ameloko A. Anthony and Rotimi O. John. 2010. 2- D Electrical Imaging And Its Application in groundwater exploration in part of Kubanni river basin-Zaria, Nigeria. *World Rural Observations.* 2(2): 72-82.

Anudu, G.K., Onuba, L.N., and Ufondu, L.S. 2011. geoelectric sounding for groundwater exploration in the crystalline basement terrain around onipe and adjoining areas, southwestern Nigeria. *J. Applied technology in environmental sanitation*. 1(4): 343-354.

Ariyo, S.O. and Adeyemi, G.O. 2009. Groundwater exploration and development in hard rock areas using electrical resistivity method: a case study from basement areas of ogun state, southwestern Nigeria. *In: Joint International Convention of 8th IAHS Scientific Assembly and 37th IAH Congress,* Hyderabad, India.

Ariyo, S.O. and Adeyemi, G.O. 2011. Integrated geophysical approach for groundwater exploration in hard rock terrain. A case study from akaka area of southwestern nigeria. *International J. Advanced Scientific and Technical Research*. 2: 376-395.

Ashvinkumarmeena. 2011. Exploration of ground water using electrical resistivity method. B.Tech(civil), National Institute of Technology, Rourkela, Orissa,769008.

Aweto, K.E. 2012. Delineation of fractured zones in crystalline basement rocks by direct current electrical resistivity method in Oke-Ila area, southwestern Nigeria.*Indian J. Sci.* 5(7): 2987-2990.

BasudeoRai, Tiwari, A. and Dubey V.S. 2005. Identification of groundwater prospective zones by using remote sensing and geoelectrical methods in Jharia and Raniganj coalfields, Dhanbad district, Jharkhand state. *J. Earth Syst. Sci.* 114(5): 515–522

Bayewu, O.O. Oloruntola, M.O. Mosuro, G.O. andWatabuni, F.G. 2012. Groundwater exploration in Ago-Iwoye area of southwestern Nigeria, using very low frequency electromagnetic (VLF-EM) and electrical resistivity. Int. Journal of Applied Sciences and Engineering Research, 1(3). Available: http://www.ijaser.com [Jul. 2012].

Bayewu, O.O., Oloruntola, M.O., Mosuro, G.O., andWatabuni, F.G. 2012.Groundwater exploration in Ago-Iwoye Area of Southwestern Nigeria, using Very Low Frequency Electromagnetic (VLF-EM) and Electrical Resistivity methods. *Int. J. Applied Sciences and Engineering Research* 1(3): 453-462

David V. Ftterman. 1987. Example of transient sounding for groundwater exploration in sedimentary aquifers.*International J. Geo*. 25(6): 685-692.

Donald M. Hussong and Doak C. Cox. 1967. Estimation of ground-water configuration near pahala, hawaii using electrical resistivity techniques.

Ezomo, F.O. And Akujieze, C. 2011.geophysical investigation of groundwater in oluku village and its environs of edo state, Nigeria. *J. Emerging Trends in Engineering and Applied Sciences (JETEAS*) 2 (4): 610-614

Girish Gopinath. 2003. An integrated hydrogeological study of the Muvattupuzha river basin, Kerala, India. Phd(Philosophy) thesis, Cochin University of Science and Technology, Cochin - 682 016.

Hadi Tahmasbinejadand Gholam R. Lashkaripour. 2010. Geoelectrical exploration for groundwater in Shooroo basin, southwest of Zahedan, Iran. In: *International Applied Geological Congress*; 26-28, April, 2010, Iran.Department of Geology, University of Mashhad, Iran. pp. 521-527.

Israil, M., Mufid al-hadithi, Singhal, D.C., and Bhism Kumar. 2003. Groundwater-recharge estimation using a surface electrical resistivity method in the Himalayan foothill region, India. *HydrogeologyJ*. 14: 44-50.

Jim Hasbrouck and Tony Morgan.2003. Deep groundwater exploration using geophysics. *International J. environ, Foren*. 1: 11-23.

Kurien, E.K., Sheeja, P.S., Ritu, P., Shazna, K. 2013. A Hydro-Geophysical Investigation of Groundwater Potential. B.Tech(Ag) thesis, Kerala Agricultural University, Thrissur, 51p.

Mahmoud, I.I., Mohamaden, AbuoShagar, S., and GamalAbd. Allah. 2009. Geoelectrical Survey for Groundwater Exploration at the Asyuit Governorate, Nile Valley, Egypt. *J. KAU: Mar. Sci.* 20: 91-108

Massing Oursingbe, Tang Zhonghua, BalogunWaheedOyelola and ZakariMahamadou. 2012. Groundwater exploration in the basement of Lake-Iro District-Chad, using electrical resistivity imaging approach.*African Journal of Pharmacy and Pharmacology.* 7(19): 2720-2729.

Mohamed A. Sabet. 1975. Vertical electrical resistivity soundings to locate ground water resources: a feasibility study. Virginia water resources research center Publications. Virginia Polytechnic Institute and State University, Blacksburg, Virginia 24061.

Mohamed Metwaly, EslamElawadi, Sayed, S. R.,Moustafal, F., Al Fouzan, S.,Mogrenand AlArifi, N. 2011. Groundwater exploration using geoelectrical resistivity technique at Al-Quwy'yia area central Saudi Arabia. *International Journal of Physical Sciences*.7(2):317-326.

Muhammad Arshad, J.M. Cheema and Shafique Ahmed.2007. Determination of lithology and groundwater quality using electrical resistivity survey.*International J. Agriculture and biology*. 9(1): 143-146.

Ochukoanomohanran. 2011. Underground water exploration of Oleh, Nigeria using the electrical resistivity method.*Scientific Research and Essays.* 6(20): 4295-4300.

OluwafemiOmowumi. 2012. Electrical resistivity imaging survey for shallow site investigation at university of ibadan campus southwestern Nigeria. *ARPN Journal of Engineering and Applied Sciences* 7(2): 187-196

Oseji, Julius Otutu and Ujuanbi, O.2009. Hydrogeophysical investigation of groundwater potential in Emu kingdom, Ndokwa land of Delta State, Nigeria. *International Journal of Physical Sciences*. 4 (5): 275-284..

Owen, R.J., Gwavava O., and Gwaze P. 2005. Multi-electrode resistivity survey for groundwater exploration in the Harare greenstone belt, Zimbabwe. Hydrogeology J. 14: 244–252.

Parmasivam, K., Vijayakumar, G., and Sharma, K.K. 2011. Subsurface investigations in lower Palar river basin using vertical electrical resistivity surveys. *International Journal of Engineering Science and Technology (IJEST)*3(6): 5116-5125

RosliSaad, Nawawi, M.N.N., and EdyTonnizamMohamad. 2012. Groundwater Detection in Alluvium Using 2-D Electrical Resistivity Tomography (ERT). Available: www.ejge.com/2012/Ppr12.035alr.pdf.

Ruby, D., Chitra, C., Vasantha, A., Ramasubbulakshmi, T., and Manivel, M. 2010. Integrated analysis of Geophysical Data of Ponnaiyar river basin using Arcview GIS Software. *InternationalJ.geomatics and geosciences.* 1(3): 456-465.

Selvam, S. 2012. Groundwater subsurface investigations in PachaipentaMandal, Andhra Pradesh using vertical electrical sounding resistivity surveys. *Online J. Earth sciences*. 6(1): 1-5.

Selvam, S. and Sivasubramanian, P. 2012. Groundwater potential zone identification using geoelectrical survey: A case study from Medak district, Andhra Pradesh, India. *International J. Geomatics and Geosciences*. 3(1):55-62.

Sharma, S.P. and Baranwal, V.C. 2005. Delineation of groundwater-bearing fracture zones in a hard rock area integrating Very Low Frequency Electromagnetic and Resistivity data. *Journal of AppliedGeophysics*.57:155-166

Stephen O. Ariyo and Gabriel O. Adeyemi. 2009. Role of Electrical Resistivity Method for Groundwater Exploration in Hard Rock Areas: A Case Study from Fidiwo/Ajebo Areas of Southwestern Nigeria. *J. Science and technology*. 10(1):483-486.

TagelAssefa. 2008. Geophysical Investigations for Groundwater Potential Assessmentand Mapping Structures for possible connections between LakesLangano and Shala, Main Ethiopian Rift. M.Sc(geophysics), Addis Ababa University.

Ushie, F.A. and Nwankwoala, H.O. 2011. A preliminary geoelectrical appraisal for groundwater in Yalla, Southern Benue Trough, South-East Nigeria. *Middle-East J. Scientific Research* 9 (1): 1-07.

DECLARATION

We hereby declare that this project report entitled **'A HYDRO-GEOPHYSICAL INVESTIGATION OF GROUNDWATER BY ELECTRICAL PROFILING"** 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.

Afthab Saeed P.P
(2010 – 02- 001)

Place:
Date:

Fasludeen N.S
(2010 – 02 - 015)

CERTIFICATE

Certified that this project work entitled **"A HYDRO-GEOPHYSICAL INVESTIGATION OF GROUNDWATER BY ELECTRICAL PROFILING"** is a record of project work done jointly by Afthab Saeed P.P (2010 – 02 - 001) and Fasludeen N.S (2010 – 02 - 015) 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.

Dr. Kurien E. K.
Associate Professor and Head
Department of LWRCE
KCAET,Tavanur,

Place: Tavanur
Date :

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Afthab Saeed P.P

Fasludeen N.S

DEDICATED TO OUR ALMA MATER

AND

AGRICULTURAL ENGINEERING PROFESSION

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SYMBOLS AND ABBREVIATIONS

ρa	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 salts
VES	Vertical electrical sounding
VLF-EM	Very low frequency-electromagnetic
Wn	Soil water content