GEOPHYSICAL TECHNIQUES FOR AQUIFER CHARACTERISTIC STUDIES – A CASE STUDY OF PERUMATTY GRAMA PANCHAYATH IN KERALA

BY

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PROJECT RREPORT

Submitted in partial fulfilment of the requirement for the degree of

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KELAPPAJI COLLEGE OF AGRICULTURAL ENGINEERING AND TECHNOLOGY, TAVANUR- 679 573, MALAPPURAM, KERALA, INDIA

2024

DECLARATION

We hereby declare that this project entitled **"GEOPHYSICAL TECHNIQUES FOR AQUIFER CHARACTERISTIC STUDIES – A CASE STUDY OF PERUMATTY GRAMA PANCHAYATH IN KERALA"** is a bonafide record of project work done by us during the course of study and that the report has not previously formed the basis for the award to us of any degree, diploma, associateship, fellowship or other similar title of another university or society.

Place: Tavanur

Date: 21/06/2024

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CERTIFICATE

Certified that the project entitled **"GEOPHYSICAL TECHNIQUES FOR AQUIFER CHARACTERISTIC STUDIES – A CASE STUDY OF PERUMATTY GRAMA PANCHAYATH IN KERALA"** is a record of project work done jointly by **Ms. ARCHANA A P (2020-02-046) and Mr. MUHAMED SHIBILI T K (2020-02-034)** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associate ship to them.

Place: Tavanur

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DEDICATED TO OUR AGRICULTURAL ENGINEERING PROFESSION

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SYMBOLS AND ABBREVATIONS

%	Percentage
‘	Minute
“	Seconds
°	Degree
°C	Degree Celsius
KCAET	Kelappaji College of Agricultural Engineering and Technology
Km	Kilometer
M	Meter
Mm	Millimeter
R	Resistance
VES	Vertical Electrical Scanning

INTRODUCTION

CHAPTER I

INTRODUCTION

Water is the most essential element required for life. Groundwater is the primary source for the intrinsic need of water by human being. Socio-economic development is closely linked with the availability and accessibility of groundwater resources. But there is a problem nowadays with the prodigal use of water by humans and their activities. The availability of inland water is dwindling in many parts of the world, the problem that is expected to grow with the population and climate change in the future. The availability of freshwater is a basic prerequisite for human survival and the economic development of the Nations (Gao *et al.* 2019; Shu *et al.* 2020). However, because of the increasing population, industrialization, increasing dependence on irrigation, infrastructure deficiencies and the inherent high variability of precipitation and discharge; water resource scarcity is already common in many regions of the world and expected to become more acute (Shu *et al.* 2020).

Groundwater has an important role in meeting the water requirements of agriculture, industrial and domestic sectors in India. About 85% of India's drinking water supplies and 60% of its irrigation requirements are dependent on groundwater resources. If the current trends continue, 60% of all the groundwater aquifers of India will be in critical condition by 2032 (World Bank, 2012). India is the largest user of groundwater in the world as it uses an estimated amount of 230 $km^3$of groundwater per year, which works out to be over a quarter of the global total. Groundwater is an annually replenishable resource but its availability is non-uniform in space and time.

Kerala is a tiny strip of land located at the south-western tip of India between North Latitudes of $80^0$18´ and $12^0$48´ and East Longitudes of 74^0 52´ and 77^0 22, occupying only 1.2% of India's land area. Geographically, it can be described as an elongated strip of land cushioned between the Western Ghats in the east and the sandy shores of the Arabian Sea in the west. Its land area is 38,863 km^2 with a length of 560 km and width ranging between 11 km and 124 km. Though Kerala forms only 1.2% of the total area of India (3,287,263 km^2), 3% of the country's population inhabits the state. The state is subdivided into 14 Districts, 21 Revenue Divisions, 75 Taluks and 1635 Revenue Villages for administrate convenience and into 152 Blocks, 6 City Corporations, 87 Municipalities and 941Grama Panchayaths for decentralised governance.

As per the 2011 Census, about 62% of the population of Kerala depends on groundwater for the purpose of drinking alone. The latest estimate (2008-09) of the Groundwater Resource Potential of Kerala by the Groundwater Evaluation Committee (2012) indicates that the total available resource is 6029 Mm^3 and the average level of development is 47% annually.

Palakkad (Palghat) is the land of Palmyrahs and Paddy fields and is the major paddy growing area of the State. It is often called as the 'Gateway of Kerala'. There is considerable change in the land use and cropping pattern in the district for the last five years. Due to low income from paddy and coconut, farmers are changing the cropping pattern to cash crops like sugarcane, vegetables and flower cultivation. Over dependence on groundwater for domestic, irrigation and industrial purposes in the district has led to the lowering of water table and water scarcity especially along the eastern parts. In most of the areas especially in eastern part of the district decline of water levels necessitates deepening of existing dug wells and putting deep bore wells thereby increasing cost of pumping and quality deterioration. Local enquiry revealed that farmers have taken loan from the banks for putting bore wells and fitting pump sets for irrigation purposes. The district receives on an average 2362 mm of rainfall annually. During 1998 the district recorded a good rainfall of 2407 mm and subsequently the rainfall has been decreased considerably.

Perumatty Panchayath is situated in the eastern side of Palakkad District in Chittur Block bordering the state of Tamil Nadu. The study area lies between Latitudes of $10^0$37'53" N and $10^0$41'29" N and Longitudes of $76^0$43'28" E and $76^0$53'05" E having an area of 60.91 km^2. The Pachayath comes under Chitturpuzha sub-basin of Bharathapuzha river basin. Perumatty Panchayath and the entire Chittur Block has been identified as over exploited area with respect to groundwater i.e., the extraction of groundwater is more than that of the recharge.

This irrational over extraction is mainly due to the over dependence on groundwater for the domestic, irrigation and industrial purposes. Eventually this has led the land barren and dry.

The assessment of groundwater potential within Perumatty Panchayath holds significant importance for several reasons. An in-depth understanding of groundwater availability is paramount for formulating sustainable management strategies, ensuring efficient resource utilization. Given potential shifts in water demand due to factors such as population growth and land use alterations, analysing groundwater potential becomes pivotal for anticipatory planning. Notably, not all regions exhibit equal groundwater accessibility, making it imperative to discern areas with abundant resources from those facing scarcity. Moreover, such analysis aids in averting the overexploitation of groundwater reservoirs. Consequently, a comprehensive examination encompassing both traditional and geophysical investigative methods is undertaken to ascertain groundwater availability and depths accurately. Given the inherent limitations of conventional approaches, the preference leans towards geophysical investigations for their ability to yield more precise outcomes.

The electrical resistivity method stands as a widely adopted geophysical technique for groundwater exploration globally. Among its applications, Vertical Electrical Sounding (VES) emerges as a galvanic depth sounding method, demonstrating considerable utility in groundwater investigations owing to its straightforwardness and dependable nature.

An electrical resistivity meter, also referred to as a resistivity imaging device, is a tool utilized for gauging the electrical resistivity of materials or subsurface formations. Through acquiring readings at various positions and depths, this meter facilitates the generation of a resistivity profile delineating the subsurface characteristics. Electrical resistivity meters encompass a variety of types, spanning from handheld devices to more elaborate systems employed for sophisticated geophysical surveys. The selection of a meter is contingent upon the particular application and the desired degree of precision and resolution.

The IPI2WIN software serves as a valuable tool for analyzing and visualizing data pertaining to groundwater levels and flow rates, facilitating the mapping of aquifers. Through this software, users can pinpoint and delineate aquifer boundaries, as well as estimate key parameters such as thickness, hydraulic conductivity and storativity. Additionally, IPI2WIN enables the creation of cross-sectional views depicting the aquifer system and the generation of contour maps illustrating water table elevations. A notable advantage of utilizing IPI2WIN for aquifer mapping lies in its capacity for spatial analysis of groundwater data.

In recent years, there has been a greater emphasis on prioritizing groundwater resources. The identification of groundwater potential not only aids in safeguarding the quality of these resources, but also serves to mitigate overexploitation, thereby ensuring the sustainability of water extraction practices.

Within this framework, the present study aims to explore the subject titled "Geophysical Techniques for Aquifer Characteristic Studies – A Case Study of Perumatty Grama Panchayath in Kerala" with the following objectives:

1. To investigate the geophysical attributes of the geological formations within Perumatty Panchayath using the Electrical Resistivity Meter.
2. To generate resistivity profiles and pseudo cross-sections of the aquifer formations within Perumatty Panchayath using the IPI2WIN software.

REVIEW OF LITERATURE

CHAPTER II

REVIEW OF LITERATURE

An overview of earlier research on aquifer mapping and several techniques for groundwater inquiry is given in this chapter.

2.1 GROUND WATER

The dependence of human and ecological communities on groundwater and their respective challenges varies substantially across the globe, but in no location is groundwater not utilized. The dependence of communities on groundwater can be seasonal or episodic; for example the resource may become critical to survival during severe drought when surface water resources run dry (Jakeman *et al*., 2016).

Groundwater is a very important component of water resources in nature. Groundwater is defined as subsurface water that fill in soil pore spaces and in fracture of rock formations (Riwayat *et al*., 2018). A summary of the groundwater management covers concepts and procedures, covering topics like groundwater allocation, recharge and protection. This article focuses on groundwater-based economies in developing nations, where rapid resource development has resulted in significant social and economic gains over the last 20 years, despite its worldwide reach. The sustainability of the resource base that underpinned most of ¸endangered on a fairly large geographical basis, leading to the conclusion that aquifer degradation is much more than a localized concern.

The percentage of households that utilize groundwater in comparison to other sources is, however, rarely measured because national and international databases tend to be more facility-focused than resource-focused. provided information that will help development partners assisting this region in their work and improve the incorporation of resource considerations into the delivery of water services. Findings confirm the argument that, in order to achieve sustainable water services for everyone, governments and development organizations need to increase their involvement with groundwater resource management.

2.2. GEOPHYSICAL INVESTIGATIONS FOR GROUND WATER EXPLORATION

In order to investigate the ground water resources, geophysical investigations are carried out on the soil surface by detecting physical parameters like density, conductivity, resistivity, magnetic, electromagnetic and radioactivity. These techniques identify variations, or anomalies, in the physical characteristics of the crust of the earth. The primary geophysical techniques that are helpful in resolving some hydrogeology-related issues include the electrical, seismic, gravity, and magnetic techniques.

2.2.1 Gravity Method

This method measures the variations in density on the surface of the earth using gravimeters, which may reveal underlying geologic features. In sedimentary terrain, it is a popular geophysical technique for determining groundwater and mineral resources. Murthy and Raghavan (2002) had investigated the underexplored application of gravity variations in groundwater exploration within hard crystalline rocks, such as granite formations. By conducting a gravity survey at Osmania University Campus, Hyderabad, India, the research demonstrates correlations between gravity anomalies and lithological variations, as well as thickness of weathered zones. Negative gravity values corresponded to areas of higher groundwater yield, particularly in deeply weathered granite regions. Overall, the findings affirm the viability of gravity surveys as a valuable tool for groundwater exploration in crystalline rock environments.

2.2.2. Magnetic method

The magnetic method involves measuring variations in the Earth’s magnetic field caused by subsurface structures and materials. The Earth’s magnetic field interacts with magnetic minerals in the subsurface. Variations in magnetic susceptibility (ability to become magnetized) create anomalies that can be detected using magnetic surveys. Oni *et al.* (2020) conducted a ground magnetic survey in Modomo, Nigeria to delineate subsurface structures and estimate overburden thicknesses for groundwater investigation. Measurements were taken at intervals of 10–100 meters along access routes and corrected for diurnal variation. Data enhancement techniques were applied to map edges and estimate depths to structures. Overburden thicknesses were estimated using 2D magnetic subsurface modeling along eight profiles. The study identified 24 lineaments with various orientations, correlating significantly with structures derived from resistivity images. Comparable thicknesses were observed between magnetic-derived and borehole-derived overburden thicknesses, affirming the method's reliability for groundwater potential assessment in basement complex terrains.

2.2.3. Seismic method

There are two types of seismic methods: seismic reflection method and seismic refraction method. The seismic refraction method involves creating a minor shock near the earth's surface, either through the collision of a heavy instrument or a small explosive charge and then measuring the time it takes for the ensuing sound or shock wave to travel known distances. Seismic reflection methods provide information about geologic structure thousands of meters beneath the surface.

Grelle and Guadagno (2009) examined the seismic refraction profiles and created the water seismic index for the southern Italian region. The groundwater levels and the water seismic index were discovered to be associated by the researchers as they examined the propagational velocity of P and S waves through saturated and unsaturated mediums.

2.2.4 Electrical magnetic method

Two methods of EM survey are Time-domain (TDEM) EM surveys and Frequency domain (FDEM) EM surveys. TDEM methods are based on the principle of using electromagnetic induction to generate measurable responses from sub-surface features. FDEM is related to the measurements at one or more frequencies.

Vargemezis *et al*. (2012) detected the presence of groundwater in Northern Greece using electrical and EM methods of geophysical investigations and suggested the promising locations to construct wells. The potential groundwater regions were proposed by exploring the water levels using very low frequency electromagnetic method.

2.2.5 Electrical resistivity method

Through the use of two electrode pairs known as current electrodes and potential electrodes, two additional electrode pairs known as potential electrodes, the potential difference across the ground that results from sending current into the ground is measured in conjunction with Electrical Resistivity techniques. The apparent resistance, which is dependent on the electrode arrangement and the resistivity of the subsurface formation is calculated as the ratio of the potential difference (ΔV) to the current (I).

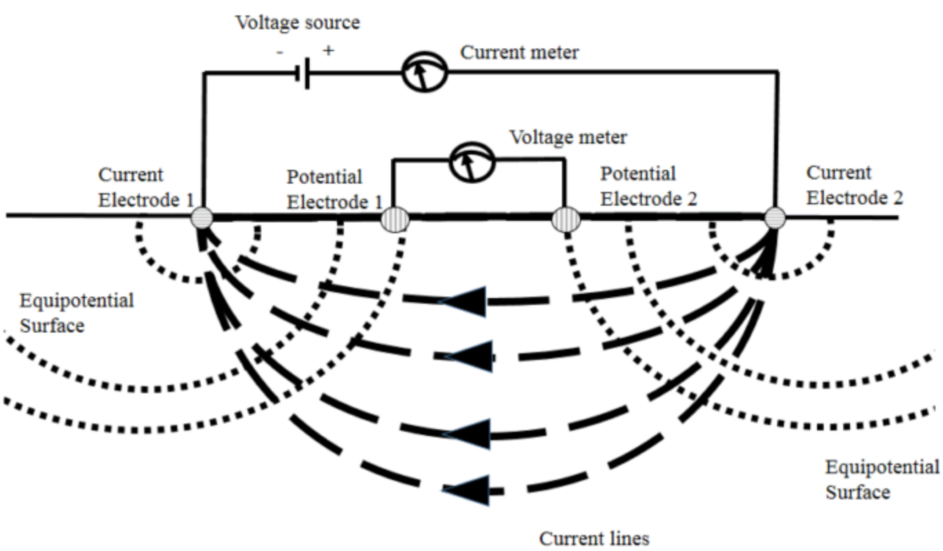

Fig. 2.1 Electrical resistivity method

Sajeena *et al.* (2017) revealed that one essential method for groundwater exploration is the geophysical approach. In order to accurately and thoroughly understand the hydrogeological conditions of the subsurface, geophysical techniques are used. As per the study, the efficacy of geophysical techniques is contingent upon their ability to identify and quantify underlying hydrogeological heterogeneities or variations. To explore the groundwater potential locations in the Kadalundi River Basin, the study employed a Vertical Electrical Sounding (VES) technique with a Signal Resistivity Metre (MODEL-SSR-MP-ATS). Using nine Schlumberger electrode configurations and thirteen Wenner electrode configurations, a VES study was conducted at 22 locations throughout a regional span of 1122 km^2 in the Kadalundi River Basin.

Riwayat *et al.* (2018) proposed a useful alternative strategy for groundwater exploration, like ERM, might complement the current conventional method and generate a thorough and convincing result that is sustainable and effective in terms of cost, time and data coverage. During a site inquiry, the traditional techniques for gathering data on the earth layer include excavation and test boring. The primary drawback of the traditional approach is that it only offers information at the actual drilling site. The purpose of this study was to shed light on the use of ERM in groundwater exploration. The study suggested that the ERM results may be utilized as further data to help solve issues with leachate, subterranean storage, groundwater pollution, and water supply sources.

Araffa *et al*. (2019) investigated aquifer in Northern Red Sea, Egypt using RTP magnetic data to illustrate depth of basement rocks and subsurface structures with major structural trends in various directions. Geo-electrical survey was conducted with 24 VES stations using Schlumberger configuration, revealing four geo-electrical units including alluvium, sand and gravel, sandstone (aquifer) and limestone. Aquifer unit identified with low resistivity sandstone ranging from 6 to 45 m thickness, representing post-Zeit formation of Quaternary (Pliocene-Pleistocene).

Fajana, A. O. (2020) assessed groundwater potential in a specific area by analyzing aquifer characteristics derived from vertical electrical sounding (VES) data. Thirty VES investigations were conducted using Schlumberger-vertical-electrical-sounding, with data interpreted quantitatively through partial curve matching and computer-assisted forward modelling. Isopach and isoresistivity maps of aquifer units were generated, dividing the area into three zones based on groundwater potential: high (C), medium (B), and low (A). The study found that zones with thinner overburden layers have higher groundwater potential, with the aquifers in the north-eastern and south-eastern parts of the area identified as particularly promising in terms of quality and yield potential for community water supply. Subsurface porosity calculations using Archie's Law further support these findings**.**

2.2.5.1 Vertical Electrical Sounding (VES)

VES is used to determine the resistivity variation with depth. The resistivity variations with depth is calculated using VES. A resistivity meter is used to determine apparent resistivity. The resistivity value that is determined is not the actual resistivity of the subsurface; rather, it is the "apparent" resistivity of a homogenous ground that, for a given electrode layout, will yield the same resistance value. A computer program must be used to invert the observed apparent resistivity values in order to calculate the true subsurface resistivity**.**

2.2.5.2 Horizontal profiling

In this case, the spacing between the electrodes remains fixed, but the entire array is moved along a straight line. It gives information about lateral changes in the subsurface resistivity, but it cannot detect vertical changes in the resistivity.

Ozcep *et al*. (2009) measured the electrical characteristics of soil using geophysical techniques of vertical electrical sounding and conducted tests for several soil types. Golcuk and Istanbul were the study's locations. VES (Vertical Electrical Sounding) was used to measure the electrical resistivity in this area utilizing resistivity equipment made by McPHAR. Soil water contents were measured for geotechnical purposes by performing soil mechanics laboratory operations on soil samples taken from borings.

Zawawia *et al.* (2011) carried out a resistivity imaging profiling research. It is a crucial method for gathering data for geophysical surveys in order to identify concealed water and the Beriah Landfill Site has used it. In this investigation, two-dimensional geo-electric imaging was employed. Determining the depth of bedrock, the water tables, and the aquifer layers from the subsurface, as well as a suitable well site, were the main objectives of the survey. Six resistivity lines in the subsurface soil and groundwater surrounding the landfill region were mapped using an imaging technique in this investigation. With the aid of an ABEM LUND electrode and an SAS4000 resistivity meter, surveys were carried out, and 2-D resistivity inversion was used to evaluate the observed resistivity profiles.

Gupta *et al*. (2015) studied the two-dimensional (2D) resistivity survey of the Chikotra basin, which is located in the southern region of Kolhapur district in Maharashtra's Deccan Volcanic Province. The main goal of the project was to use electrical resistivity imaging to identify the research area's aquifer zones. The hard rock and weathered overburden were encased in cracked and weathered basalt, which seemed to be the source of groundwater. The resistivity models indicated that a potential aquifer zone with a respectable thickness of weathered basement was located in the northern portion of the research region. The models also showed that there were multiple areas in the basin with substantial water-bearing potential in the subsurface rocks, suggesting prospective groundwater exploration opportunities.

Shishaye and Abdi (2016) carried out a study to identify two well site options for water supply purposes using surface geophysical methods. For the benefit of the study, hydro-geological and geological studies were added to the geophysical surveying operations. Using the integrated techniques, the anticipated well site locations were determined together with the appropriate resistivity and thickness values.

Jamaluddin and Emi (2018) described the geo-electric method as one of the measurement methods for analyzing the underlying strata's geological data. The lateral and vertical anomalies of the material resistivity were found using the Wenner-Schlumberger array arrangement. The research area underwent two-dimensional profiling in order to ascertain the electrical resistivity of the various soil layers. After processing the data with the software Res2Dinv, a 2D resistivity cross section was produced. Data were gathered throughout a 70 m length when utilizing a Wenner-Schlumberger configuration with electrodes placed 5 m apart. After processing the data, an approximate resistivity estimate with an iteration error of 87.9% was obtained, ranging from 1000 to 1548 m. Alluvium and coastal precipitation with grain in the form of gravel, sand, and small stones were present at the research site.

Teye (2021) carried out an electrical resistivity assessment in 11 communities in Ga West Municipal City to find out if the basement rocks beneath the towns' new settlement areas had any zones that may support water. In order to achieve this, ABEM Terrameter SAS 300C was used to conduct vertical electrical sounding and 1-dimensional electrical resistivity profiling in these communities. Both vertical electrical sounding and electrical resistivity profiling were performed using the Schlumberger electrode array. After modeling the 31 anomalous locations found during vertical electrical sounding, resistivity curves of the A, H, K, AA, KH, QH, and HKH types were used to describe the 3, 4, and 5-layer subsurface structures.

The Wenner and Schlumberger designs are the most widely used electrode arrangements (configurations) in the electrical resistivity method.

2.2.5.3. Wenner array

The Wenner Configuration maintains all four electrodes at identical distances 'a' along a line, which is known as electrode spacing. All of the electrodes are moved simultaneously for every measurement, maintaining the same inter-electrode distance. The potential difference is monitored across the inner electrodes while the outer electrodes get a regular current flow. The apparent resistivity (ρaw) value is obtained by multiplying the resistance by the configuration factor 2πa.

$$\rho_{aw} = 2\pi aR$$

$$\text{where } R = \frac{\Delta V}{I}$$

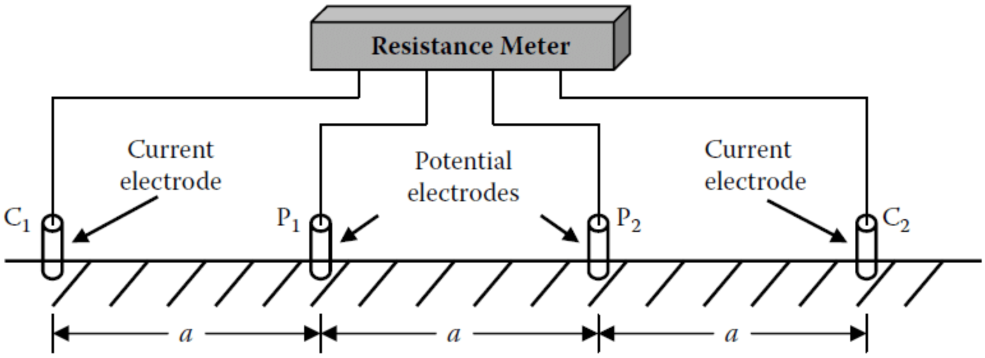

Fig. 2.2 Wenner electrode configuration

Kurien *et al*. (2013) conducted a hydro-geophysical investigation of groundwater using electrical resistivity method using the IGIS signal stacking resistivity metre model SSR-MPATS. The vertical electrical sounding (VES) was carried out using the Wenner electrode configuration. The study was carried out to identify the potential aquifer locations and to determine the pattern of local aquifer distribution. The resistivity and thickness of different subsurface layers at a certain place was determined by gradually expanding the electrode spacing. The inverse of the resistance measured 1/R was plotted against the Wenner electrode spacing on a linear graph to identify the thickness of various layers. The 2D cross-section of strip resistivity was analysed to find a location that would be ideal for a recharge structure.

Cubbage *et al*. (2017) referred to the Wenner array as a widely used measurement technique for gathering geo-electrical data for 2D profiles and 1D soundings. According to the study, the Wenner array's strong signal is useful since the receiving dipole grows in size in direct proportion to the broadcasting dipole. Since this array can only be employed in a single-channel acquisition mode, it was determined that the main drawback was the low data acquisition efficiency. A solution to address the Wenner array's shortcomings was to modify it by adding more receiver dipoles.

2.2.5.4. Schlumberger array

In Schlumberger configuration, all the four electrodes are kept in a line similar to that of Wenner but the outer electrode spacing is kept large compared to the inner electrode spacing, usually more than 5 times. For each measurement only current electrodes are moved keeping the potential electrodes at the same locations. The potential electrodes are moved only when the signal becomes too weak to be measured.

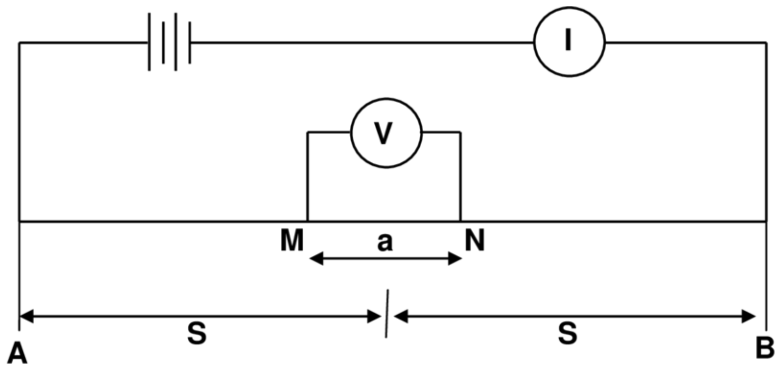

Fig. 2.3 Schlumberger electrode configuration

$$\rho_{as} = \frac{\left(\frac{AB^2}{2}\right) - \left(\frac{MN^2}{2}\right)}{MN}$$

$$\text{where } R = \frac{\Delta V}{I}$$

Ojalebi *et al*. (2002) compared the two common electrode arrays - the Wenner and Schlumberger - used in the geo-electric resistivity method for groundwater exploration within a typical area of basement complex. The results of the study indicated that Schlumberger electrode array has a high investigating depth per unit current electrode separation and is more suitable for subsurface delineation and groundwater exploration.

Arshad *et al*. (2007) carried out an electrical resistivity survey in order to study the groundwater conditions such as depth, thickness, location of the aquifer and the type of water along the Jhang Branch canal. Vertical electrical soundings were carried out at 9 locations up to a depth of 200 m using Schlumberger electrode configuration. It was inferred from the resistivity data that the aquifer was of an alluvial formation. Lithology and the groundwater quality of the aquifer were determined using the data. The increasing value of the resistivity of the aquifer indicated the existence of fresh groundwater.

Selvam (2012) carried out a study to illustrate the application of the vertical electrical sounding method of research in the groundwater exploration in Pachipenta Mandal and neighboring areas. Nine sites in four villages, separated by 200–300 meters, had VES surveys done up to a depth of 200 meters. The ABEM SAS 300 C terrameter was used to generate the field data. For the Schlumberger soundings, the current electrode spacing (AB) varied between 2-300 m (AB/2-1-150 m). The measurement range for potential electrode spacing (MN) was 03–10 m (MN/2-015–5 m). The field data was mimicked using the Winner software. It was discovered that there were greater odds of groundwater accommodation at sites VES 1 and VES 5.

Selvam and Sivasubramanian (2012) carried out a geo-electrical resistivity survey by vertical electrical soundings (VES) in the Medak District of Andhra Pradesh, India in order to evaluate the underlying geology and groundwater potential zones in the area. Schlumberger electrode arrangement was used to record 26 vertical electrical soundings, with current electrode spacing (AB/2) varying from 1 to 150 m. The curve matching and electrical imaging computer programme IPI2WIN had been used to interpret the field data. Interpretations revealed the number, thickness, and depth of underlying formation layers.

Mohammad *et al*. (2013) conducted vertical electrical sounding (VES) survey using the Schlumberger configuration at 16 VES stations. The obtained field data were analysed using computer software (IPI2WIN). The VES results showed the heterogeneity of the underground geological sequence. The geological sequence below the study area consisted of soil, weathered layer, partially weathered and fresh bedrock. The result showed that the groundwater efficiency based on the IPI2WIN method around Malang City is still high to be used not only for domestic water supply but also for irrigation.

Kumar *et al*. (2014) has done geo-hydrological investigations on the main campus of Banaras Hindu University in Varanasi, Uttar Pradesh, India, to evaluate the groundwater characteristics for identifying suitable areas for groundwater research and resource management. Nine vertical electrical sounding (VES) sites were selected and surveys were conducted by Schlumberger configurations in different locations inside the campus premise. Both curve matching and the computer-assisted automatic iterative resistivity sounding approach had been used to interpret the sounding data. Four geo-electrical cross sections were created along the profiles based on the interpreted sounding results. Four layers were revealed by the data interpretation, with the top thin layer typically covering the other three thick levels. The borehole data supported the interpreted results well. The results depicted proper geo-hydrological conditions for existence of good aquifers suggesting continued supply of groundwater in the campus for an extended period.

Arunbose*et al*. (2018) studied an approach to assess groundwater status near Tiruchendur, Tuticorin District, Tamil Nadu, India. A total of 12 VES were performed in the area with the Schlumberger configuration. A DDR3 resistance meter (IGIS Pvt. Ltd.) was used for data collection. The obtained field data were analysed and interpreted using the IPI2WIN software, which provides an automatic interpretation of the apparent resistance. The results of the quantitative interpretation of the geo-electrical data indicated that the study area consisted of three to five electrical layers. The resistivity of the resulting layer varies from 1.3 Ωm to 1512 Ωm. From a total of 12 vertical electric soundings, 3 VES depicted good groundwater potential and quality, and 6 VES depicted poor quality groundwater potential.

Sahoo *et al.* (2022) conducted the Vertical Electrical Sounding in a part of Krushnaprasad Block to isolate the coastal aquifers which were affected by saltwater contamination. A total of 9 soundings with Schlumberger electrode arrangement was done and the results were analysed using IPI2WIN software. The results brought out an indication of underlying strata affected by saltwater. The higher resistivity value (more than 30 Ωm) indicated the lithology without any presence of saline water and the low resistivity value (1 Ωm) indicated aquifers with saline water presence. The resistivity cross-section separating depth of 9 to 25 metre was identified to have a clay layer with lower resistivity value (0.5 Ωm) indicating saline aquifer.

2.3. IPI2WIN

The IPI2WIN software is a program designed for automatic or semi-automatic analysis of single piece 1D geo-electrical survey data to get the smallest error (Mohammad *et al*., 2013).

Smegha and Sajeena (2022) conducted aquifer characteristics studies at the ayacut areas of Bakkikayam regulator situated across the Kadalundi River Pandikasala, Vengara, Malappuram district using earth resistivity techniques. Vertical Electrical Sounding (VES) surveys were conducted using a Signal Stacking Resistivity Meter (MODEL-SSR-MP-ATS) at 18 locations and were interpreted using IPI2WIN software in order to analyze the aquifer characteristics of the study area. According to the VES studies, the top soil in the study area is either laterite soil or hydromorphic soil, with a thickness of 0.75 to 4 m. Laterites of varying hardness were found at depths ranging from 4 to 17 m. In some locations, there was lithomargic clay that was less than 2 m thick beneath the laterites. These layers were found to sit on top of weathered rock that ranges in thickness from 2 to 14 m, then hard rock that may or may not have fracture.

MATERIALS AND METHODS

CHAPTER III

MATERIALS AND METHODS

3.1 STUDY AREA

Perumatty Panchayath is situated eastern side of Palakkad District in Chittur Bblock bordering the state of Tamil Nadu. The study area lies between the latitudes 10^{0}37’53” N and 10^{0}41’29” N and longitudes 76043’28” E and 76053’05” E having an area of 60.91 km^2 comes under Chitturpuzha sub-basin of Bharathapuzha river basin. Perumatty Panchayath and the entire Chittur Block has been identified as over exploited area with respect to groundwater i.e., the extraction of groundwater is more than that of the recharge. The study area includes micro watersheds like Kalyanappetta, Mullanthodu, Sarkkarpathy and Muthuswamy.

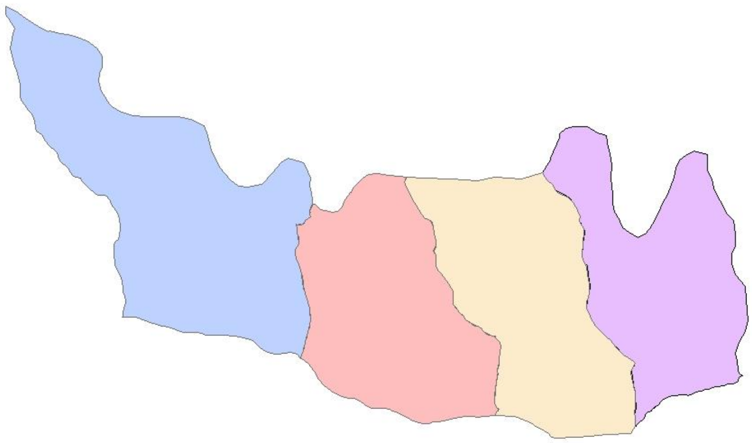

Fig. 3.1 Location map of the study area

3.2 ELECTRICAL RESISTIVITY SURVEY

The vertical electrical sounding method was carried out to analyse the aquifer characteristics of different locations in the study area using Earth Resistivity Meter (MODELSSR-MP-ATS).13 locations in the study area was selected for doing VES survey. Wenner electrode configuration was used to do the VES survey. The current electrode spacing (AB) ranged from 3 m to 60 m

(AB/2 = 3 to 30 m) and potential electrode spacing (MN) ranged from 2 to 20 m (MN/2-1 to 10 m) was selected for the study. At each VES station, electrodes were placed in a straight line and the inter-electrode spreads were gradually increased about a fixed centre. Current was applied into the ground and the potential difference (V) due to this current was measured and recorded against the electrode spacing. As the electrode spacing increases, the penetration of current also increases. The penetration of current below the surface is proportional to half of the distance between two current electrodes. With the available values of current and potential difference of the electrode configuration adopted, one can get the apparent resistivity (ρ). A decrease in the resistivity value indicates the presence of fractures, joints, water content etc. in the formation.

3.2.1 Electrical resistivity meter

An electrical resistivity meter is a geophysical tool used to investigate the subsurface properties of the earth. It works by measuring the electrical resistivity of the ground, which can provide information about the distribution of water, minerals, and other subsurface features.

The basic components of an electrical resistivity meter for ground water exploration include:

3.2.1.1 Electrodes

The electrodes (Plate 3.1) are the parts of the meter that encounters the ground and conducts the electric current to the soil. There are typically four electrodes, two for passing the current into the ground and two for measuring the voltage difference.

Plate 3.1 Electrode

3.2.1.2 Current source

A 24 V chargeable battery is used as a current source. The current is typically a low frequency alternating current, ranging from a few milli amperes to several amperes. Plate 3.2 and Plate 3.3 shows the battery and battery charger of the electrical resistivity meter respectively.

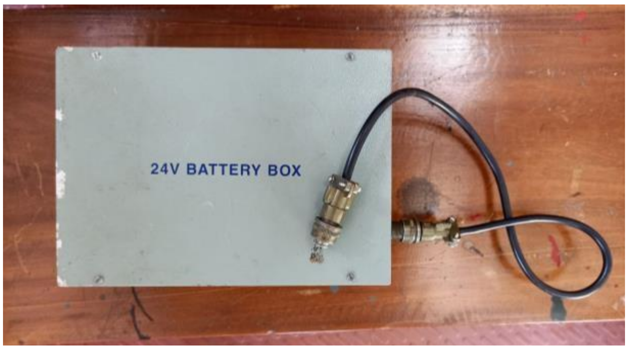

Plate 3.2 Battery

Plate 3.3 Battery charger

3.2.1.3 Data acquisition unit

The data acquisition unit (Plate 3.4) is responsible for recording the voltage measurements and storing the data for later analysis. It may also include signal processing.

Plate 3.4 Data Acquisition unit of Electrical resistivity meter

3.2.1.4 Display unit

The display unit (Plate 3.5) is used to visualize the resistivity data in real-time or after the measurement has been completed. It may include software for data analysis and interpretation.

Plate 3.5 Display unit

3.2.1.5 Cables

The cables (Plate 3.6) are used to connect the electrodes, current source, and the data acquisition unit together.

Plate 3.6 Cables

3.2.1.6 Winches

There are four winches with sufficient length of wire, two winches for current electrodes and two winches for potential electrodes. The open end of wires is equipped with a clip pin, which is used to connect the wire to the electrodes. Banana sockets are provided at both ends of the winches to connect the instrument. Plate 3.7 shows the winches.

Plate 3.7 Winches

In short, an electrical resistivity meter is a complex system that requires careful calibration and operation to obtain accurate and reliable data. It is commonly used in geologic and environmental investigations, such as groundwater exploration, mineral exploration, and mapping geological structures.

3.3 SELECTION OF VES LOCATIONS

The study area's map was sourced from Google Earth, and the VES locations were chosen randomly. This method ensured that the selected sites were distributed across different terrains and geological features, thereby improving the geophysical survey's reliability. A total of 13 VES locations were identified and labelled sequentially from L1 to L13.

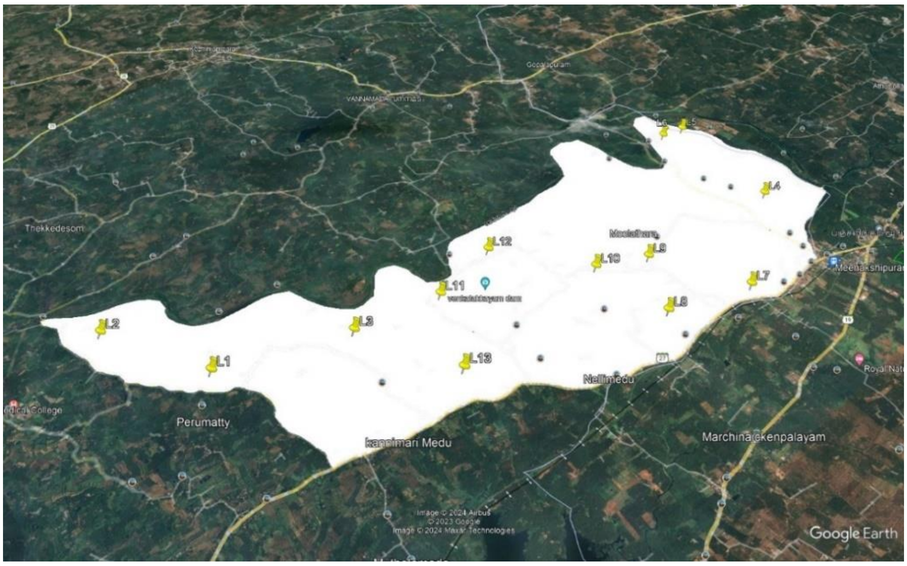

Fig. 3.2 VES locations in the study area

Table 1. Details of VES locations

Locations	Latitude	Longitude	Elevation
L 1	10^{0}40'09" N	76^{0}47'42" E	181.74 m
L 2	10^{0}41'01" N	76^{0}47'15" E	176.43 m
L 3	10^{0}39'48" N	76^{0}48'42" E	189.79 m
L 4	10^{0}38'44" N	76^{0}52'26" E	233.46 m
L 5	10^{0}39'51" N	76052'44" E	217.75 m
L 6	10039'54" N	76052'30" E	207.45 m
L 7	10^{0}38'09" N	76^{0}51'21" E	234.89 m

L 8	10^{0}38'24" N	76^{0}50'38" E	226 m
L 9	10^{0}38'53" N	76^{0}51'00" E	181.74 m
L 10	10^{0}39'05" N	76^{0}50'35" E	223.36 m
L 11	10^{0}39'40" N	76^{0}49'26" E	197.89 m
L 12	10^{0}39'48" N	76^{0}50'04" E	204.47 m
L 13	10^{0}39'00" N	76^{0}49'05" E	205.6 m

3.4 DATA COLLECTION

3.4.1 Reconnaissance survey

A reconnaissance survey was conducted in 13 identified locations to check the suitability for VES survey. An area having minimum 60 m length without any obstructions and with less compacted soil is best suited for the survey.

Plate 3.8 Reconnaissance survey of VES locations

3.4.2 Vertical electrical sounding

The Schlumberger configuration was used for obtaining the required data and the change in resistivity according to increasing depth was noted. Likewise, the survey was carried out in all the 13 locations of the study area. Plate 3.11 shows the photographs of carrying out the experiment in the field.

Plate 3.9 VES survey using Electrical resistivity meter

3.5 INTERPRETATION OF VES DATA

The data obtained from the VES survey of 13 locations across Perumatty Panchayath were initially interpreted using IPI2WIN software. The software gives an output that displays resistivity, thickness and depth of different soil layers from the ground surface.

3.5.1 Computer inversion techniques

In order to avoid the chance of error in the interpretation and judgement of manual curve matching procedure, computer inversion program IPI2WIN version 2.1 developed by the Moscow State University (2001) was used in this study.

The input data given for the execution of inversion includes:

i. Field measurements as spacing and apparent resistivity.
ii. Type of electrode arrangement used (Wenner, Schlumberger or Dipole)
iii. Number of layers
iv. Assumed layer resistivity (ρ) and thickness (h)

The software used by IPI2WIN employed an iterative process. Apparent resistivity data was modelled for the type of field survey geometry employed, and a starting resistivity model was selected based on previous knowledge from ground truthing or averaged geophysical observations. The resistivity model was then modified depending on the discrepancy between the calculated and observed data after the generated data and the real data were compared. Until the computed data and the measured data matched within an interpreter-defined error margin, this process was repeated.

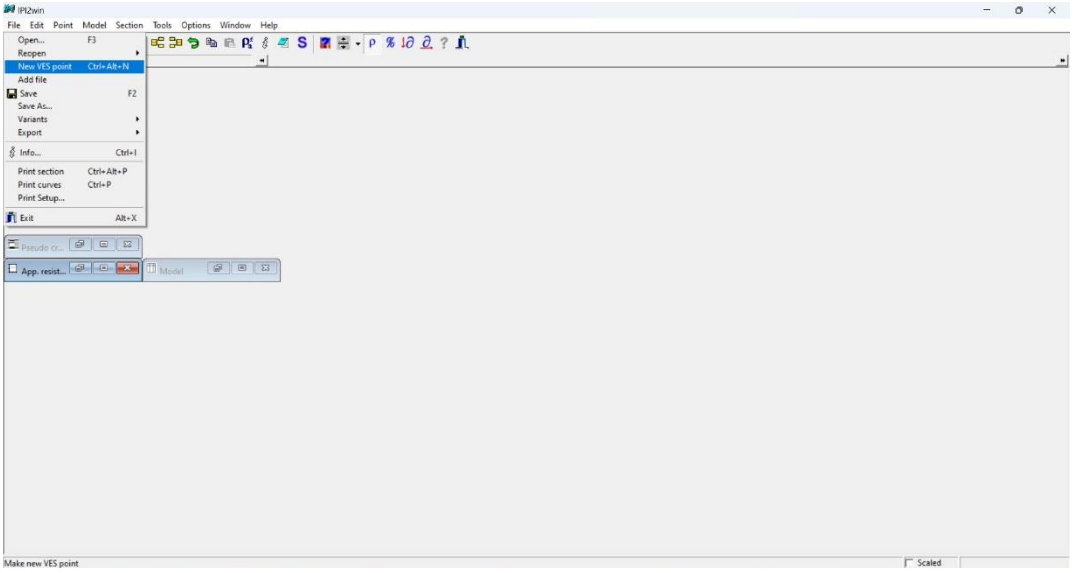

Fig.3.3 Window of IPI2WIN software creating VES file

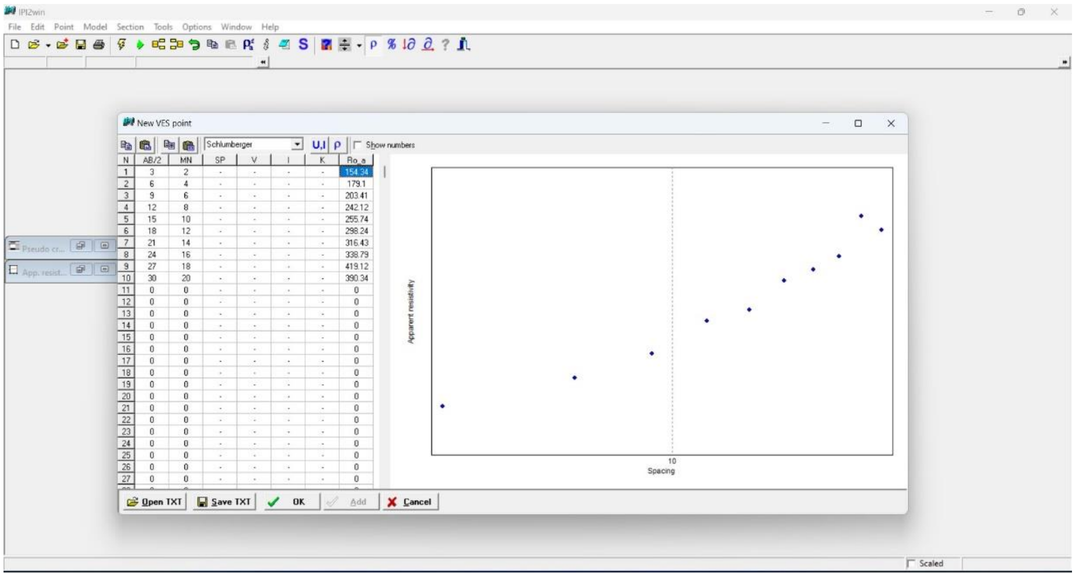

Fig 3.4 Adding input in VES File

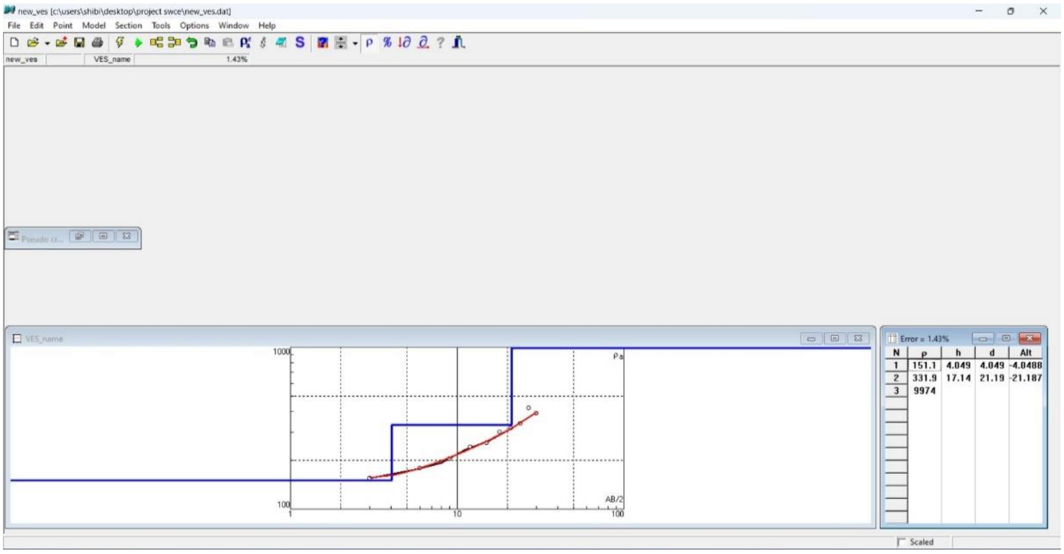

Fig. 3.5 Sounding curve

Using sounding curves derived from the VES data interpretation process using IPI2WIN software, the kind and quantity of layers in the substrata of the research region were determined.

3.5.2 Resistivity and pseudo cross sections

The resistivity and pseudo cross sections are used to find the water availability in the locations we are selected. The following procedure was then followed:

File →Add file →Select the same location →open →Save →click ok

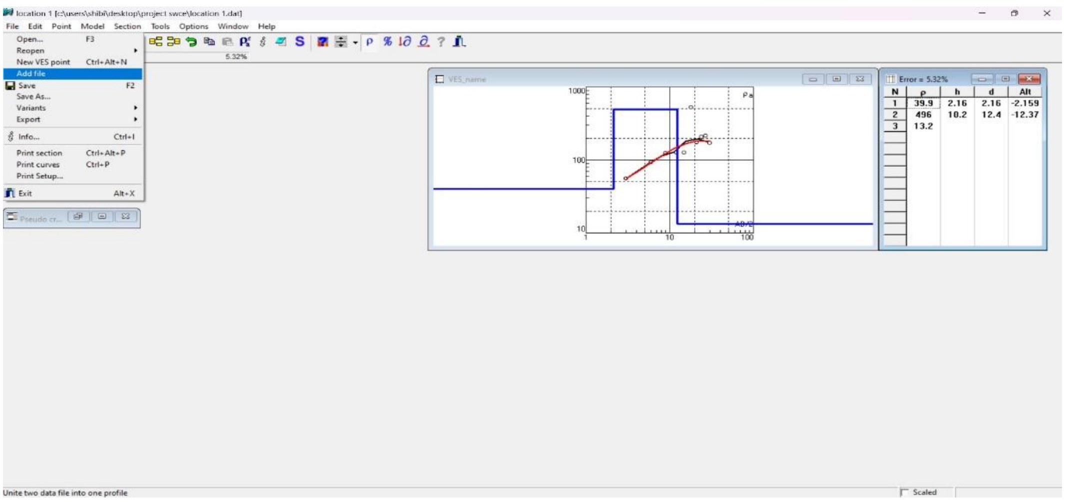

Fig. 3.6 (a) Procedure for creating resistivity and pseudo cross sections

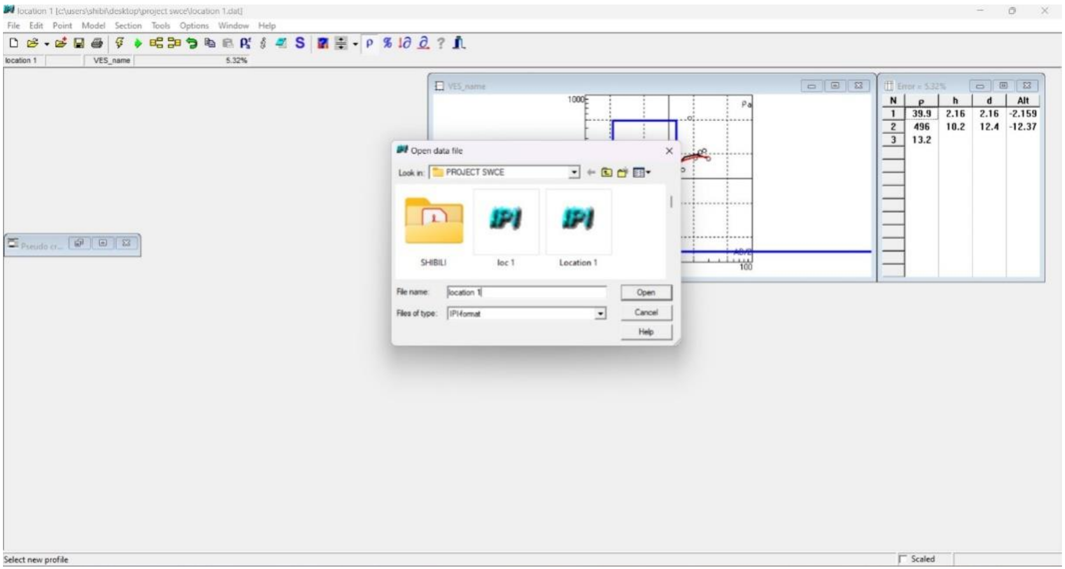

Fig. 3.6 (b) Procedure for creating resistivity and pseudo cross sections

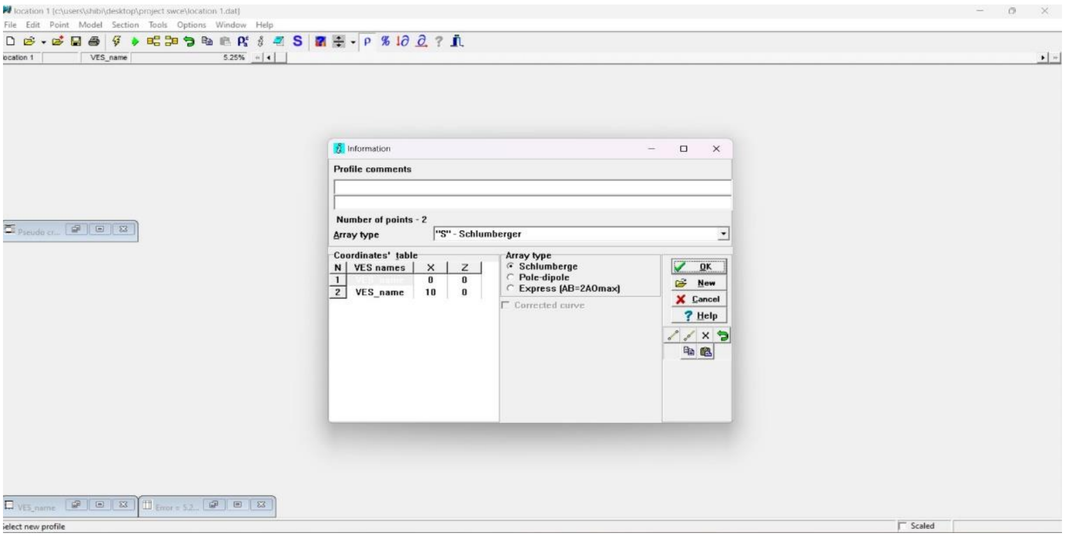

Fig. 3.6 (c) Procedure for creating resistivity and pseudo cross sections

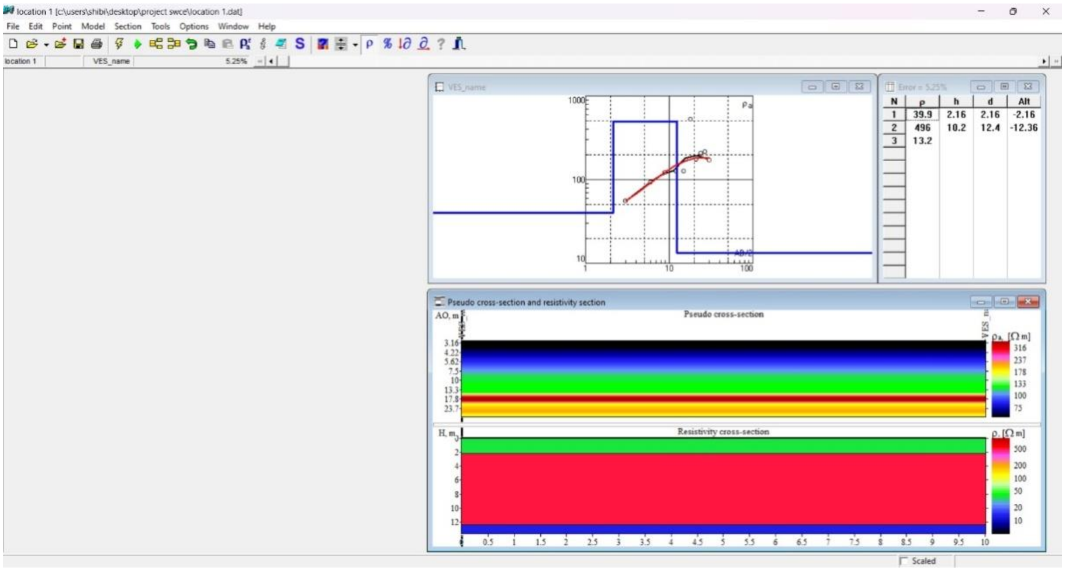

Fig. 3.7 Resistivity and pseudo cross sections

3.5.3 Sounding curves

Many combinations of sounding curves were developed, taking into account the maximum electrode spacing, the hydro-geological and geological formations, and other factors. Curves with two layer examples that are ascending and descending are the easiest to understand. The curve will be climbing if the earth is composed of two layers, either loose top soil or a compacted, weathered basement. If the bottom layer is conductive due to saline water or other saturated conditions and the upper layer is highly resistant, a falling curve is produced (Brijesh and Balasubrahmanian, 2014).

Three layered geology of ground substrata can provide four different kinds of sounding curves. A sounding curve with a low resistivity at its centre ($\rho1 > \rho2 < \rho3$) is referred to as a H type curve, if ρ1, ρ2, and ρ3 represent the resistivity of three successive layers. These curves are seen in hard rock terrains, where the top layer is composed of dry, highly resistive top soil, the second layer is a worn, water-saturated layer that is low resistivity, and the final layer is compact, very resistive hard rock. A type curve exists when the resistivities of the layers increase continuously ($\rho1<\rho2<\rho3$). These kinds of curves are seen in hard rock environments with conductive soil. K type curves are sounding curves with a maximal hump and low resistivity values ($\rho1<\rho2>\rho3$) on either side of the peak. When it comes to coastal regions, these curves are caused by a freshwater aquifer sitting on top of a clayey layer that is covered in a layer of saline water. A sounding data set with a resistivity that decreases consistently ($\rho1> \rho2>\rho3$) will produce a Q type curve, which is typical of coastal regions with salty water (Brijesh and Balasubrahmanian, 2014).

There are eight different combinations of four layer curves (HK, HA, KH, KQ, AA, AK, QQ, and QH) as well as complex sounding curves that reflect multilayer circumstances (HKHK, KHKH, HAA, etc.) that can be interpreted (Brijesh and Balasubrahmanian, 2014).

RESULTS AND

DISCUSSIONS

CHAPTER IV

RESULTS AND DISCUSSIONS

The variations in the levels of ground water of a region are primarily influenced by a number of elements such as precipitation, topographical features, soil characteristics, land use patterns, geology, hydraulics of rivers and geomorphology. These groundwater fluctuations can be determined effectively by using various geophysical methods. The results obtained from the electrical resistivity method carried out in Perumatty Grama Panchayath and the interpretations of the data are discussed in this chapter.

4.1 AQUIFER CHARACTERISTICS OF THE STUDY AREA

4.1.1 Interpretation of VES data

The field data collected from VES survey were interpreted using IP12WIN software to obtain the resistivity values of different subsurface layers and thickness of each layer which are given in Table 4.1. By the interpretation of sounding curves, 2 to 3 subsurface layers where identified within the study area with sounding curves H, K and A types. The presence of three layer substrata are represent by H, K and A sounding curves.

Table 2. Resistivity data interpretation and corresponding thickness

Locations	ρ1 (Ωm)	ρ2 (Ωm)	ρ3 (Ωm)	h1 (m)	h2 (m)	h3 (m)	Depth to bedrock(m)
L1	39.9	496	13.2	2.16	12.4	-	12.36
L2	42.7	114	12931	1.65	13.1	-	13.15
L3	31.5	43422	58.6	2.46	13.1	-	15.56
L4	684	160	1055	1.45	2.17	-	3.62
L5	151.1	331.9	9974	4.049	17.14	-	21.189
L6	60.2	63.5	0.734	1.33	12.1	-	13.48
L7	159	23.7	32825	1.32	2.17	-	3.484
L8	1148	120	1595	0.487	6.79	-	7.278

L9	182	25.4	256	1.09	1.83	-	2.922
L10	197.2	3273	39.58	4.197	6.416	-	10.613
L11	141	78.9	24210	2.17	6.75	-	8.92
L12	43.98	193.7	9437	3.096	9.289	-	12.385
L13	28.3	4070	40.7	2	4.69	-	6.69

4.1.1.1 H type curve

The locations L4 (Muthuswami), L7 (Sarkkarpathy), L8 (Mullanthodu), L9 (Sarkkarpathy) and L11 (Mullanthodu)showed 'H' type curve with three-layer substrata (ρ1 > ρ2< ρ3) with the middle layer having the lower resistivity. The resistivity of first layer ranged from 141 to 1148 Ohm-m which indicated the presence of clayey or laterite in top soil. The resistivity of second layer ranged from 23.7 to 160 Ohm-m which indicated the presence of sandy soil formation. The third layer of L7 and L11 are shows 32825 and 24210 Ohm-m respectively which indicates hard rock. The resistivity ranges were taken from the study conducted by Azhar *et al*. (2017).

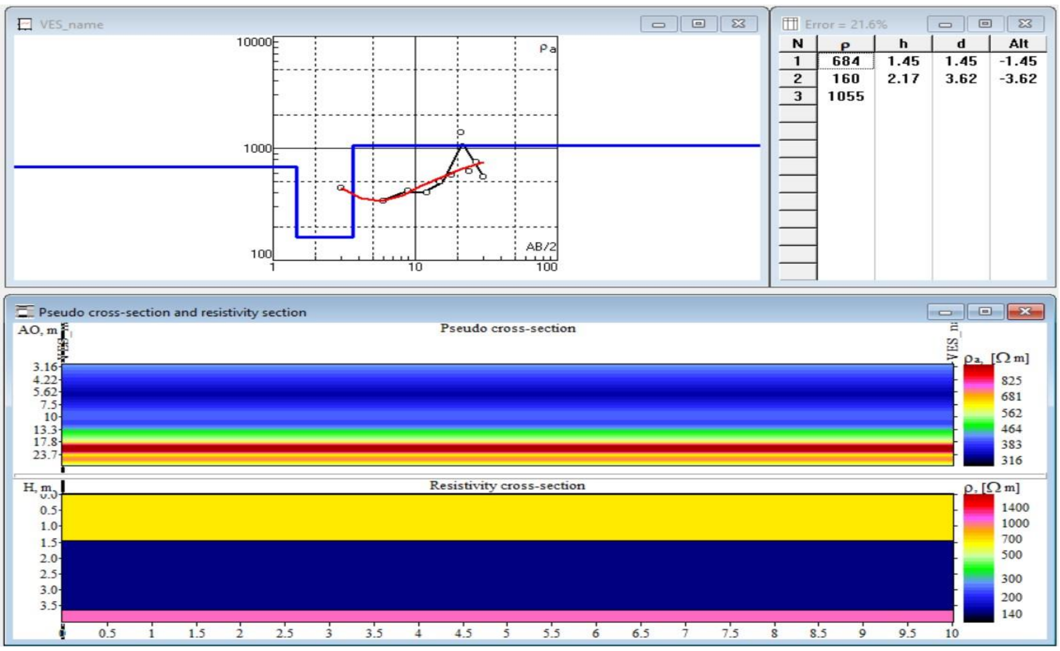

Fig. 4.1 Sounding curve of the location L4 (H-Type)

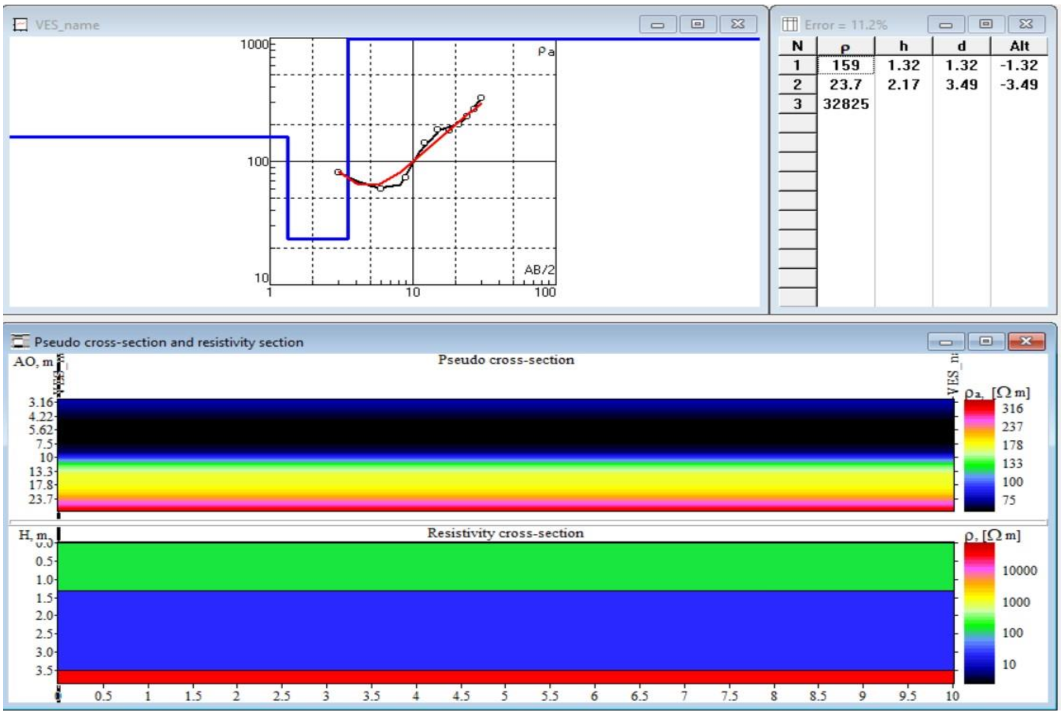

Fig. 4.2 Sounding curve of the location L7 (H-Type)

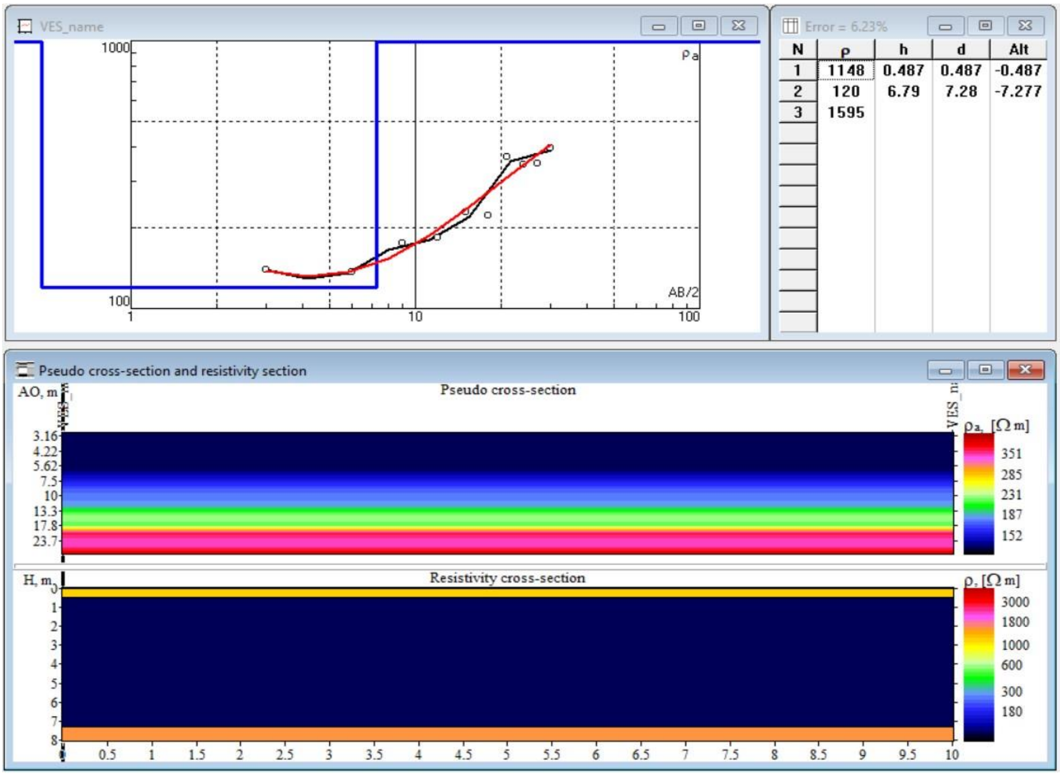

Fig. 4.3 Sounding curve of the location L8 (H-Type)

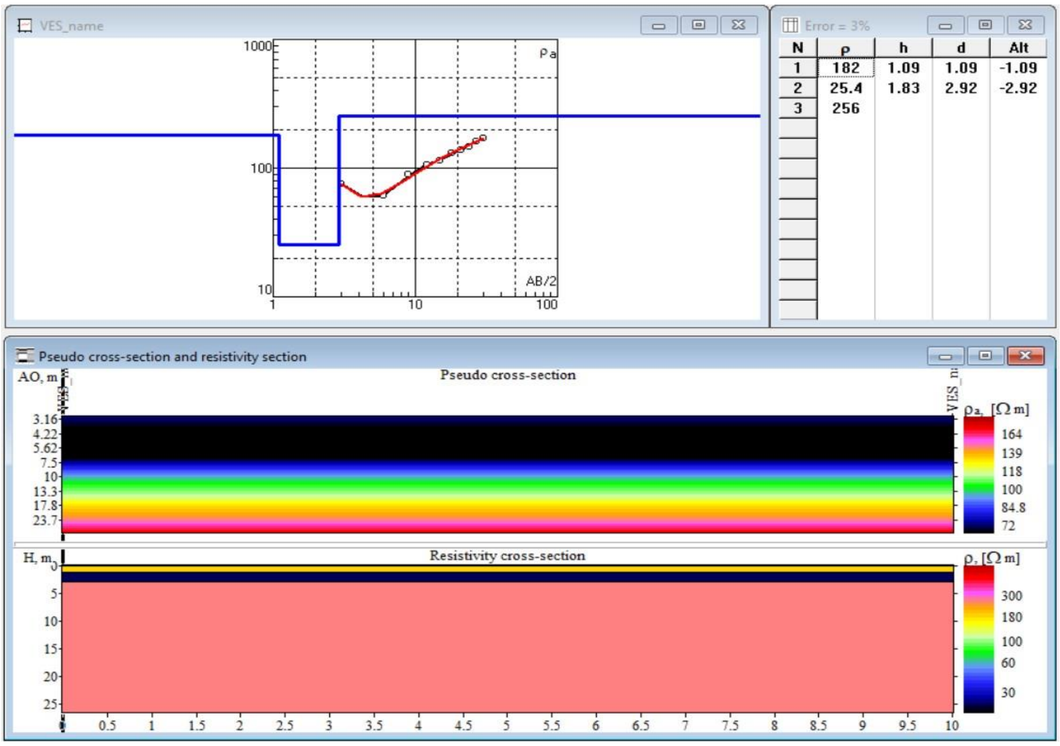

Fig. 4.4 Sounding curve of the location L9 (H-Type)

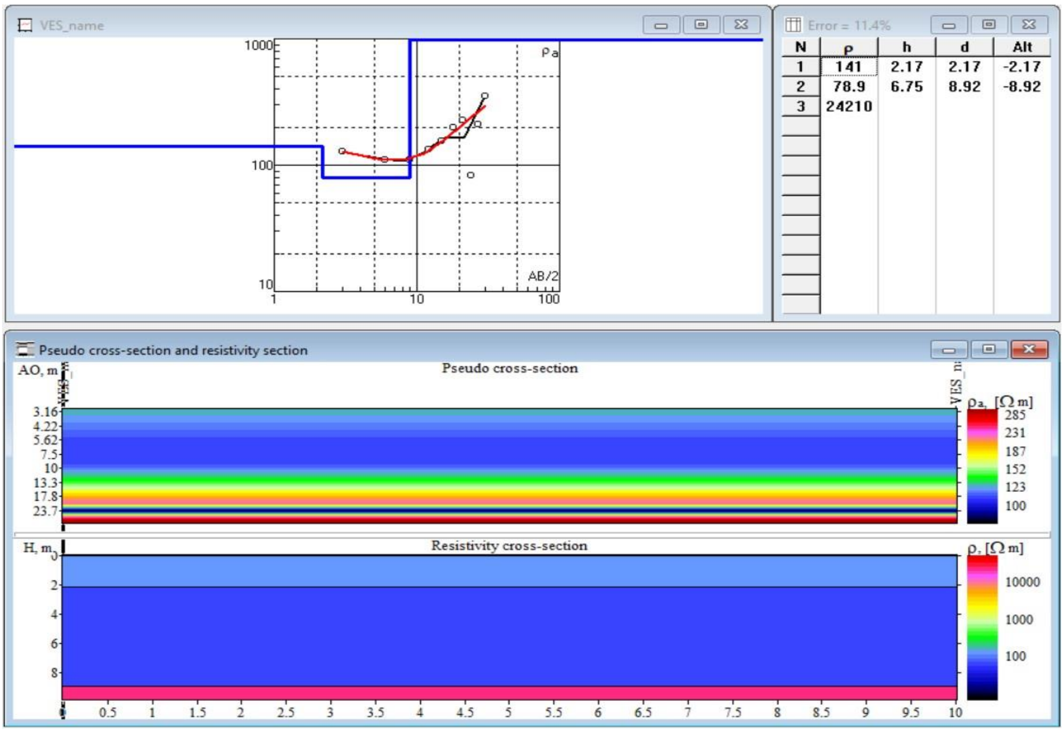

Fig. 4.5 Sounding curve of the location L11 (H-Type)

4.1.1.2 K type curve

The locations L1(Kalyanappetta), L3 (Kalyanappetta), L6 (Muthuswami), L10 (Sarkkarpathy) and L13(Kalyanappetta) showed 'K' type curve with three layer substrata (ρl< ρ2> ρ3) with the middle layer having the higher resistivity. The resistivity of first layer ranged from 28.3 to 197.2 Ohm-m which indicates the presence of sandy or clayey soil. The resistivity of second layer ranged from 63.5 to 43422 Ohm-m which indicated the presence of laterite and hard rock formation. The resistivity of third layer ranged from 0.734 to 58.6 Ohm-m which indicated the presence of clay formation.

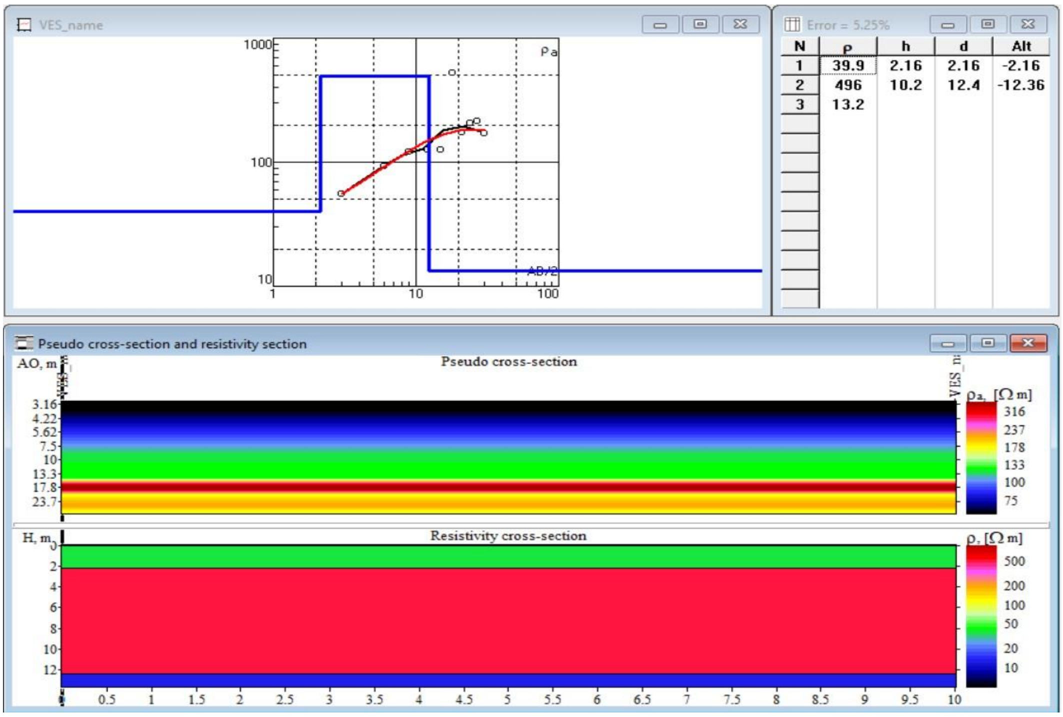

Fig.4.6 Sounding curve of the location L1 (K-Type)

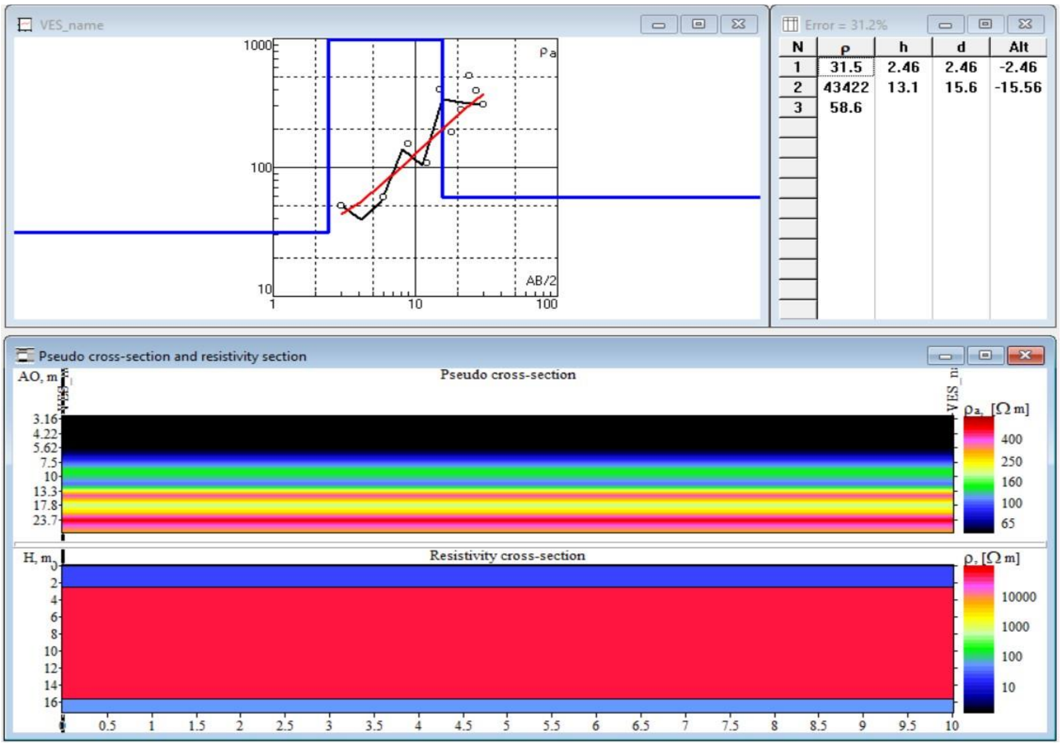

Fig.4.7 Sounding curve of the location L3 (K-Type)

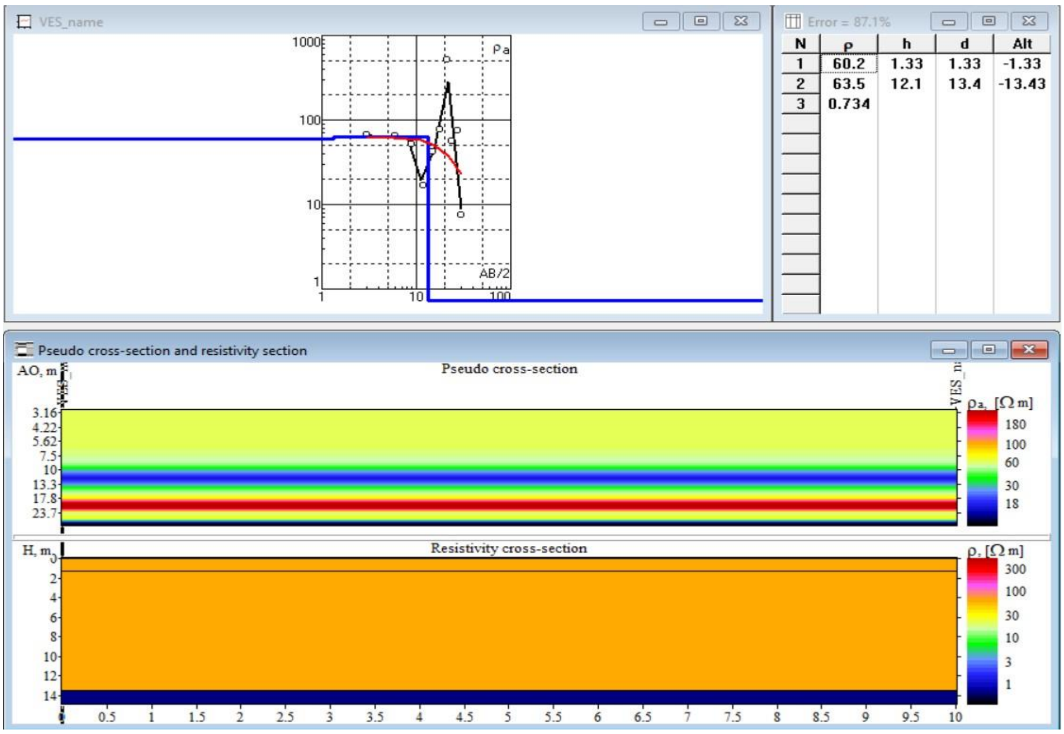

Fig.4.8 Sounding curve of the location L6 (K-Type)

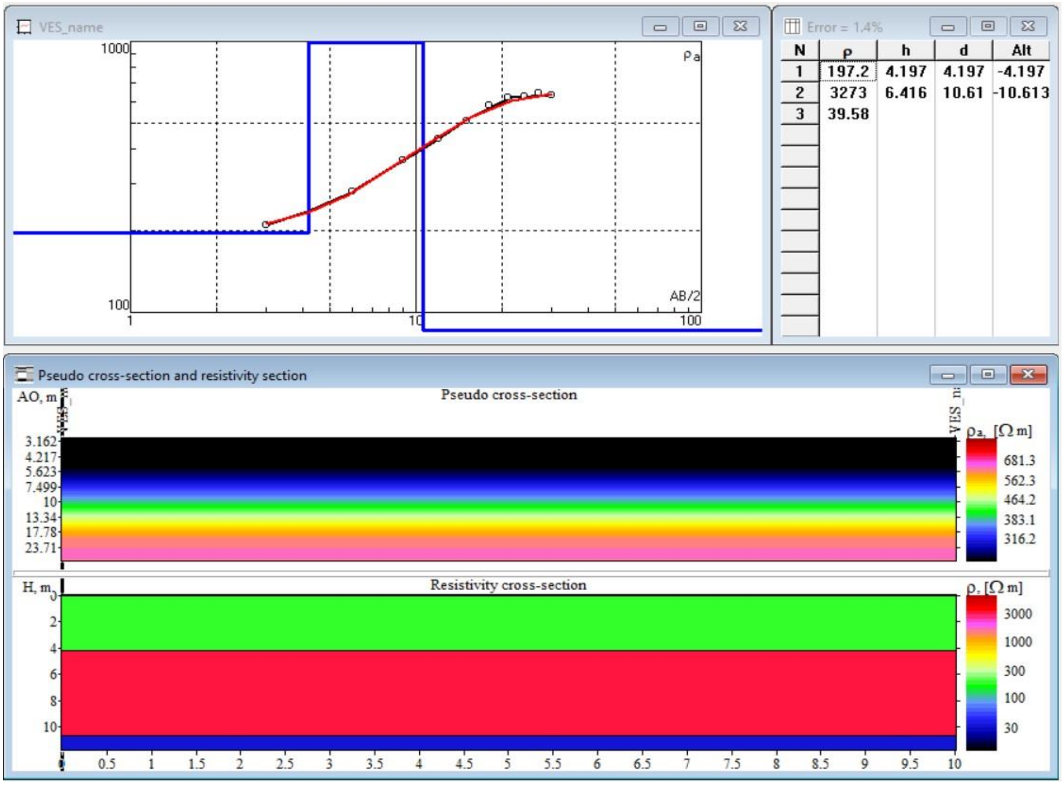

Fig.4.9 Sounding curve of the location L10 (K-Type)

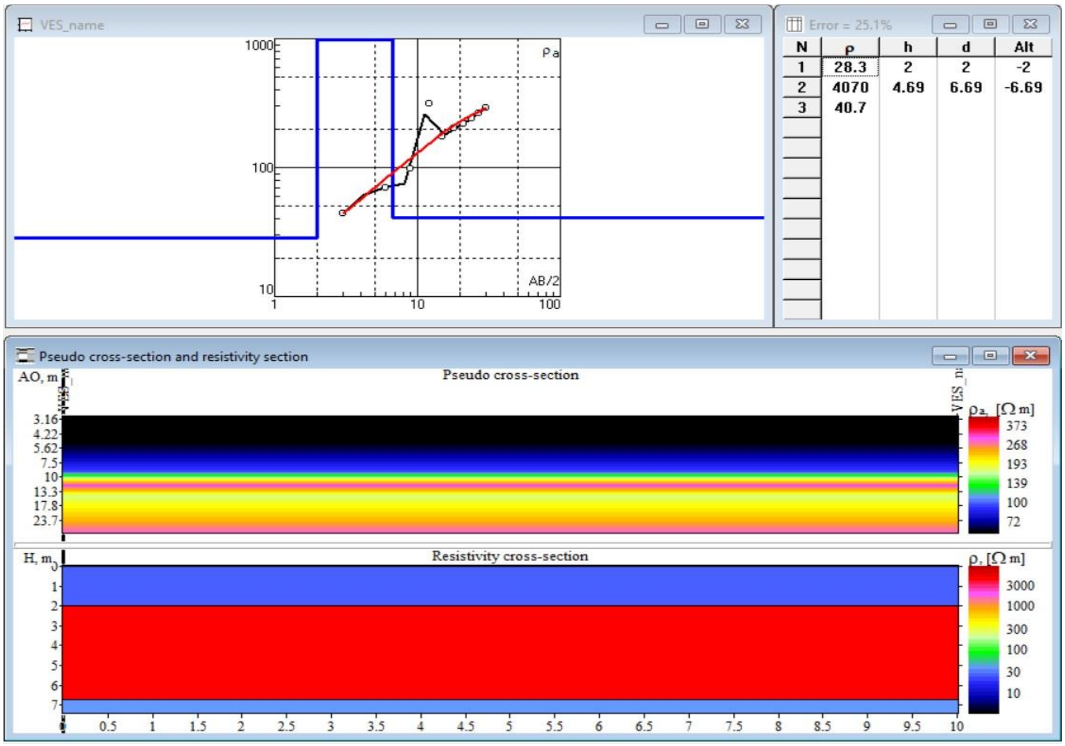

Fig.4.10 Sounding curve of the location L13 (K-Type)

__4.1.1.3 A type curve__

The locations L2 (Kalyanappetta), L5 (Muthuswami) and L12 (Mullanthodu) showed 'A' type curve with three layer model with the resistivity sequence of ρl< ρ2< ρ3. The resistivity of first and second layer ranged from 42.7 to 331.9 Ohm-m which indicates the presence of clayey soil. The resistivity of third layer ranged from 9437 to 12931 Ohm-m which indicated the presence of hard rock formation.

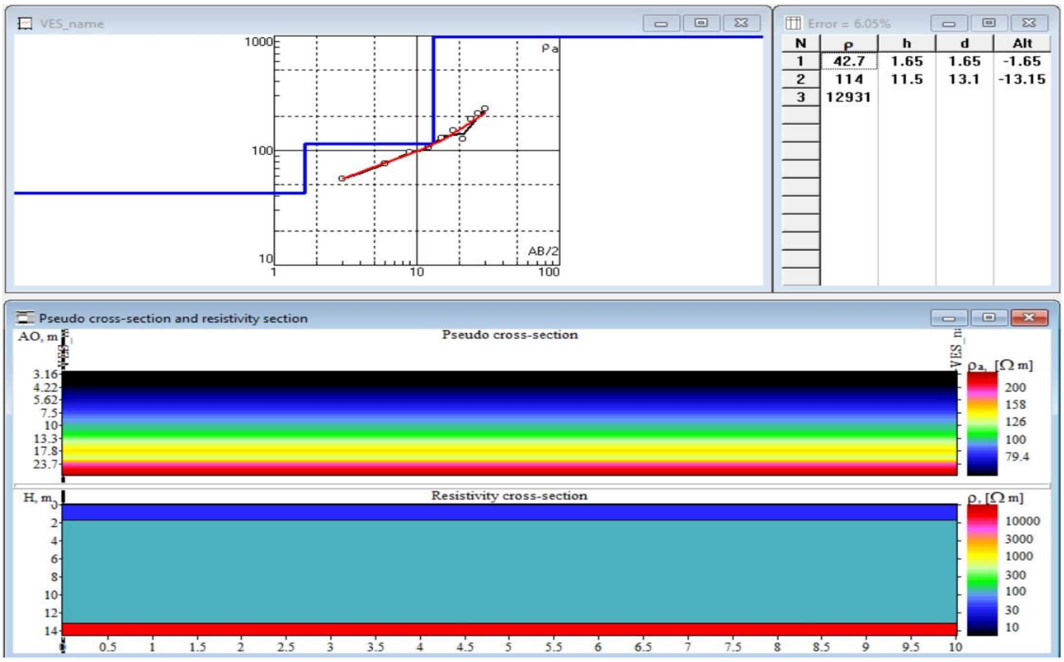

Fig.4.11 Sounding curve of the location L2 (A-Type)

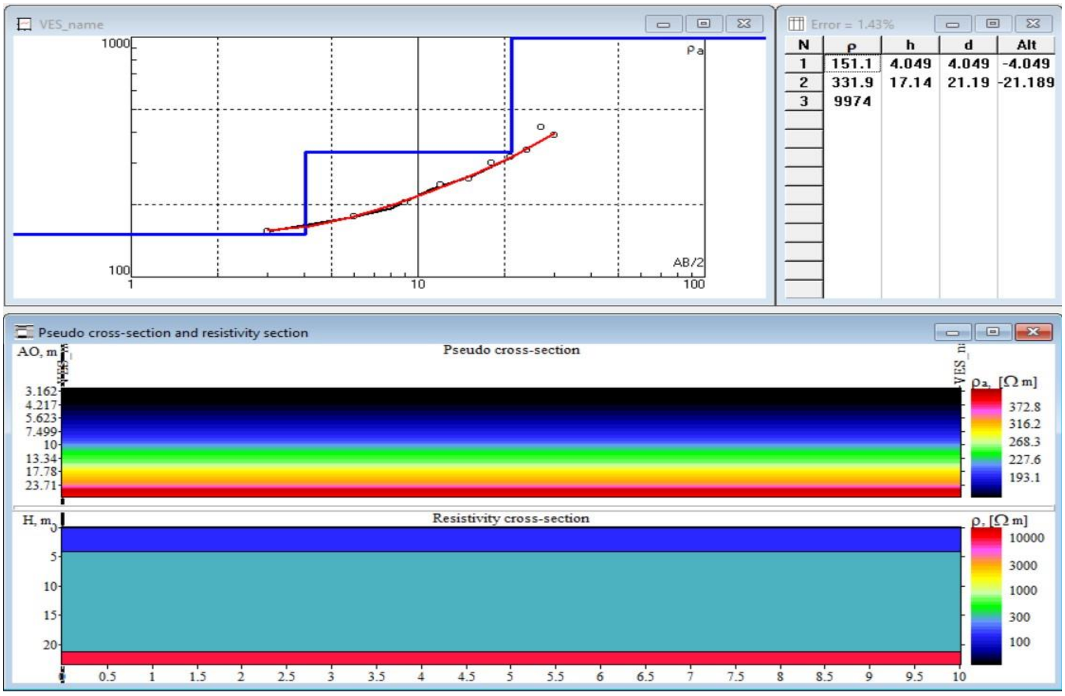

Fig.4.12 Sounding curve of the location L5 (A-Type)

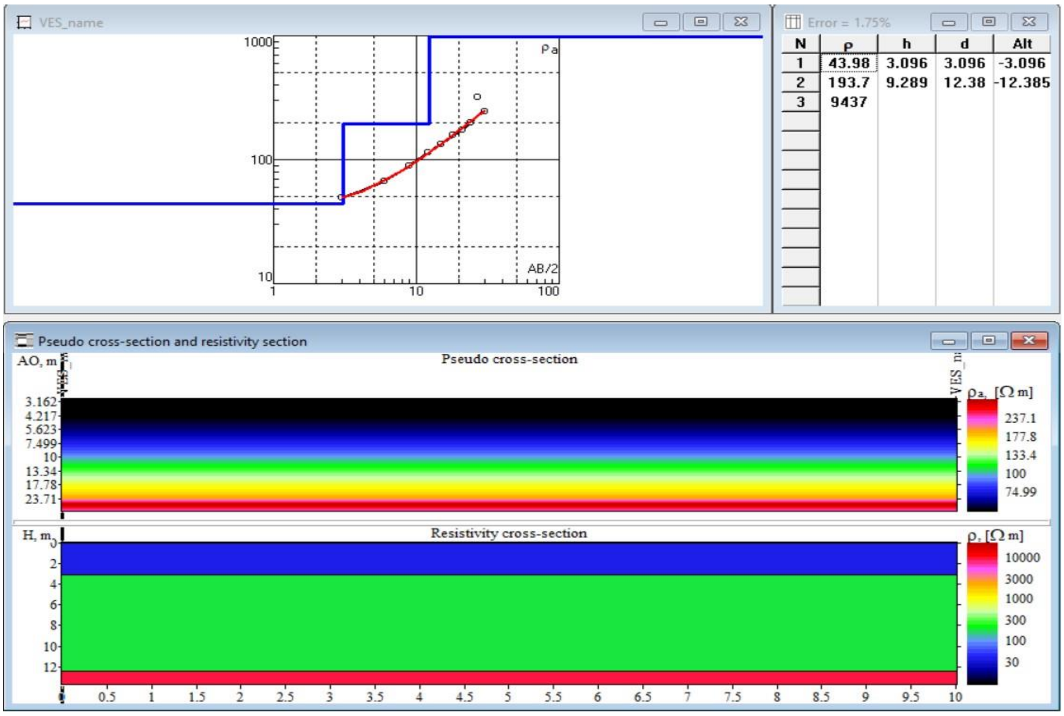

Fig.4.13 Sounding curve of the location L12 (A-Type)

By using the pseudo cross- sections we can identify the resistivity and water availability of different regions.

SUMMARY AND CONCLUSION

CHAPTER V

SUMMARY AND CONCLUSION

Groundwater resources are investigated through geophysical studies carried out on Earth's surface, which involve the observation of physical characteristics such as density, velocity, conductivity, resistivity, magnetic, electromagnetic and radioactive phenomena. The measurement of signals from induced or natural processes pertaining to the physical characteristics of subsurface formations is included in geophysical methods. They identify variations or anomalies in the physical characteristics of the crust of the earth. Elasticity, electrical resistivity, density, and magnetism are the characteristics that are measured most frequently.

In the present study, the groundwater potential zones of Perumatty Grama Panchayath were analysed and investigated using electrical resistivity method. The geophysical study and reconnaissance survey were carried out to determine the appropriateness of the chosen sites. Using a signal stacking resistivity meter, a Vertical Electrical Sounding (VES) survey was carried out in the designated places to investigate the hydro-geological features of the region. The resistivity measurements were acquired and the VES survey was conducted using the Schlumberger electrode arrangement.

The output obtained from VES survey was interpreted using the sounding curves derived from IPI2WIN software from the sounding curves of 13 locations. These locations showed three layered substrata. A total of 3 types of sounding curves were obtained. viz. H, K and A type.

H type sounding curves having a resistivity profile $\rho1 > \rho2 < \rho3$, were found in the locationsL4 (Muthuswami), L7 (Sarkkarpathy), L8 (Mullanthodu), L9 (Sarkkarpathy) and L11 (Mullanthodu). H type curve indicates good aquifer characteristics with lower resistivity in the middle layer. L7 and L11 had a third layer of resistivity 32825 and 24210 ohm-m which indicates the presence of hard rock.

K type sounding curves having a resistivity profile $\rho l < \rho 2 > \rho 3$,were founded in the locations L1 (Kalyanappetta), L3 (Kalyanappetta), L6 (Muthuswami), L10 (Sarkkarpathy) and L13 (Kalyanappetta) shows very high value of resistivity in the middle layer which indicates hard rock. The top and bottom layers mainly show a clayey soil formation.

A type sounding curves having a resistivity profile $\rho l < \rho 2 < \rho 3$,L2 (Kalyanappetta), L5 (Muthuswami) and L12 (Mullanthodu) shows higher resistivity value in the third layer which shows hard rock but first and second layer shows clayey soil formation.

From the study it can be concluded that, out of 13 locations, 5 locations showed H type and 3 locations showed A type sounding curves. These locations show comparatively higher water potential in both top and middle layer of soil formation.

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CHAPTER VI

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GEOPHYSICAL TECHNIQUES FOR AQUIFER CHARACTERISTIC STUDIES – A CASE STUDY OF PERUMATTY GRAMA PANCHAYATH IN KERALA

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ABSTRACT OF PROJECT REPORT

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ABSTRACT

Groundwater exploration and management are critical due to the increasing demand and over-exploitation of this vital resource. Electrical resistivity surveying, a geophysical method, has proven to be an effective technique for subsurface investigations, including groundwater detection. This thesis presents the application of electrical resistivity methods in groundwater exploration in Perumatty Grama Panchayath, Palakkad, Kerala.

The methodology involved Vertical Electrical Sounding (VES) and resistivity imaging to identify and delineate groundwater potential zones. A total of 13 locations were surveyed using the Schlumberger electrode configuration. The resistivity data were interpreted using IPI2WIN software, resulting in the identification of three types of sounding curves: H-type, K-type, and A-type.

H-type curves ($\rho 1 > \rho 2 < \rho 3$) were observed in five locations (L4, L7, L8, L9, and L11), indicating good aquifer characteristics with lower resistivity in the middle layer. K-type curves ($\rho 1 < \rho 2 > \rho 3$) were found in five locations (L1, L3, L6, L10, and L13), showing high resistivity in the middle layer, indicating hard rock formations with clayey soil in the top and bottom layers. A-type curves ($\rho 1 < \rho 2 < \rho 3$) were observed in three locations (L2, L5, and L12), indicating hard rock in the third layer and clayey soil in the first and second layers.

The study successfully identified aquifer zones and provided insights into the subsurface geology of Perumatty Grama Panchayath. The H-type and A-type locations showed comparatively higher groundwater potential in both the top and middle layers. These findings demonstrate the efficacy of electrical resistivity methods in hydro-geological studies and highlight their importance in sustainable groundwater resource management. The results suggest that the electrical resistivity method is a reliable tool for identifying groundwater potential zones, which is essential for effective groundwater management in the study area.