Chowgule College

GEOPHYSICAL SURVEY USING VERY LOW FREQUENCY ELECTROMAGNETIC METHOD TO DELINEATE BORE-WELL POINTS FOR RECHARGE AS WELL AS FOR PRODUCTION PURPOSE AND PREPARING A DECENTRALIZED WATER MASTER PLAN BYSETTING UP A RAINWATER HARVESTING SYSTEM FOR PARVATIBAI CHOWGULE COLLEGE OF ARTS AND SCIENCE AUTONOMOUS, GOGOL, MARGAO-GOA

A project report submitted in partial fulfilment of the requirement of degree of

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CERTIFICATE BY SUPERVISOR

Certified that the Project Report is a record of work done by the candidates themselves under my guidance during the period of study and that to the best of my knowledge, it has not previously formed the basis of the award of any degree or diploma of any other University

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MARGAO

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CHAPTER I

INTRODUCTION

1.1 AIMS AND OBJECTIVES

The primary aim of the study is to delineate suitable bore-well points for recharge as well as for productivity purpose in Parvatibai Chowgule College of Arts and Science Autonomous, Gogol, Margao-Goa using the Very Low Frequency – Electromagnetic (VLF EM) geophysical method and Setting up a Rainwater Harvesting System for the college. In order to achieve the aim, the following objectives have been set:

1) Carry out VLF EM survey in the area under investigation on a grid pattern.
2) To identify suitable bore-well points for drilling.
3) GPS marking of the anomalous points in the field.
4) To prepare contour maps to understand the groundwater occurrence in the subsurface.
5) To prepare and suggest a decentralized water master plan by setting up a rainwater harvesting system.

The premise of the college has been located on the downslope of a small mound. The North Western and South Eastern boundaries of the campus are bounded by two gullies. During every rainfall a huge amount of rainfall is found down to gush down these gullies into drains.

A need is thus felt to augment the supply of water requirements of the college by tapping such water and prepare a plan showing recharge points.

1.2 INTRODUCTION

In India water resources are not uniformly distributed over the country due to uneven rainfall in time and space, and highly varied hydro-geological set up. Nearly 65 percent of the country is occupied by hard rock's whose receptiveness to absorb precipitation is limited, so also their capacity to store and transmit water. As a result even in high rainfall areas, water scarcity is felt in summer months. Major portion of the hard rock area receives rainfall less than 1000mm and most of the drought prone areas are occupied by hard rocks. Hard rocks are devoid of primary porosity, the secondary porosity developed due to tectonic and erosive activities, generally confined to depth of 100-200m. Groundwater potential available is limited. Because of the low storage available the fluctuation of the water table is high and steep declining trends have set in due to over exploitation. There are also wide variations in the aquifer parameters. This necessitates a multi-disciplinary approach to assess the ground water potential, scope of its development and management (K.C.B. Raju, GJMGSI No.69, 2008, pp1-20).

Groundwater is a significant contributor as a vital source catering to the ever growing needs of water in the country. Post-independence the urge to become self-sufficient in food grains production led to the accelerated exploitation of groundwater which now accounts for 50 percent (and in some quarters estimated as 70 percent) of the total irrigation in the country. It has also proved to be a sustainable source for drinking water. The situation is critical in the peninsular hard rock areas. Hard rock aquifers are by nature limited in their potentials and uneven in occurrence, being confined mostly to the weathered residuum, fracture and fissures, generally within a depth of 60meters. A major part of this terrain falls in drought prone zone with uncertain rainfall regime affecting both surface water availability and natural recharge to groundwater. Mushrooming of bore wells arising out of excessive dependence on groundwater has been responsible for groundwater mining or overdevelopment (Subhajyoti Das, 2008).

History of Groundwater Development

Groundwater is safe, potable and free from impurities and it provides a sustainable source for drinking water.

Several droughts in most of the states where agriculture is a prime occupation brought in the need for systematic hydrogeological surveys and exploration were speeded up by the Groundwater Division of Geological Survey, and Exploratory Tube wells Organization (ETO), to support accelerated groundwater exploitation to insure agriculture and drinking water against rainfall vagaries. Use of sophisticated tools like remote sensing, geophysical probing also aided groundwater exploration and its enhanced exploitation (Subhajyoti Das, 2008).

Groundwater Overexploitation

Overexploitation or groundwater mining is when groundwater drafts exceed its annual recharge and dents into the static reserve occurring below the zone of dynamic fluctuation. Various workers have defined overexploitation by referring to various physical manifestations and environmental consequences (CGS, Subhajyoti Das, 2008).

The adverse fall outs of groundwater overdevelopment are equally diverse: (1) continuous decline of water level; (2) drying of wells; (3) fall in well yield and shrinkage of well command;

(4) reversal of hydraulic gradient in the coast and seawater intrusion; (5) decline in base flow of streams and their increasing pollution; (6) pollution of groundwater; (7) drinking water scarcity;(8) various other adverse effects on ecology and environment. (CGS, Subhajyoti Das, 2008).

Groundwater Pollution

Groundwater quality is a crucial aspect of groundwater management. Overexploitation and various anthropogenic activities have led to increasing deterioration of groundwater quality which is a matter of worry. In the overexploited areas of Tamil Nadu, Andhra, Karnataka or Rajasthan groundwater invariably shows high concentration of fluoride is of geogenic origin. Increasing fluoride contents above appreciable levels in drinking water has been directly correlated with pumping rates, declines and fluctuations of water levels (KON, 1992).

Ground water contributes to about eighty percent of the drinking water requirements in the rural areas, fifty percent of the urban water requirements and more than fifty percent of the irrigation requirements of the nation.

Rainwater Harvesting System

Rainwater Harvesting is a simple technique of catching and holding water whenever and wherever it falls. Either we can store it in tanks or we can use it to recharge the groundwater depending upon the situation.

Methods of RainWater Harvesting System

There are two ways of harvesting rainwater:

- Surface run-off harvesting

  Surface runoff water harvesting system includes collection, treatment (purification), and storing of storm-water for its eventual reuse.It also includes other catchment areas from man-made surfaces, such as roads, gardens and playing fields.The main challenge of surface runoff water harvesting is removal of pollutants in order to make the water available for reuse.

- Roof top rainwater harvesting

  It is a method of catching rainwater where it falls. In rooftop rainwater harvesting, the roof becomes the catchment, and the rainwater is collected at the roof of the building. The water can either be diverted to artificial recharge system or stored in a tank.

1.3 PHYSIOGRAPHY OF GOA

The state is classified into three types of terrain. This grade is from:

- Low lying coastal-estuarine plains to the West
- Undulating region in the central part
- The steep slopes of the Western Ghats on the eastern border.

1.4 LOCATION OF GOA

The State of Goa lies on the West Coast of India between N14° 53' and N15°48'. The entire length of the coastline is about 100 kilometres, and is broader towards the North. The western and Eastern are approximately E73°39' and E74°20' respectively. The State of Goa has been divided into two districts:

1. North Goa
2. South Goa

The western coastal-estuarine plains with tablelands

It consists of low-lying features such as estuarine mudflats, mangroves, sandy beach, fields and settlement areas. The estuarine plains extend over 10 to 12 km inland. These plains are more prominent in North Goa; yet they do not stretch uniformly and are interrupted by low (less than 100 meters high) laterite topped plateaus. These tablelands often form rocky headlands abutting the sea front and between them lie the sandy beach stretches of the low lying coastal plains. In the Southern part of the state, i.e Quepem and Canacona coast, the coastal estuarine plains are much smaller, remote and limited in extent. Here the terrain is hilly and mountainous even near the Coast.

The central undulating region

This region ranges from 100 to 600 metres and is made up of relict hills. It is a transition between the lower coastal plain and plateau terrain and the steeper, higher terrain of the Western Ghats. The Western Ghats are situated further inside in North Goa and hence the region is broader to the north. The hills and valleys of this undulating region are aligned in a NW-SE direction. In North Goa the structure of the rock formations is NW-SE and therefore the inland hill ranges remain almost parallel to the coast. In South Goa the structure of the rock formations is trending WNW-ESE and therefore the hill ranges and the Ghats have a trend closer to E-W and as the coastline is almost trending NW-SE the E-W trending hills and ridges encounter the sea at their Western ends.

The Western Ghats:

It is a hilly region that consists of steeper and higher ranges ranging from 600 to 1000 meters. It covers the Eastern and the Southern portion of Goa. The Western Ghats are also known as Sahyadris and have a general NW-SE trend except for the ranges in south Goa. In North Goa, they are over 40 km away from the sea. In the south however, the trend of the hills, is almost East-West (WNW-ESE). In this region, a western arm of the Ghats also known as the Karmal Ghat, literally meets the sea in its lower contacts. As a result, the talukas of Quepem and Canacona have very limited areas of the coastal estuarine plain and the midland region translates very sharply into the Ghat region.

1.5 DRAINAGE

The State of Goa is drained by the west flowing rivers namely Terekhol, Chapora, Mandovi and Zuari. The Sahyadri hill ranges in the east form the main watershed. The streams originating here flow in westerly and northwesterly direction to join the Arabian Sea. Major portion of the State is drained by the two rivers, namely Mandovi and Zuari. The river Terekhol forms the northern boundary of the State and separates it from the Maharashtra State. The other smaller rivers draining the State are Chapora, Baga, Saleri, Sal, Talpona and Galgibaga.

The underlying rocks govern the drainage system in the area. The drainage pattern in general is dentritic type. The major river Zuari follows the NW synclinal axis. The river valleys are 'V' shaped in the eastern high hill ranges, broaden in central midlands and become 'U' shaped in the low lands and coastal plains.

1.6 CLIMATE AND RAINFALL

The State has a tropical-maritime monsoonal type of climate with distinct orographic influence. The climate is humid throughout the year. Due to the maritime climate, the diurnal variation in temperature is not much. The months of January and February are dry with clear skies and generally pleasant. May is the hottest month with a temperature of about 30°C and January is the coolest month with temperature of about 25°C.

Rainfall occurs during the monsoon period from June to September. Over 90% of the annual rainfall occurs during the monsoon period. The remaining 10 % occurs during the pre-monsoon period from March to May and post-monsoon period from October to December. However, the rainy season extends from May to November.

The analysis of Rainfall data for the period from 1970 to 2000 from 12 stations over the Goa state indicates that the monsoon rainfall is in the order of 3460mm (90 % of annual rainfall), 218.1mm (6%) during post monsoon period of October to December and 102.5(4%) from January to May months. The total annual rainfall over the Goa state based on 30 years rainfall data is of 3483.3mm. The minimum rainfall of 2611.7mm is recorded at Mormugao station in South district and maximum of 5090mm is in Sanguem station also from South Goa. The annual normal rainfall in North Goa ranges from 2766.9 at Panaji along the west coast and highest at Valpoi in the east (Ghats section) indicating that the rainfall increases from west to east.

Average rainfall in North Goa is 3400.1mm. Similarly in South Goa it ranged 2611.7 mm at Marmugao in west coast and maximum at Sanguem in the east, again in the Ghat section indicating that the rainfall increases from west to east. The total annual normal rainfall in south Goa is 3733.13mm.

The months of June (840.7mm) and July (1246.9mm) are the wettest months with around 2187.6mm (62.80% of annual normal rainfall) rainfall in two months. Rainfall during the months of January and February is minimal. Valpoi in North Goa and Sanguem in South Goa, both in the interior hilly areas, are wettest places in the state.

1.8 GEOLOGY OF GOA

Covering an area of about 3700 sq. km. on the West coast of India, the state of Goa forms a part of the Indian Precambrian shield. In this region, there are greenschist supracrustal rocks, which overlie Anmod Ghat Trondhjemitic Gneiss, which is the oldest known rock found in Goa. This gneiss forms the basement for the Goa Group of rocks. It is fine grained and has a metamorphic fabric. Petrographically the composition varies from trondhjemite, tonalite to granodiorite (TTG). Granites, dolerites and gabbros of relatively younger age intrude these rocks. The Deccan Traps of the late Cretaceous are found only at the north-eastern border of the state. Laterite, alluvium and sand, cover most of the geological formations.

The Goa Group of rocks consists of low grade metamorphic rocks greenschists facies and is divided into the Barcem, Sanvordem, Bicholim and Vageri Formations in the ascending order of superposition.

The Barcem formation, the oldest stratigraphic unit which is dominant in South Goa, accounts for a thickness of over 2 km. It consists mainly of meta-volcanics and meta-basites with few meta-sediments.

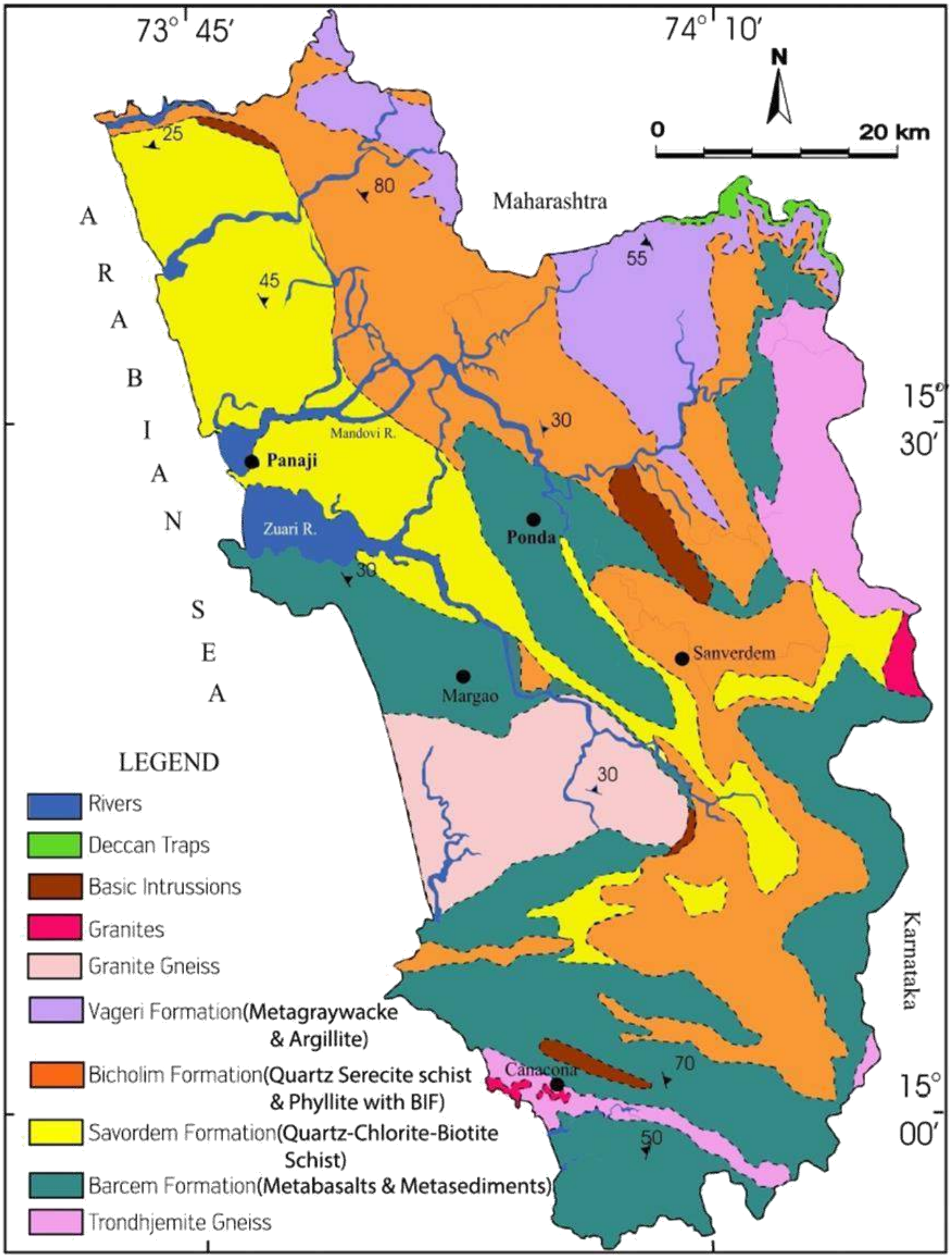
The Sanvordem Formation rests on the Chandranath Granite Gneiss with a metaconglomerate at the base and comprises of metagreywacke and argillite. Best section of this formation is exposed along the railway track between Sanvordem railway station and Periudoc which is over 1.2 km thick. The metagreywackes are slightly schistose and show graded bedding. The argillites are grey in colour and consist of quartz in a sericite-chlorite matrix with opaques.

This Bicholim Formation consists of amphibole schists, ferruginous and manganiferous phyllites, limestones and banded ferruginous quartzites. Average thickness of the Formation is about 1.4 km (Gokul et al. 1985).The banded ferruginous quarztites serve as the protores for the iron ore deposits that are extensively developed in this formation. The BHQs are finely laminated and consist of alternate laminae of hematite/magnetite and chert. The banded iron formation (BIF) consists of two sub-facies namely the hematite sub-facies and the magnetite sub-facies, both of which show inter digitated relationship. The hematite sub-facies predominate in the north-western and central part of the State while the magnetite sub-facies are largely confined to the central and the south-eastern part.

The Vageri Formation overlies the Bicholim Formation. It is best exposed to the northeast of Valpoi. It comprises of metagreywacke-argillite with intercalated metabasalts. The metagreywackes are grey to greyish green in colour, compact and show poorly developed schistosity. The metabasalts occur as narrow, lenticular intercalations within the metagreywacke and it exhibits a poorly developed foliation at some places.

Table 1: Geological Sequence of Goa

Late Cenozoic to recent		Sand, alluvium, lateritic soil and laterite
Upper cretaceous to lower Eocene		Deccan trap volcanic and dolerite dykes
Early Proterozoic (<2500 My)		Acidic and Basic intrusive including granites, gabbros, dolerite dykes and ultramafics.
A R C H A E A N	**(DHARWAD SUPER GROUP)**	Vageri formation: detrial metasediments (quartzites metagraywakes and argillites) with some metavolcanics.
	GOA GROUP OF ROCKS (3000-2500 MY)	Bicholim formation: mainly chemogenic sediments (phyllites and banded haematite quartzite and limestone)
		Savordem formation: detrial sediments including metaconglomerates, quartzites, metagraywackes and argillites.
		Barcem formation: mainly metavolcanic and metabasites with few metasediments.
	(<3000 My)	Basement trondhjemite Gneiss



Map 1.1: Geological map of Goa

CHAPTER II

AREA OF STUDY

2.1 General Geology of South Goa

Four distinct morphological units from west to east divide the physiography of South Goa, namely:

i. Coastal plain with marine landforms on the west
ii. Vast stretch plains adjoining the coastal plain
iii. Low dissected denudation hills and tablelands towards the east, and
iv. Deeply dissected high Western Ghats denudation hills along the eastern most part of the district.

2.2 Hydrogeology

Occurrence and movement of groundwater is dependent on various factors like type of rock formation, topography, groundwater recharge, rainfall received etc. In South Goa it is observed that groundwater occurs in those rocks which have primary porosity and permeability or in those having secondary porosity attained due to weathering, leaking, tectonics, solutions, etc.

Laterite, alluvium, granite, granite gneiss, metavolcanics and metasediments are the groundwater formations which are found in South Goa.

2.3 Types of Aquifers

Groundwater occurs in many types of geological formations, the most important aquifers being:

1. **Laterites**

Laterites are the most important water bearing formations. Laterites are highly jointed and fractured and these properties determine their water bearing capacity. Groundwater occurs under water table conditions in lateritic formations.

2. **Alluvium**

Alluvium makes up good aquifers and is constrained mostly to banks of rivers. Alluvium aquifers consist of fine to coarse sand with intercalations of sandy loam, silt and clay.

3. **Granite and Granite Gneiss**

Groundwater exists under unconfined, semi-confined and confined conditions in weathered and fractured zones of granite and granite gneiss.

4. **Metavolcanics**

Metavolcanics are very poor in groundwater in unaltered state. However, groundwater is found to occur in zones having secondary porosity and permeability caused due to weathering, joints and fractures.

5. **Metasediments**

Shales, phyllites, schists, metagraywackes, argillites and quartzites commonl consist of metasediments.

Map 2.1: Map showing location of study area

CHAPTER III

METHODOLOGY

Many geophysical methods find application in locating and defining subsurface water resources. They provide rapidly collected information on the geological structure and prevailing lithologies of a region without the large cost of an extensive drilling program. The geophysical survey results determine the location of a minimum number of exploratory boreholes required for both essential aquifer tests and control of the geophysical interpretation. A geo-hydrological survey is supplemented by geophysical survey to ascertain water bearing zones of shallow, deep horizons and salinity levels.

3.1: VERY LOW FREQUENCY METHOD

The VLF EM method belongs to the electromagnetic methods applied in near-surface geophysics. Its main application is the mapping of vertical discontinuities such as faults, flexures and ore mineralization zones (Saydam 1981). It is used also in hydrogeological studies and detecting deposits of particular rock material (Chandra 2015).

The VLF method uses electromagnetic waves of very low frequency in terms of radio waves. The instrument measures the radio signal distortion. From the standpoint of geoelectrical methods, these frequencies are considered to be quite high. The sources of such waves are strong military radio stations used to maintain communication with submarines. There are 11 major VLF transmitters distributed around the world (Reynolds 2011). They are emitting waves in the frequency range from 15 to 30 kHz. Electromagnetic field is polarized cylindrically around the antenna. Registered electromagnetic waves can be divided into:

- Ionospheric waves, which once or multiply bounce off the ionosphere and the surface of the earth. The most common are singly (first sky hop) and doubly (second sky hop) reflected waves;
- Spatial waves, which propagate in the air, directly from the transmitter to the receiver;
- Ground waves, which propagate in the soil. These are recorded only at short distance from the source.

Source signal is described by cylindrical coordinates, but it is better to transform it into Cartesian system. The primary field contains a vertical electric field component (Ez) and a horizontal (tangent) magnetic field component (Hy), both perpendicular to the direction of propagation, x, and a horizontal (radial) electric field component (Ex). Electromagnetic field properties usually are discussed for two areas: the near zone (induction) and far zone (radiation). The far zone refers to the regions in which the distance between transmitter and receiver is many times bigger than the wavelength. The VLF measurements are carried out at a great distance (far zone). Conductors in the earth modify the Hy component and create the vertical component Hz. The vertical magnetic component is measured as ratio Hz/Hy. The primary Hy penetrates into the ground and induces eddy currents forming a secondary horizontal electric component in buried conductive structures. At a great distance, the horizontal electric component is much less than the vertical electric component (Tabbagh et al. 1991). A secondary magnetic field is generated which is out of phase with the primary magnetic field. The intensity of the secondary magnetic field depends on the conductivity of the ground (Khalil and Santos 2010). Resultant magnetic field, which is produced by the interference between the primary and the secondary magnetic fields, is elliptically polarized. The parameters of interest are: (a) the orientation of the minor ellipse axis (tilt angle, α), also called the real (in-phase); and (b) the ratio of the minor to the major ellipse axes of the polarization (ellipticity, e), also called the imaginary (quadrature) component (Karousand Hjelt 1977).

The method is based on measurement of the secondary fields produced by the underground conductive bodies, which are subject to action of the primary electromagnetic field. Although the source of the waves is artificial, we classify the VLF method as passive and operating in a far field of the source. The reason is that the signal transmission is done completely independently of its registration (serves other purposes), and takes place at a distance of at least several hundred kilometers from the research area. We can therefore consider an electromagnetic wave as a planar rather than spherical wave. In the VLF method, measurements are carried out mostly along profiles parallel to each other. Theoretically, designing profiles perpendicular to the investigated structure should lead to the best results and also indicates that the structure is a good drilling target. However, the course of the structures seldom is well understood, which requires previous reconnaissance measurements (Kaufman and Keller 1981).

3.2: INSTRUMENT OVERVIEW

The instrument used for the study was the PQWT-W200, which is a Chinese instrument manufactured by the Hunan Puqi Geologic Exploration Equipment Institute which is a professional institution in China which is engaged in the R & D, manufacturing and sales of geophysical prospecting instruments.

PQWT-W200 series geophysical prospecting instrument makes the use of natural electric field source as a working farm, with resistivity contrasts of underground rocks and minerals or groundwater detected based on measuring the natural electric field on the surface at N different frequencies of the electric field component. According to their different variations to study abnormalities in geological bodies and reaching to solve geological problems are one of these electrical prospecting methods. Because this method measures the electrical component of the electromagnetic field of the earth, it is called as natural electric field method; and the corresponding frequency can be measured within 50meters, with the selected frequency, so called frequency selection method, it is always referred to as natural potential frequency method. According to this theory the design and production of equipment called potential frequency of detecting instrument, referred to natural selected frequency electric field instrument or instruments for geological exploration work. Therefore, from a professional point of view to classify, geological equipment should belong to this category in the instrument geophysical equipment among electrical equipment. From the application point of view to classify, it can be called prospecting meter or water detector. From the perspective of the measurement of field source classification, also known as natural electric field instrument, audio electric field instrument, the earth audio instrument. The instrument makes the use of earth's natural field source without going through artificial field that is omitted by the power supply system in order to achieve the simple, lightweight instrument. After data collection through the instrument's unique built-in computing functions to achieve the automatic presentation graph the collected data can also be transferred to a computer drawing to form a cross-sectional view, the geological layer, structure can be quickly determined by a clear understanding of cross-sectional view of the ore body (seam), hollow (cave), water (aquifer) thus giving specific information.

3.3: ADVANTAGES

- **High measurement speed, high efficiency**

  Completes more than 6000m profile measurement in one day to realize geological abnormality in different depths i.e. the instrument can scan up to 200m depth, the prospecting speed and efficiency is improved about 10 times more than traditional resistivity method.

- **Convenient to carry**

  Without heavy power supply, it uses low frequency signals in earth's natural electric field as signal source, and the complete set weight is less than 3kg and so it is easy to carry.

- **Simple operation**

  Equipment is automatically controlled by micro PC. You can learn its operation in 10 minutes. It will take about 30 minutes for a person without prospecting experience to finish training.

- **High accuracy**

  Using high-performance amplifiers and AD converters, FFT digital filtering techniques, PQWT-W200 has a measurement accuracy of up to 0.1mV in contrast to the traditional method of artificial electric field instrument comparable to the stability of a large number of field tests.

- **Strong anti-interference ability**

  It has advanced anti-jamming technology and multiple anti-jamming designs. You can observe abnormity curves result with good repetition even in weak signal area, city, high electric jamming area and working area with other exterior interferences via frequency selector and digital processing.

3.4: INSTRUMENT STRUCTURE

The different parts of the PQWT-W200 geophysical prospecting instrument are shown in **Fig. 3.1.**

Fig. 3.1: Different parts of PQWT-W200

3.5: THE USE OF THE INSTRUMENT

By the M, N electrode probe (transducer) via a cable, the earth's magnetic field is converted to electrical signal input to high impedance input stage , after the anti-jamming exchange amplification, frequency selection, the desired operating frequency is selected, and then by the A/D (Analog/Digital) sampling, the data is fed to the central processing unit (CPU) for data processing. Where in the entire measurement process, high-speed central processing unit (CPU) of the control, instrumentation automatic range conversion and automatic frequency selection takes place in the instrument. The last display of measured data (raw) and curves (graph) are displayed on the screen and can also be transferred on to the computer for further processing. Depending on the curves and data carried out after data analysis, one can make a geological conclusion.

3.5.1: Main Screen Description

After starting the instrument, the main screen appears which is shown in **Fig. 3.2.**

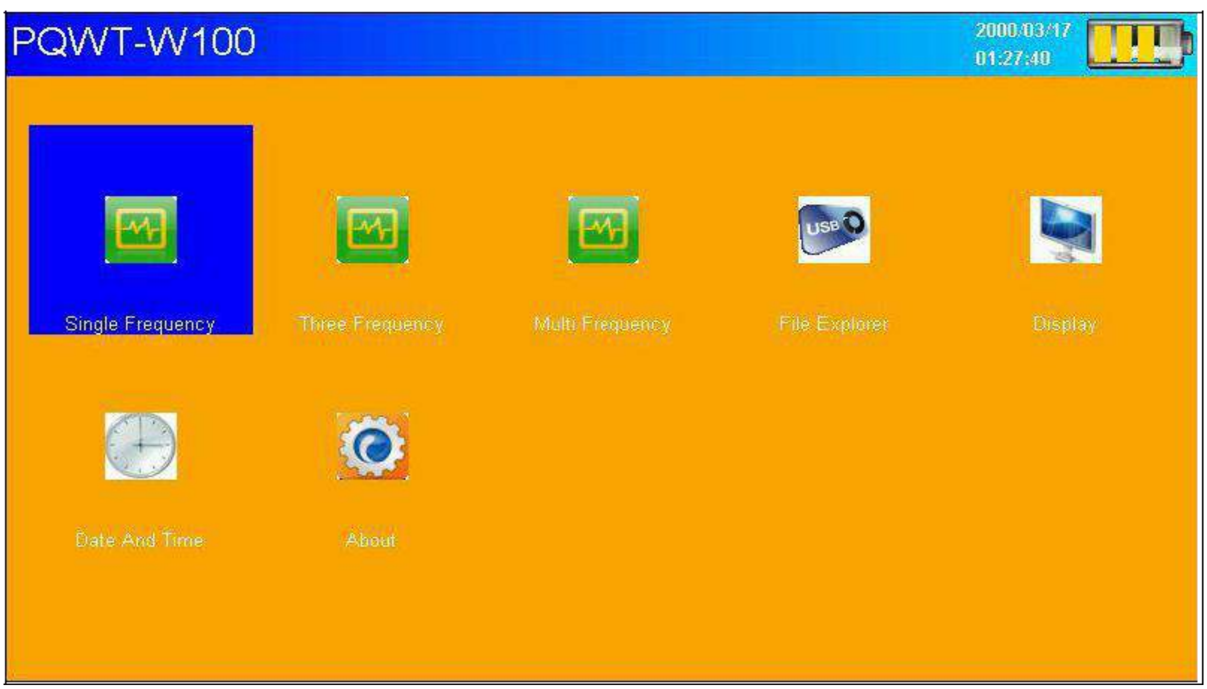


Fig. 3.2: The main screen

*Note that this is the display screen of the PQWT-W100 which is used as a sample and is the same for the PQWT-W200.

After entering the main screen, there are three states of data collection, i.e., the single frequency, triple frequency and the multi frequency. But the most preferred state of data collection is the multi frequency state as it enables the device to collect data at different frequencies (30) at different depths (up to 200m). The multi-frequency state display is shown below in **Fig. 3.3.**

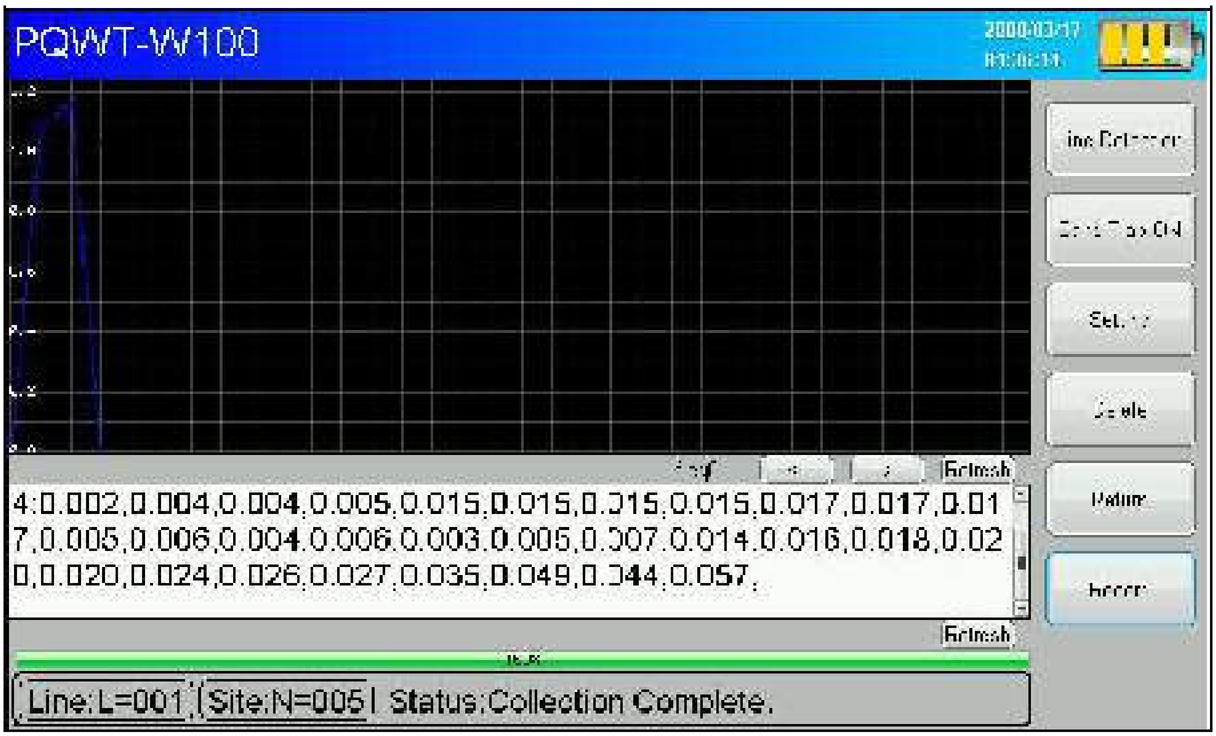


Fig. 3.3: Multi-frequency state display.

The different operations before data collection are as follows,

1. Line Detection

Check whether prospecting instrument can work normally or not before measurement. Peg down the two connected copper electrodes to the ground and put them together, click on the "Line Detection", if the detection indicator light (green) comes on, the Line or the profile is normal. Without light, unplug the two electrode rods, make the cable plug each other, and then click on the “line detection”, if there is no light, it indicates that the electrode rod failure (not pegged properly) or it is the cable fault.

2. Band Trap ON

To minimize the 50Hz frequency noise interference for the useful signal in measuring environment, to improve measurement accuracy. Turn on the band trap option (notch filter), this can improve reading value. In the case of small frequency interference the band trap can be off, but by default it is usually on.

3. Setting

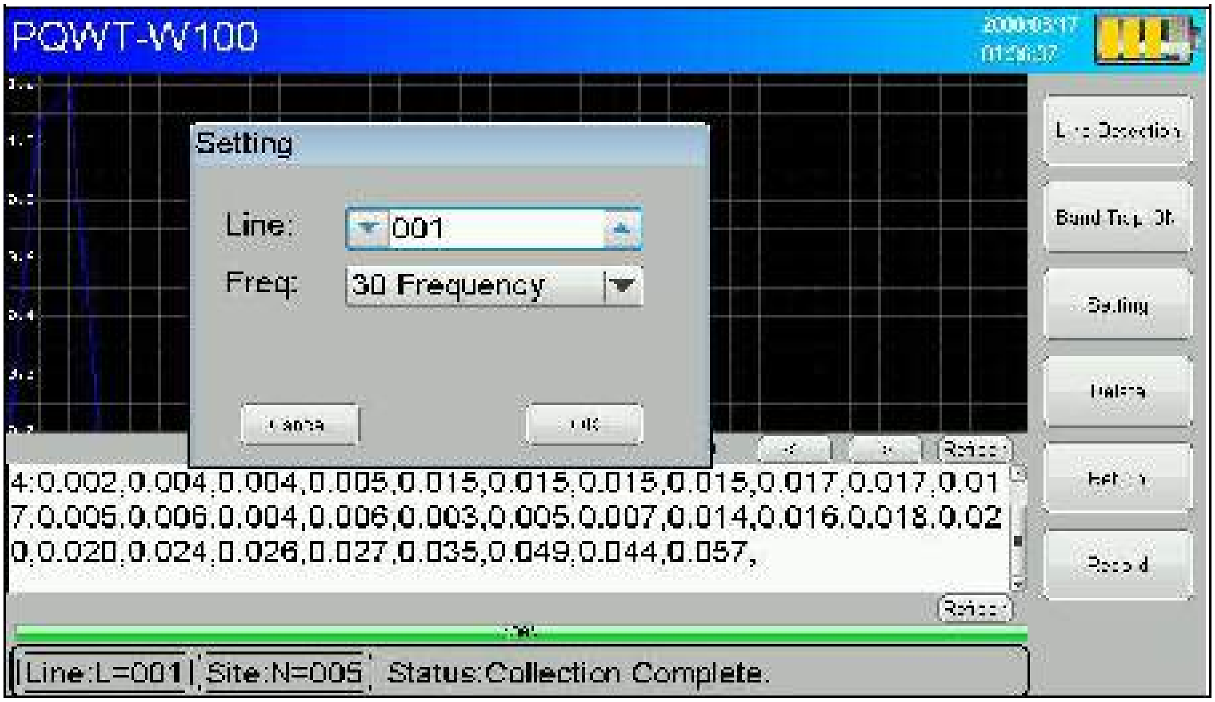


Fig. 3.4: Setting dialog box on the screen.

Click the "Setting" button, then the pop-up of the "Setting" dialog box (shown above in **Fig. 3.4**) will appear. Then select the frequency group. The group could be selected according to the different needs of sounding (in this case 30 frequencies). Then by selecting the measuring line or profile

, data collection process can be started. The instrument can store up to 999 measurement lines and each measuring line can store 999 measurement points. The display information of measuring line and measuring point is shown at the bottom left corner of the screen. The number behind "Line: L =" indicates the current line number and the number behind "Site: N =" indicates the stored measuring points on the current measuring line. For example, "Line: L =5and Site: N= 20" indicates 20points has been measured on the No. 5 line.

4. Delete

During the process of measurement or data collection, if in case of accidents or data mutations occur, the data of the last measured point or line need to be deleted, you can click on the "Delete" button. While the number behind "Site: N = " say -1, indicates that the measuring point data is deleted. Click once to delete a set of measuring point data.

5. Return

Click the "Return" button to return to the main screen after data collection is completed.

6. Record

Click on the "Record" button to start the data collection process. The screen below the status bar displays the "Waiting for operation" to "Recording Freq1 Data". Then DATA column shows the data of 30 frequencies. After data collection is completed the status will be displayed as “Collection complete”. Click the "Record" button again, but before that change the measuring line to the next number, the number after the " Site: N= " will also change to the next number, and then measure the data of next point. You can repeat this step until you complete a measuring line (N ≦999). Since the instrument stores up to 999 measuring points each measuring line , so when the number of points is 999 ("N = 999"), then click on the "Record" button, the instrument will cover the previous measurement point. Now you must press the "Setting" button after entering, re-select the " Line: 002 ", and then keep going with the measuring operation.

3.5.2: Data Output

Boot into the boot screen, and then click on the "File Explorer" to transfer the data. After clicking on file explorer the following interface will appear as shown below in **Fig. 3.5.**

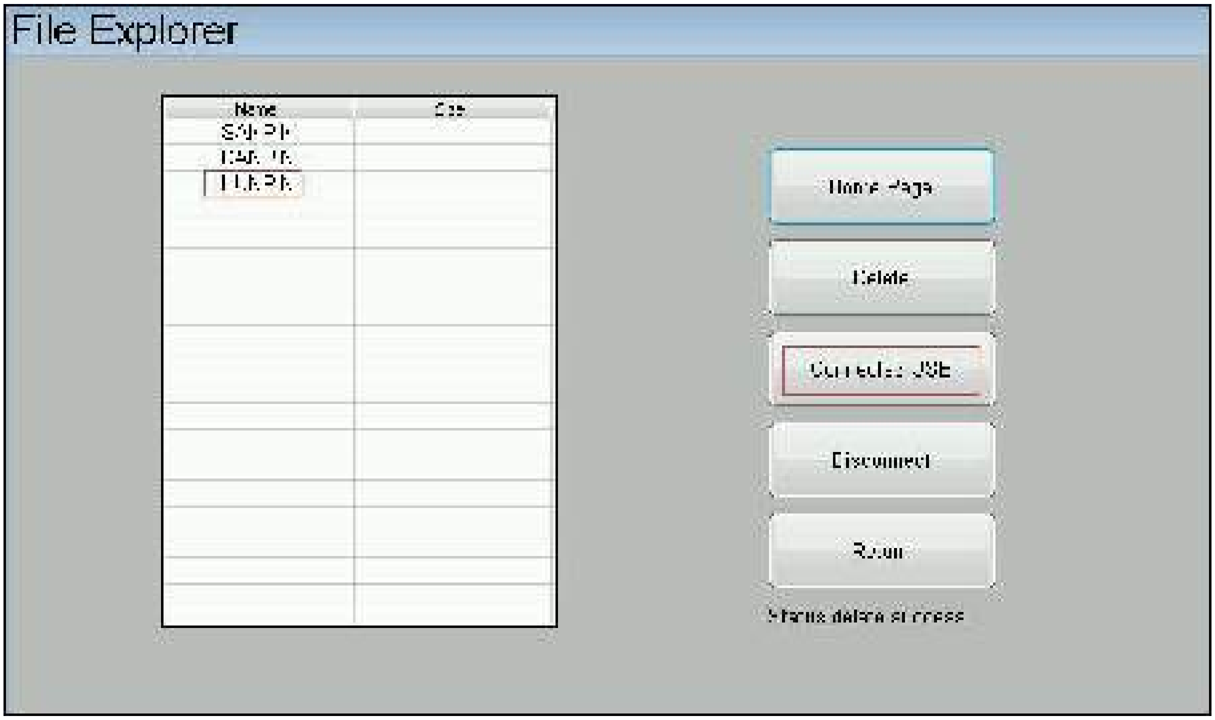


Fig. 3.5: The file explorer interface.

Click on the "Connected USB", the status will be displayed as “Connected”. Then using the data cable, connect the instrument to computer’s USB port. Then you will find the instrument’s hard drive in "My Computer", click to enter, you can find the data of HUNPIN folder and then copy the data into the computer. After transferring the data disconnect the instrument from the computer.

M N Electrode Description

The plastic electrode bar and copper electrodes are fitted to each other. This arrangement is to be handheld where the copper electrodes are inserted into the soil, the puddled soil is recommended in each insertion. Before clicking on the "Record", Press "Line Detection" firstly, to judge good

grounding, indicator lights up and then process of measuring begins. It is to be noted that on dry and hard ground, it is difficult to penetrate the electrode and the electrode should never be hammered into the ground as it will break the machine function. In such cases water and salt should be mixed with soil in a bottle, and then place the mixture on the hard ground so that the electrode can be pierced through the bottle opening. Meanwhile, there is a need to cover the line that is to be measured with salt water to improve the electrical conductivity.

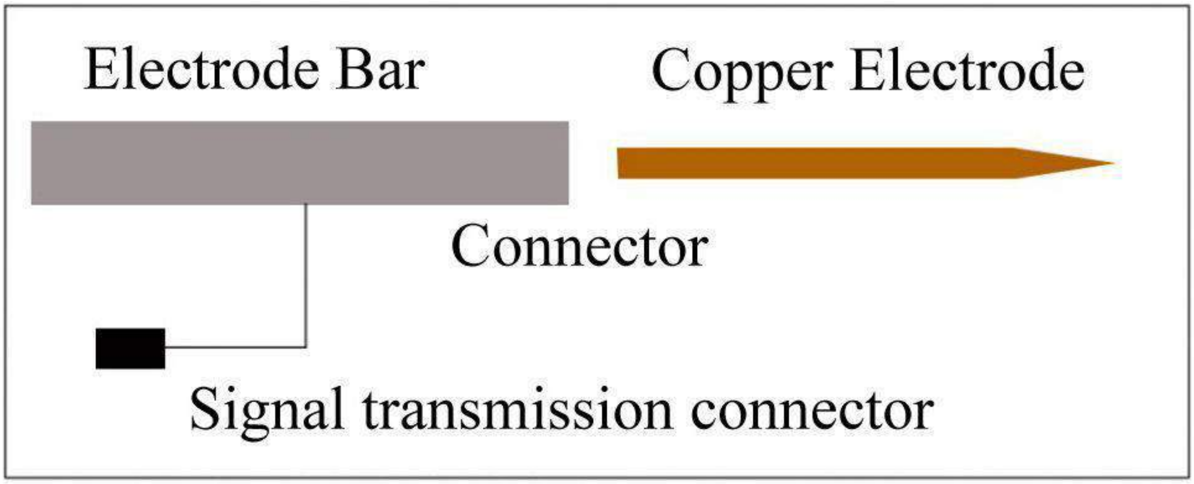


Fig. 3.6: The handheld electrode arrangement.

If an anomalous point is detected it will be a midpoint between the two electrodes, where the spacing between the electrodes is usually 5-10m or even less depending upon the space available to work in the field (as shown in **Fig. 3.7**). Dot spacing is generally about 0.5-2m, electrode spacing and dot spacing must be kept at the same distance for one measuring line.

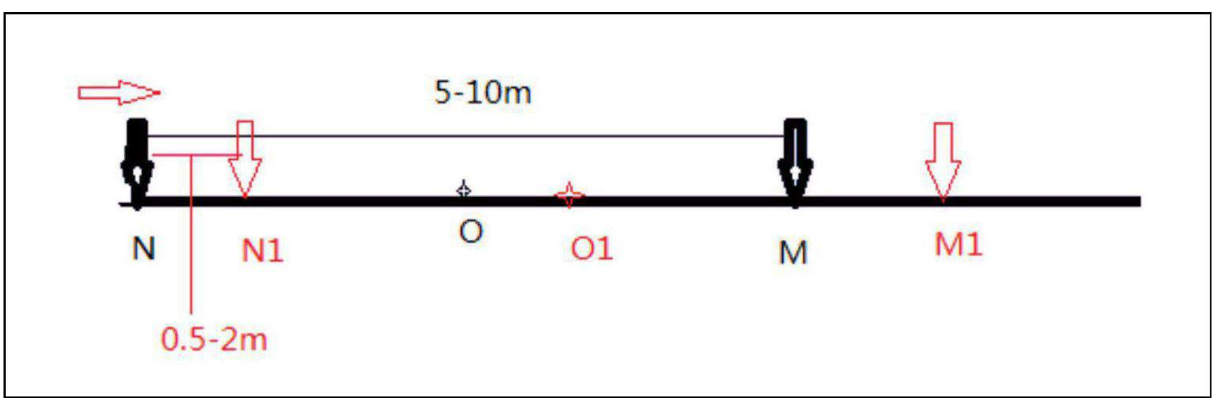


Fig. 3.7: Electrode spacing (NM) and Dot spacing (NN1)

M, N is electrode, O is the first measurement point and O1 is the second measurement point.

NM=5-10M, measuring point spacing is generally 0.5-2m.

3.5.3: Instrument Drawing Methods

1. Line Chart

Open the recorded data which is saved as an excel file named as “30FREQ_L1.xls” (L1 is the profile or line number) in the computer as shown below. Copy all values excluding L and N columns and paste to another excel file named as “PQWT-W200 30 frequency 30 points in numerical processing of 200m.xls” generated by the machine for data assimilation as shown in **Fig. 3.8** and **3.9** respectively.

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S
L	N	freq0	freq1	freq2	freq3	freq4	freq5	freq6	freq7	freq8	freq9	freq10	freq11	freq12	freq13	freq14	freq15	freq16
1	1	0.035	0.053	0.064	0.079	0.11	0.168	0.211	0.237	0.273	0.308	0.304	0.309	0.303	0.246	0.228	0.23	0.209
1	2	0.033	0.052	0.064	0.087	0.119	0.183	0.244	0.273	0.32	0.353	0.354	0.296	0.294	0.268	0.261	0.227	0.183
1	3	0.027	0.044	0.058	0.075	0.104	0.135	0.23	0.268	0.318	0.342	0.337	0.294	0.27	0.24	0.216	0.18	0.177
1	4	0.039	0.059	0.073	0.093	0.121	0.177	0.242	0.223	0.254	0.285	0.297	0.27	0.268	0.252	0.254	0.23	0.197
1	5	0.032	0.043	0.051	0.064	0.086	0.135	0.259	0.29	0.358	0.397	0.406	0.43	0.427	0.411	0.353	0.308	0.246
1	6	0.032	0.042	0.058	0.07	0.092	0.175	0.273	0.296	0.361	0.396	0.349	0.323	0.315	0.294	0.259	0.223	0.194
1	7	0.03	0.046	0.055	0.073	0.09	0.171	0.265	0.301	0.366	0.41	0.444	0.496	0.504	0.494	0.435	0.344	0.277
1	8	0.032	0.055	0.072	0.091	0.109	0.177	0.284	0.316	0.385	0.43	0.451	0.484	0.458	0.418	0.359	0.275	0.211
1	9	0.028	0.045	0.059	0.081	0.107	0.183	0.308	0.347	0.42	0.456	0.47	0.435	0.447	0.382	0.32	0.275	0.225
1	10	0.033	0.05	0.063	0.082	0.109	0.19	0.323	0.359	0.437	0.477	0.491	0.46	0.427	0.418	0.37	0.309	0.263
1	11	0.026	0.042	0.049	0.066	0.096	0.173	0.294	0.337	0.413	0.461	0.498	0.494	0.473	0.441	0.391	0.332	0.266
1	12	0.022	0.035	0.048	0.062	0.089	0.131	0.268	0.308	0.375	0.42	0.43	0.441	0.428	0.349	0.323	0.297	0.239
1	13	0.004	0.015	0.02	0.029	0.04	0.054	0.089	0.105	0.127	0.134	0.17	0.113	0.101	0.118	0.147	0.177	0.107
1	14	0.03	0.049	0.061	0.081	0.104	0.137	0.208	0.225	0.265	0.294	0.271	0.218	0.195	0.18	0.157	0.166	0.148
1	15	0.033	0.05	0.064	0.082	0.115	0.168	0.235	0.256	0.285	0.287	0.277	0.239	0.223	0.19	0.144	0.14	0.131
1	16	0.034	0.053	0.069	0.087	0.116	0.18	0.23	0.265	0.29	0.311	0.325	0.256	0.218	0.199	0.173	0.163	0.18
1	17	0.023	0.038	0.051	0.068	0.094	0.135	0.223	0.246	0.309	0.332	0.278	0.247	0.211	0.201	0.189	0.182	0.175
1	18	0.029	0.05	0.063	0.088	0.114	0.177	0.247	0.263	0.28	0.285	0.294	0.28	0.306	0.285	0.22	0.178	0.169
1	19	0.027	0.047	0.062	0.082	0.111	0.178	0.252	0.278	0.297	0.349	0.328	0.33	0.309	0.284	0.261	0.195	0.122

Fig. 3.8: The 30FREQ_L1.xls file.

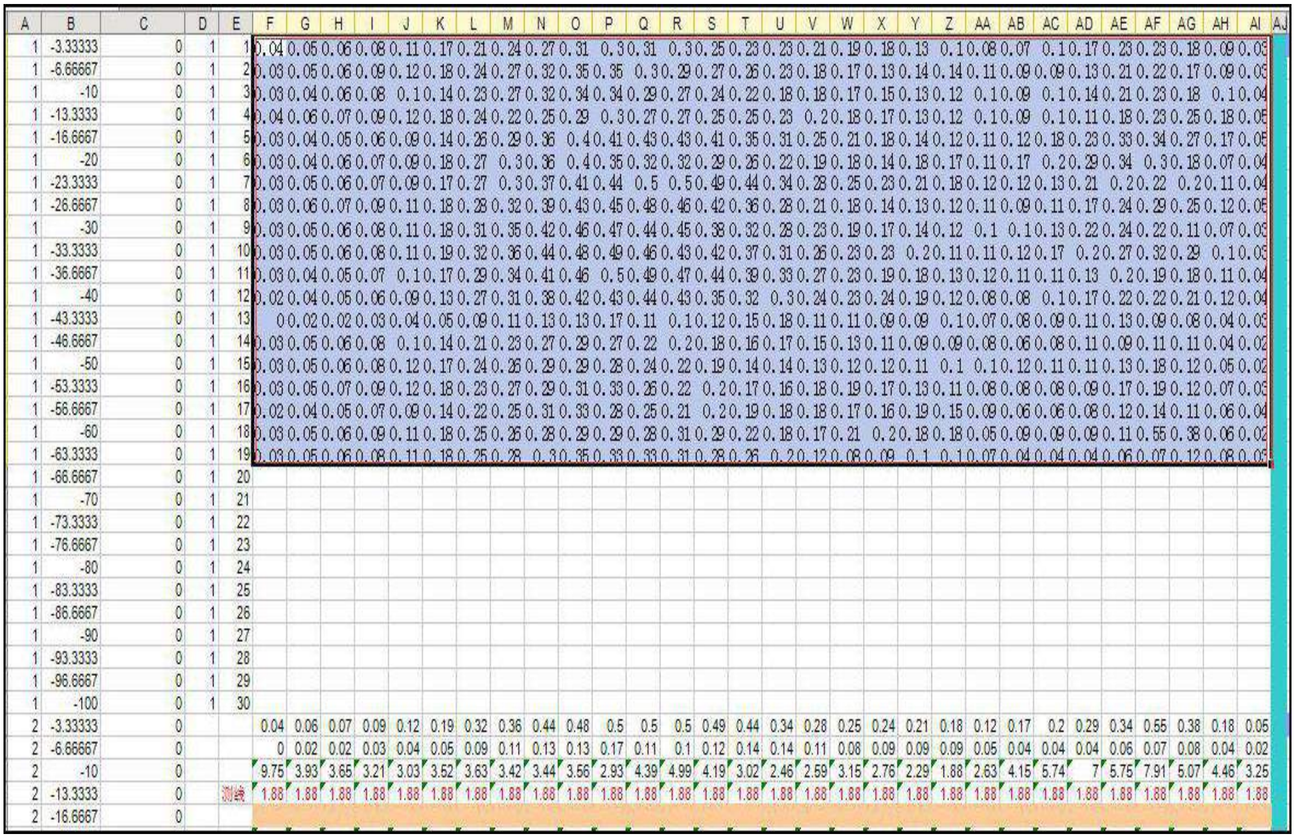


Fig. 3.9: The PQWT-W200 30 frequency 30 points in numerical processing of 200m.xls file.

Then select the copied data go to Insert →Chart→ Line graph and then a graph will be generated and then click on Switch Rows and Columns. Then the graph will appear as shown below in **Fig 3.10.**

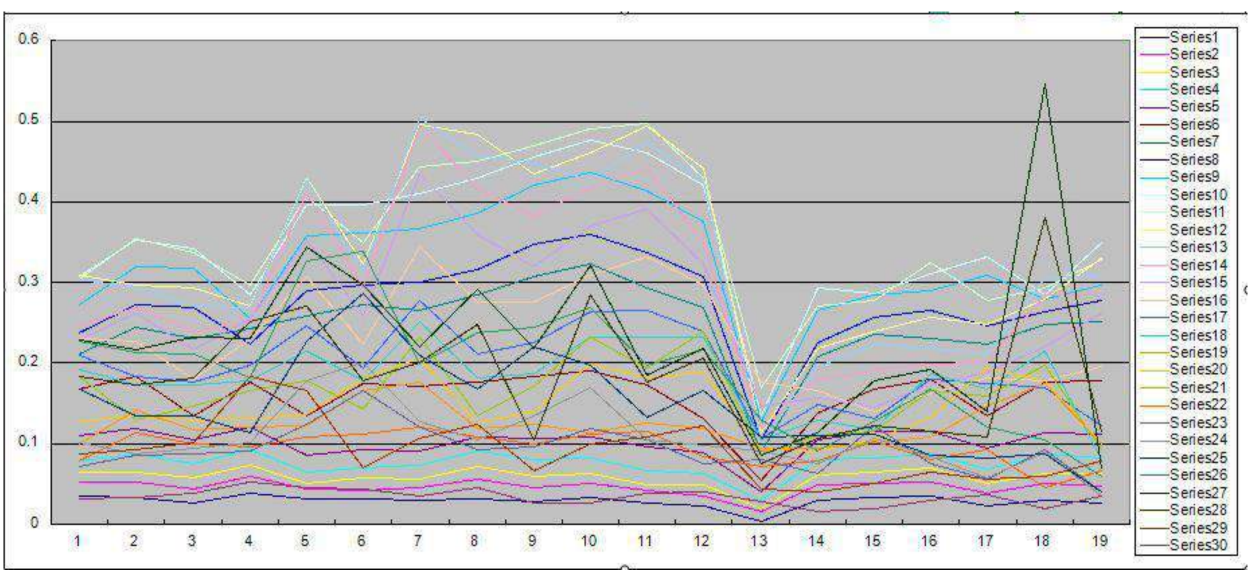


Fig 3.10: Line graph generated from the 30 frequency data.

Judging from the graph a point is selected where all the lines converge into a trough i.e. point 13 as shown in the figure above and the point is recommended for drilling.

2. Data Assimilation

Furthermore after generating the graph, for some special data, the difference of high values and low values is very big. The set of values are too many (as in **Fig 3.9**), and it's difficult to find the effective position. Hence a more refined data is required to cross-check the recommended point. In this situation, we use the method of data assimilation to make the graph and a contour map for reference and to compare the data.

A reference line and a reference point are to be selected from the values that were used to generate the graph. The criterion for selecting a reference line is that a gentler line is to be selected from the graph (before clicking on Switch Rows and Columns). The criterion for choosing a reference point is similar. The selected reference line and reference point corresponding to column and row should be marked with color for convenience. The copy the line corresponding to the row and paste it in column AT which is on the right hand side and also copy the point at intersection between the column and row in the red cell below in column AP as shown below in **Fig 3.11**.

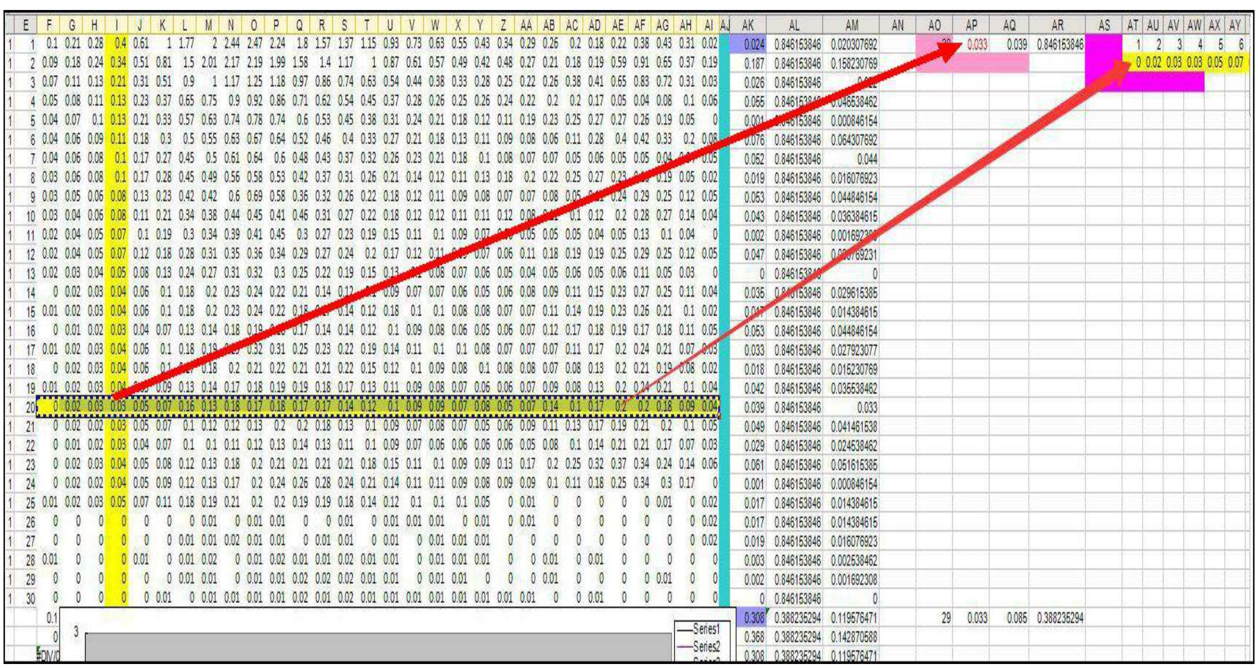


Fig 3.11: Selecting a reference line and a reference point.

After completing the above steps, a new set of values will appear below the original values on the left hand side, as shown in the red frame in **Fig. 3.12.**Make a Line Chart using the data in red frame, then compare with the original line chart. Generally the water bearing zone or the fracture judged is based on low values, but the new data has too many high values and covers many low values. In this case, a value is chosen that occurs more frequently and those values that are higher than the chosen value should be made equal to the chosen value. For example, if the chosen value is 0.2 all those values greater than 0.2 should be changed to 0.2. After this the line chart will be changed as shown below in figure 9, you can find that other low values will be more obvious than the original one i.e. the values occur under a single limit, as shown in **Fig. 3.13.**.

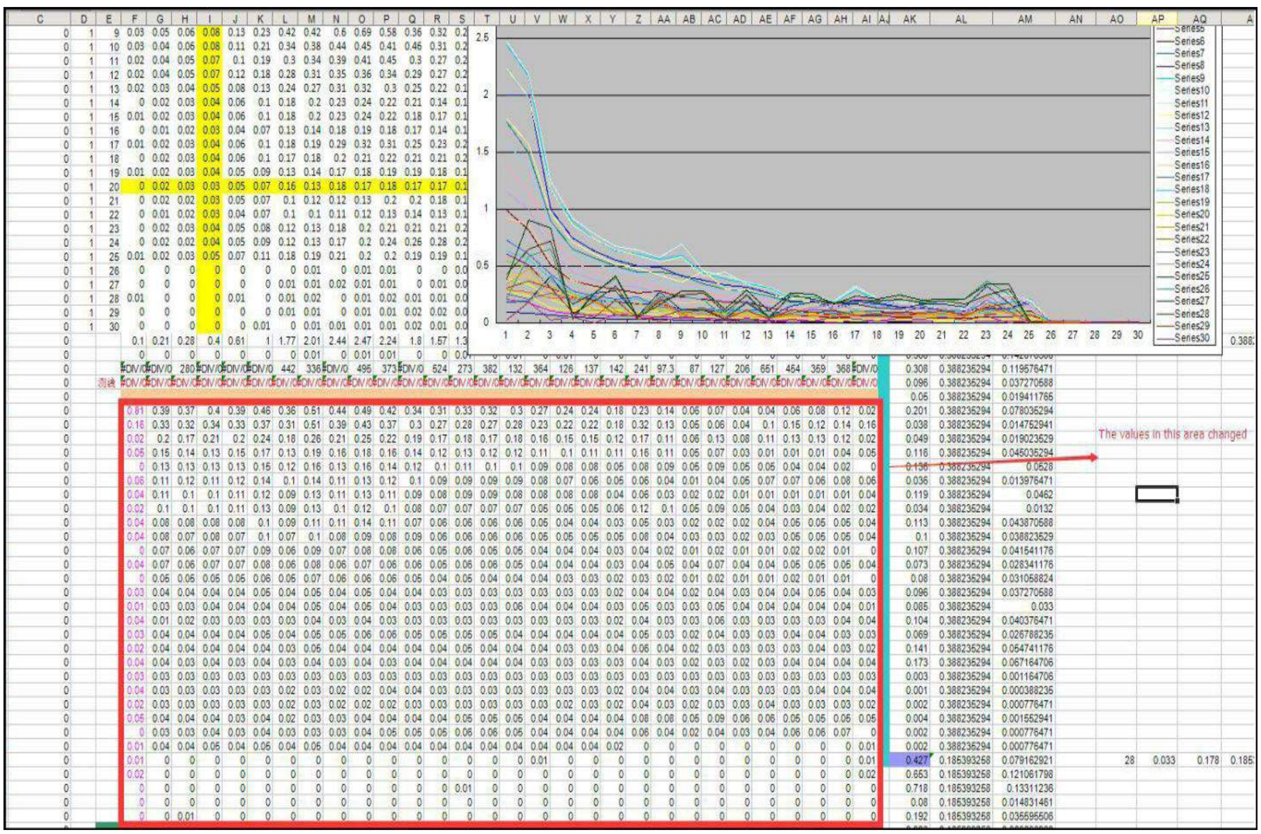


Fig. 3.12: A new set of refined values after reference line and reference point selection.

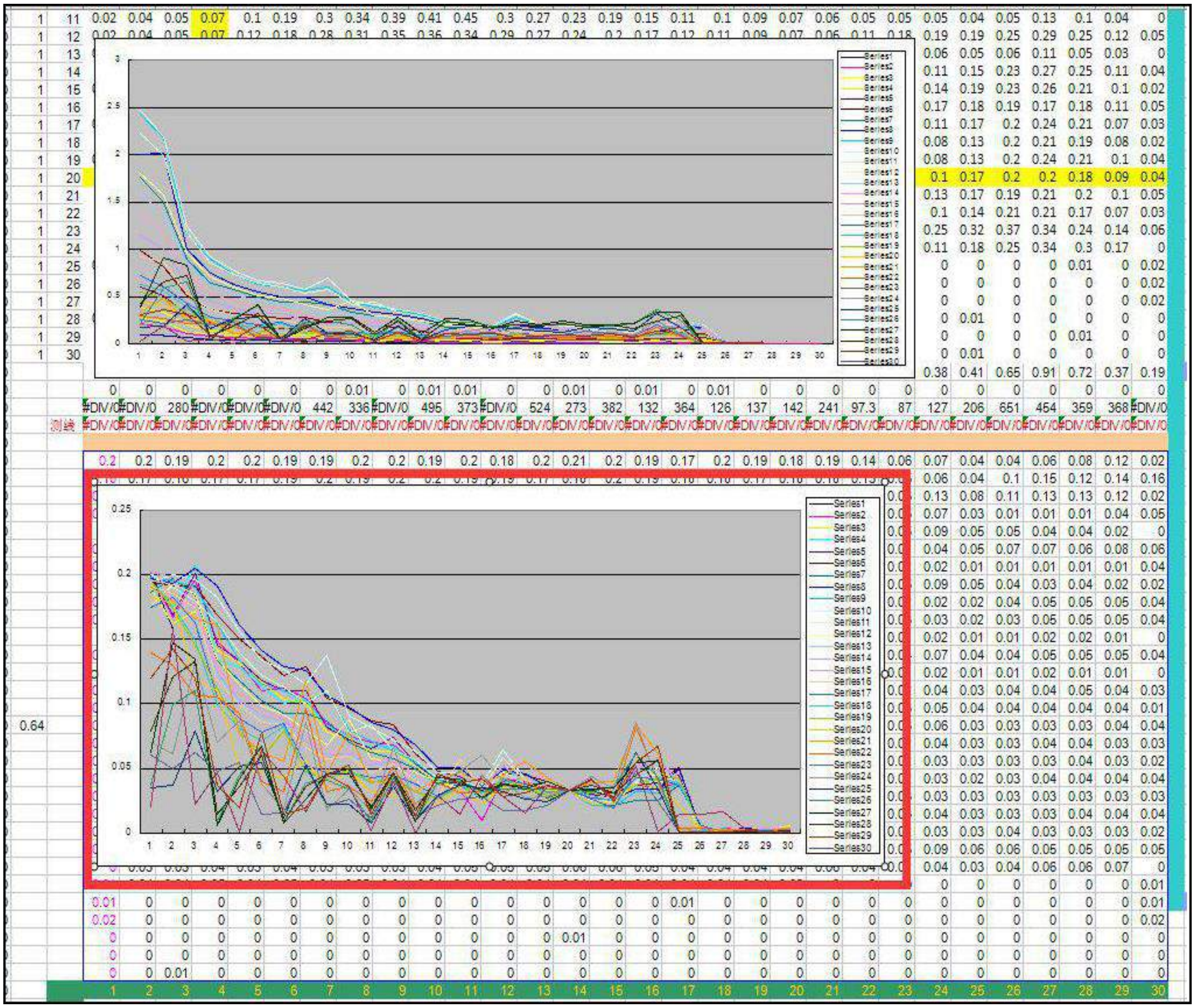


Fig. 3.13: New line chart from the new data

Then copy the new data and paste it below the green row in the excel spreadsheet. Note that while pasting the data it should pasted as transposed values. To achieve this click on Paste Special→ check Values→ check Transpose→ OK. After pasting save the file.

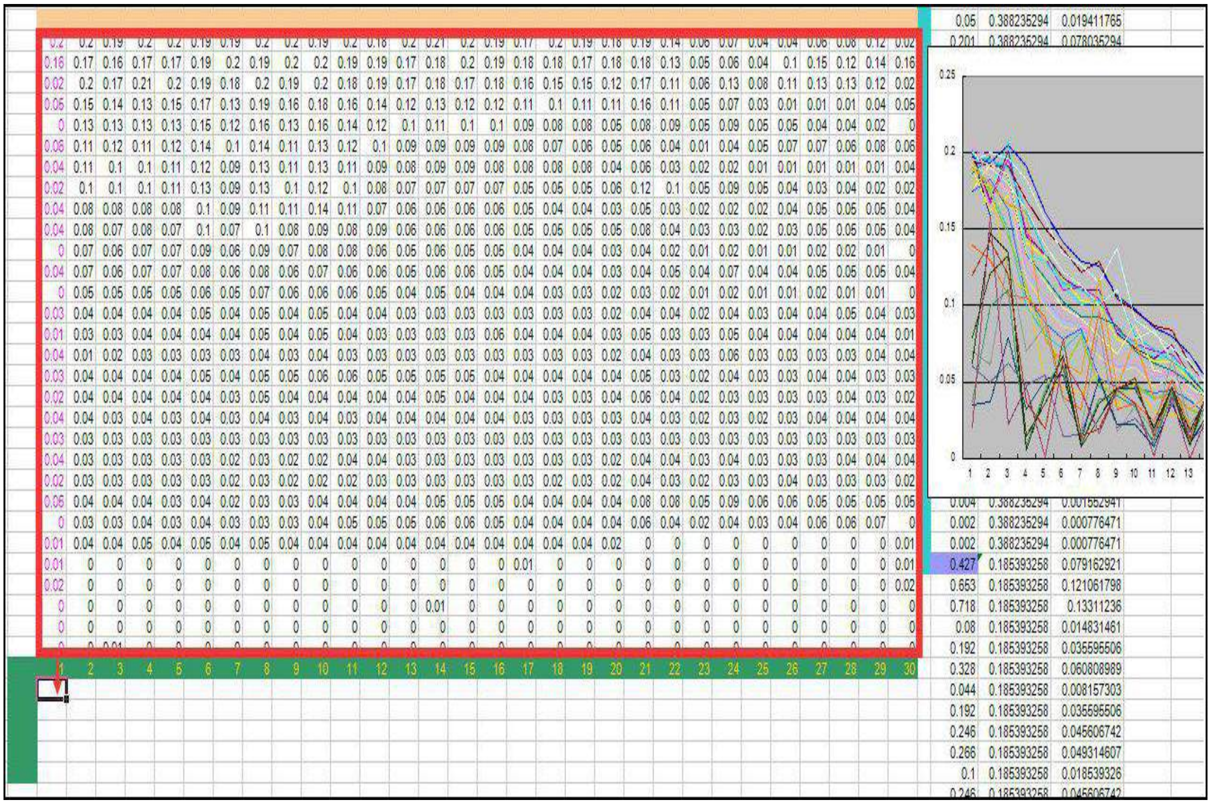


Fig. 3.14: Area where the new data should be pasted as transposed values.

3. Contour Maps

To prepare contour maps, the software used was SURFER 8. Two types of gridding methods were used to prepare contour maps; i) Triangulation with linear interpolation; to show the vertical sections of the anomalous points and ii) Kriging; to show the anomalous points laterally. The maps prepared by the kriging method were prepared for all the 30 frequencies representing different depths up to 200 m. Also mapInfo_8.5 was used to convert the coordinates to decimals of each anomalous point to prepare contour map using the kriging method. There is another file named 'Hydrogeological exploration standard color-8.clr' provided by the software package of the machine besides the excel files. This file helps to load the colors to the contour map which helps to distinguish the layers in the subsurface.

The preview of the contour map prepared using the Triangulation with Linear Interpolation gridding method is shown in **Fig. 3.15** and shows the point which is suitable for drilling. The light blue zones in the figure indicate a water bearing zone, the yellow zones indicates the fractures (dry) present in the rock in the subsurface and the orange or red zone represents the hard compact region in the subsurface. The yellow zones can also be used for recharge.

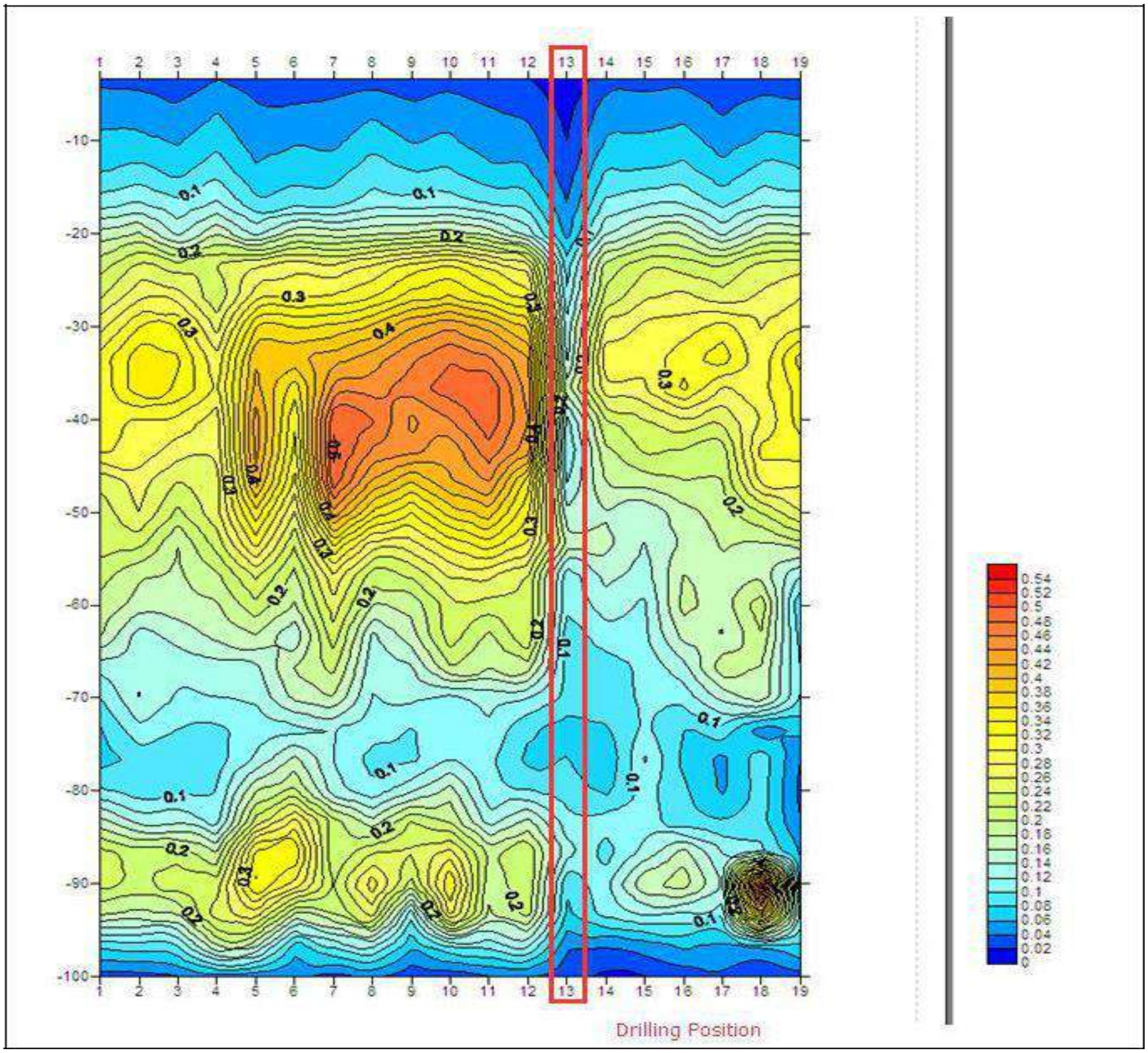


Fig. 3.15: Contour map prepared using the Triangulation with Linear Interpolation gridding method

CHAPTER 4

FIELD DATA COLLECTION & OBSERVATIONS

4.1: Field data collection

To delineate suitable bore-well points for drilling, the most comprehensive methods used are vertical electrical sounding and the very low frequency electromagnetic methods. The method used for the study was the very low frequency electromagnetic method (VLF EM). The VLF EM profiling gives the lateral variation in resistivity of the ground. The profiles were first taken along the boundary and alternate parallel profiles were taken in a grid pattern.

The field work was carried out during the month of December for a period of three days. A total of A total of 8 profiles named L879, L880, L881, L882, L883, L884, L885, L887, were taken using the multi-frequency state of data collection. The GPS (Global Positioning System) readings were taken of the delineated points. The latitudes and longitudes of the delineated points along with the VLF profile details are tabulated in **Table 4.1.**The Google Earth image of the delineated bore-well points along with the profile points is shown in **Fig. 4.1.**

Table 4.1: The VLF profile details

Sr. No.	Site No./Area	Profile No.	Total Profile Length(in m)	Point Name	Distance(in m) from zero of each profiles	Georeference
1	I	L879	25	P1	5	Lat: N15 17 21 Long: E73 58 51.2
2				P2	17	Lat: N15 17 21.23 Long: E73 58 51.1
3				P3	22	Lat: N15 17 21.3 Long: E73 58 50.8
4	II	L880	39	P4	6	Lat: N15 17 20.9 Long: E73 58 50.6
5				P5	30	Lat: N15 17 20.2 Long: E73 58 50.6
6	III	L881	24	P6	10	Lat: N15 17 21.8 Long: E73 58 50.2
7	1V	L882	28	P7	8	Lat: N15 17 23.2 Long: E73 58 50.8
8				P8	16	Lat: N15 17 23.4 Long: E73 58 50.9
9				P9	22	Lat: N15 17 23.6 Long: E73 58 51
10	V	L883	16	P10	8	Lat: N15 17 23 Long: E73 58 48.2
11	VI	L884	16	P11	4	Lat: N15 17 23.1 Long:E73 58 48.1
12	VII	L885	72	P12	57	Lat: N15 17 29.5 Long: E73 58 47.5
13				P13	63	Lat: N 15 17 29.7 Long: E73 58 47.5
14	VIII	L887	14	P14	10	Lat: N15 17 24.2 Long: E73 58 48.1

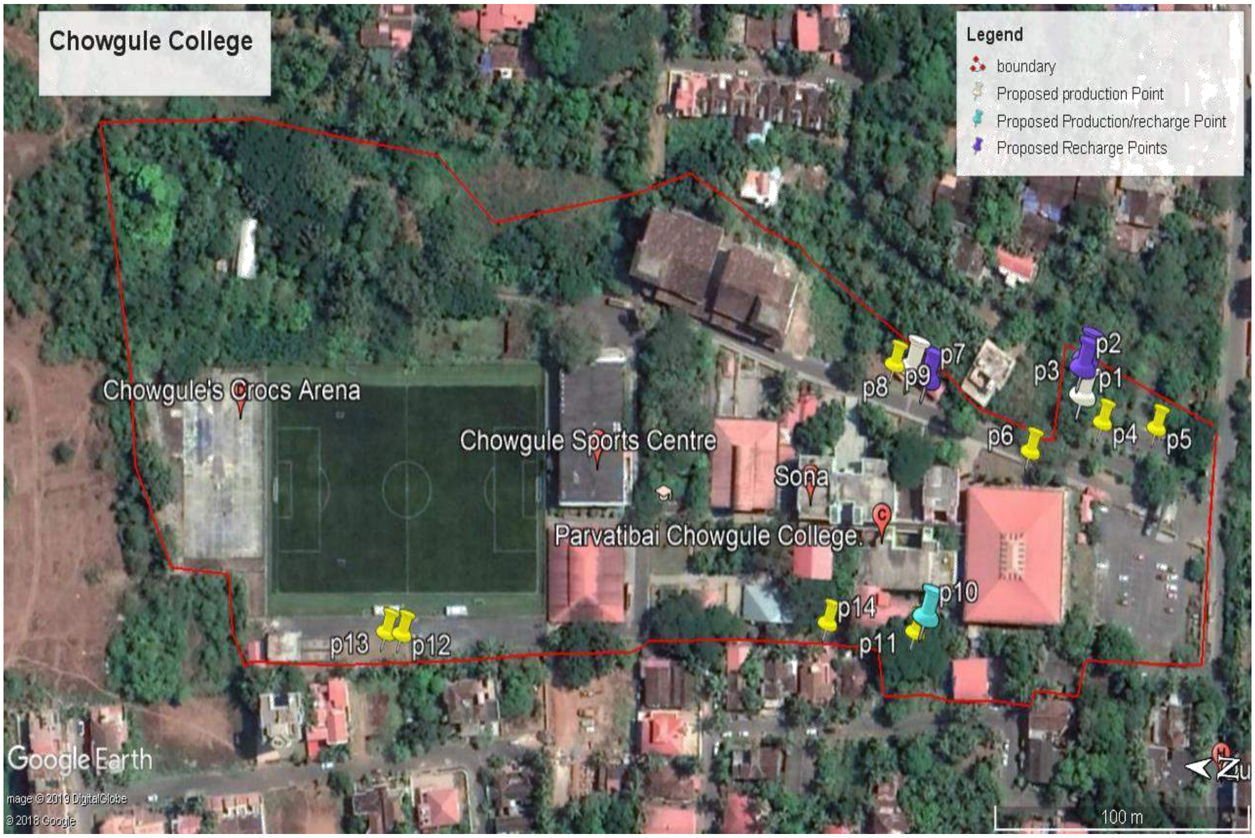


Fig. 4.1: Google Earth image of delineated bore-well points of the profile

CHAPTER 5

RESULTS AND DISCUSSIONS

5.1: Results and Discussions

From the data obtained from the VLF EM survey, a total of 15 bore-well points which are suitable for drilling were delineated and peg marked in the field. The points are to be used for both recharge and production (or groundwater extraction) purpose. All the points differ with respect to groundwater yield which in turn depends on the fractures present in the subsurface or the bedrock. These fractures serve as conduits for groundwater to flow.

The points were named P1 to P14. A total of 8 profiles named L879, L880, L881, L882, L883, L884, L885, L887, were taken using the multi-frequency state of data collection. As shown in **Table 4.1** thus, completing the profiles in a grid pattern. Points P1, P2, P3 were delineated along the L879 profile; points P4 and P5 were located along the L880 profile; while profile L881 only had P6; and P7, P8 and P9 were located along L882 profile, while profile L883 only had P10; as well as profile L884 only had P11; points P12 and P13 were identified along L885 profile, and only P14 was located along L887.

The area is covered with lateritic soil. The basement rock is encountered at 50 to 60 meter depth below ground level. Points P2, P1 and P7 are of concern from recharge point of view. At Points the depth of recharge well or infiltration well would be 30m to 40m. The preferential order of the points feasible for recharge and production are tabulated below in **Table 5.1.**The preferential order is chosen by cross-checking the resistivity values from the graph and the vertical sections. Points of low values (troughs) are chosen from the graph.

Table 5.1: Preferential order of the points for recharge and production

Sr. No.	Profile No.	Point Name	Preferences	Feasibility
1	L882	P8	1	PRODUCTION
2	L879	P3	2	
3	L883	P10	3	PRODUCTION / RECHARGE
4	L879	P2	5	RECHARGE
5	L879	P1	6	
6	L882	P7	7	

The total area under study is 53,190m^2. The average rainfall in the area is 3,000 mm. The average number of rainy days is 90.

The Rainwater Harvesting Potential for

a) Roof top = 7,360.9 m^2 x 3 m x 0.80 = 17,665.65 m^3

b) Soil and Green cover = 9872 m^2 x 3 m x 0.40 = 11,846.4 m^3

c) Tar and Concrete = 35,455 m^2 x 3 m x 0.75 = 79,773.75 m^3

Total Rainwater Harvesting Potential = 1, 09,285.8 m^3 (Annually)

Considering 90 Rainy Days, average water harvested on a rainy day = 1,214 m^3

Average monthly water consumption by the occupant in the study area is 1,170 m^3. The rainwater if harvested totally can fulfil the water requirement of occupants for days. Plus the occupant will be water positive for next 6 years.

5.2: VLF EM PROFILES

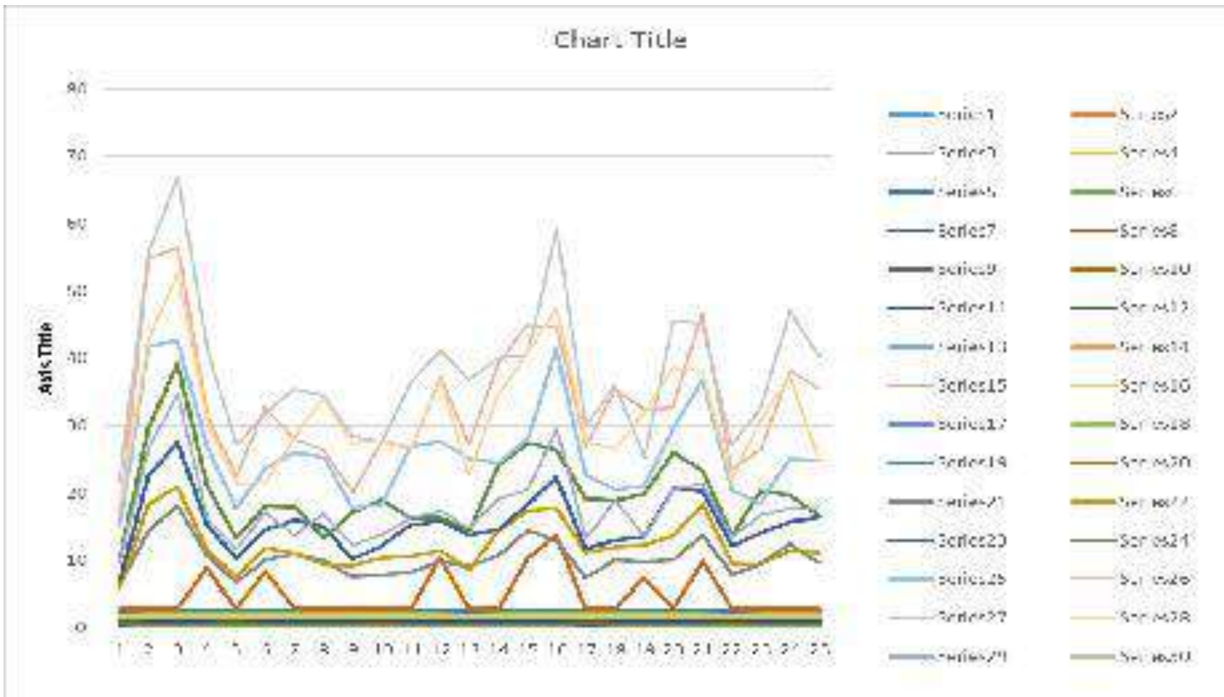


Fig. 5.1: VLF EM PROFILE No. L879

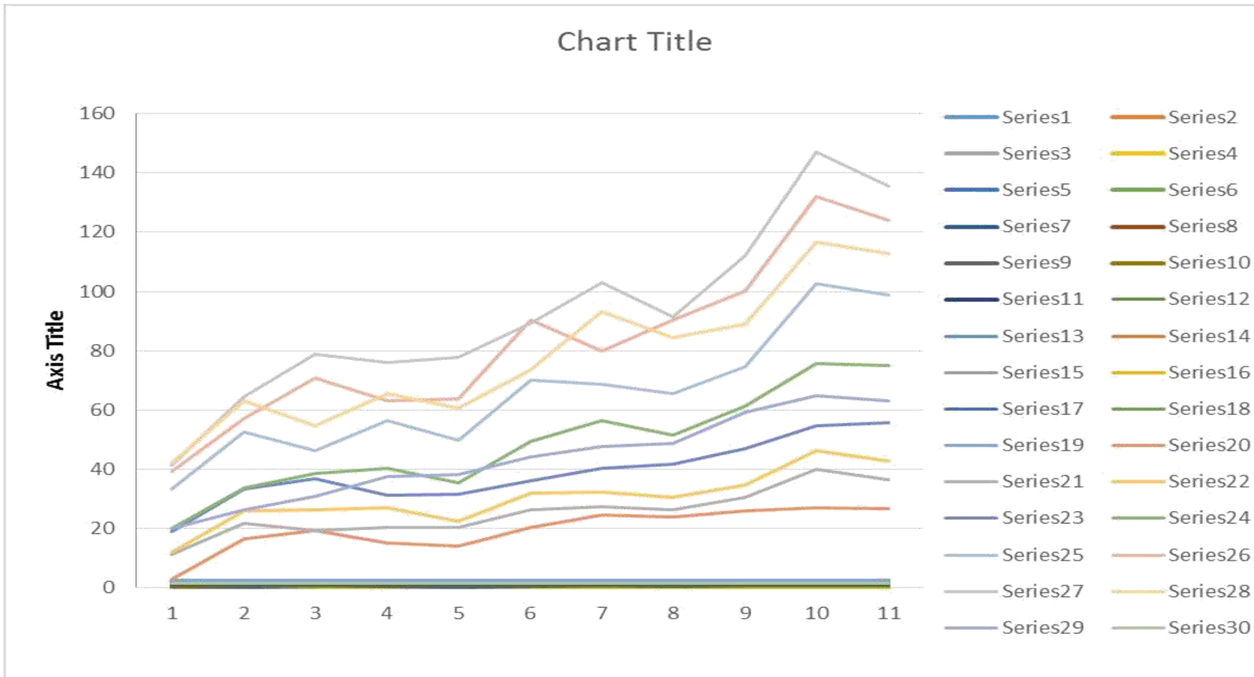


FIG. 5.2: VLF EM PROFILE NO.L880

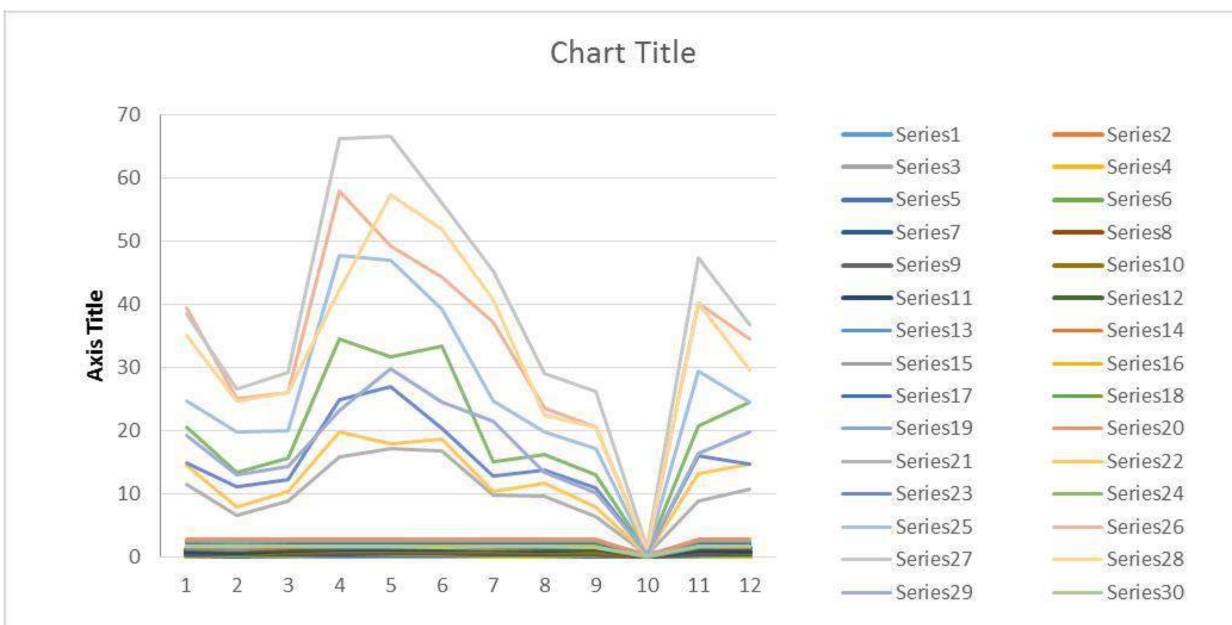


Fig. 5.3: VLF EM PROFILE No. L881

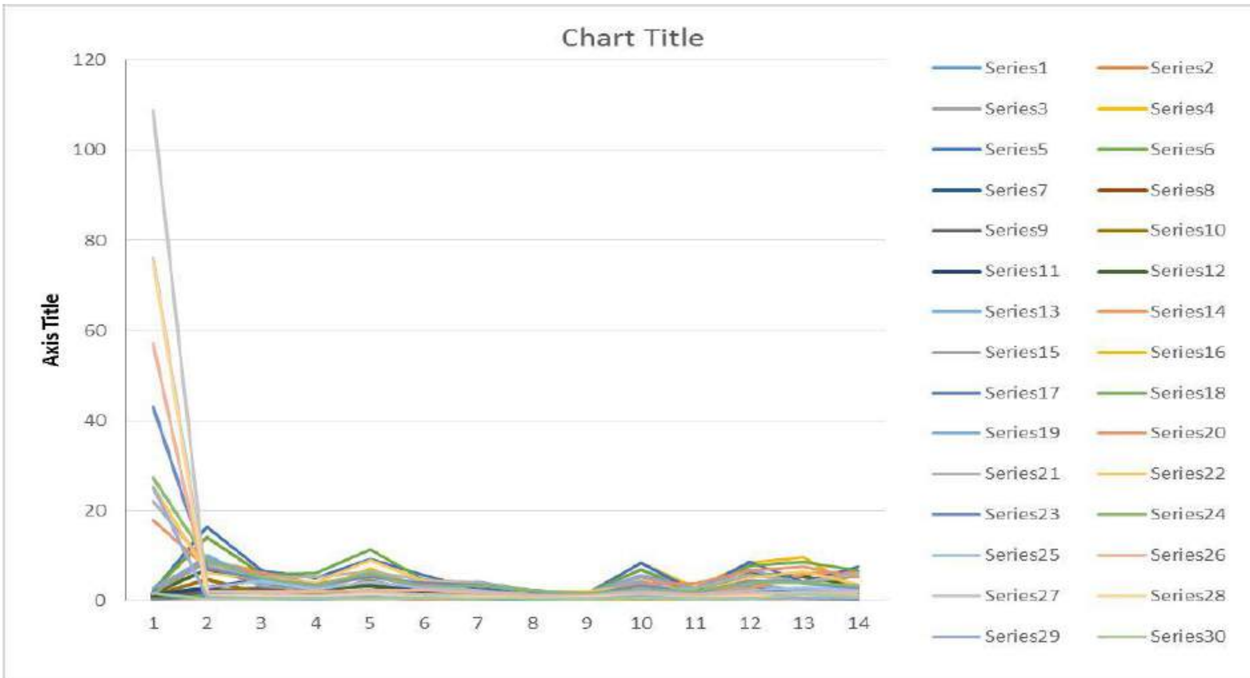


Fig.5.4: VLF EM PROFILE No. L882

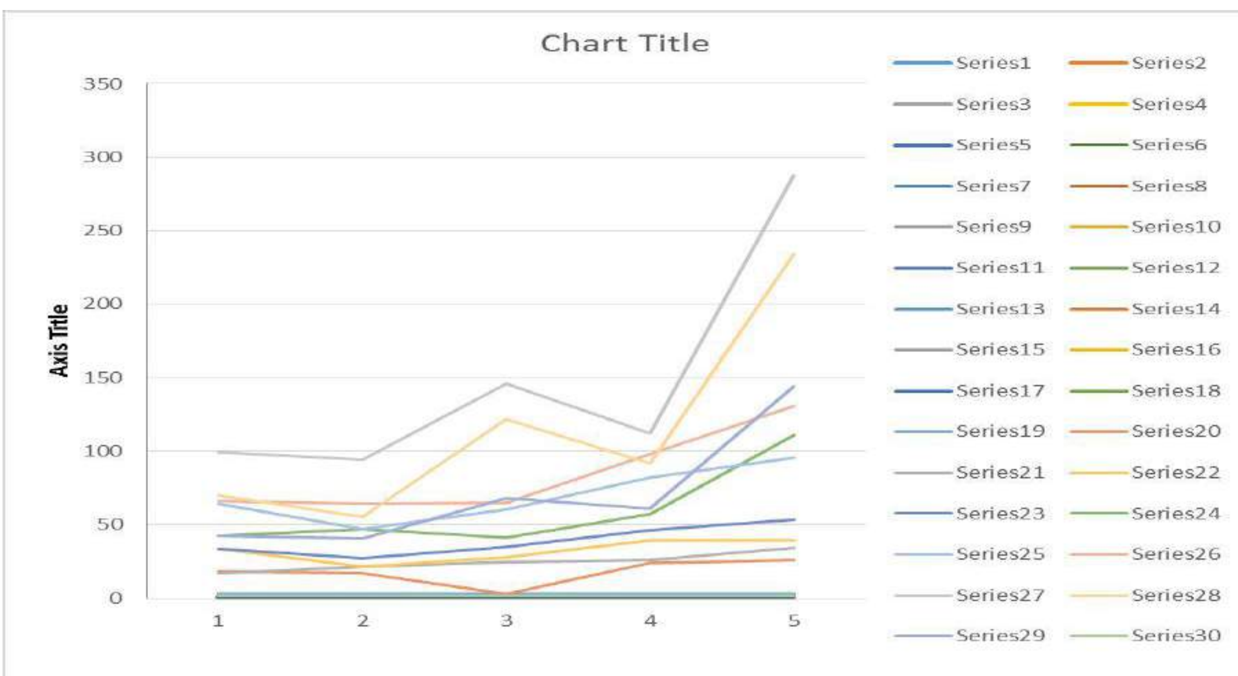


Fig. 5.5: VLF EM PROFILE No. L883

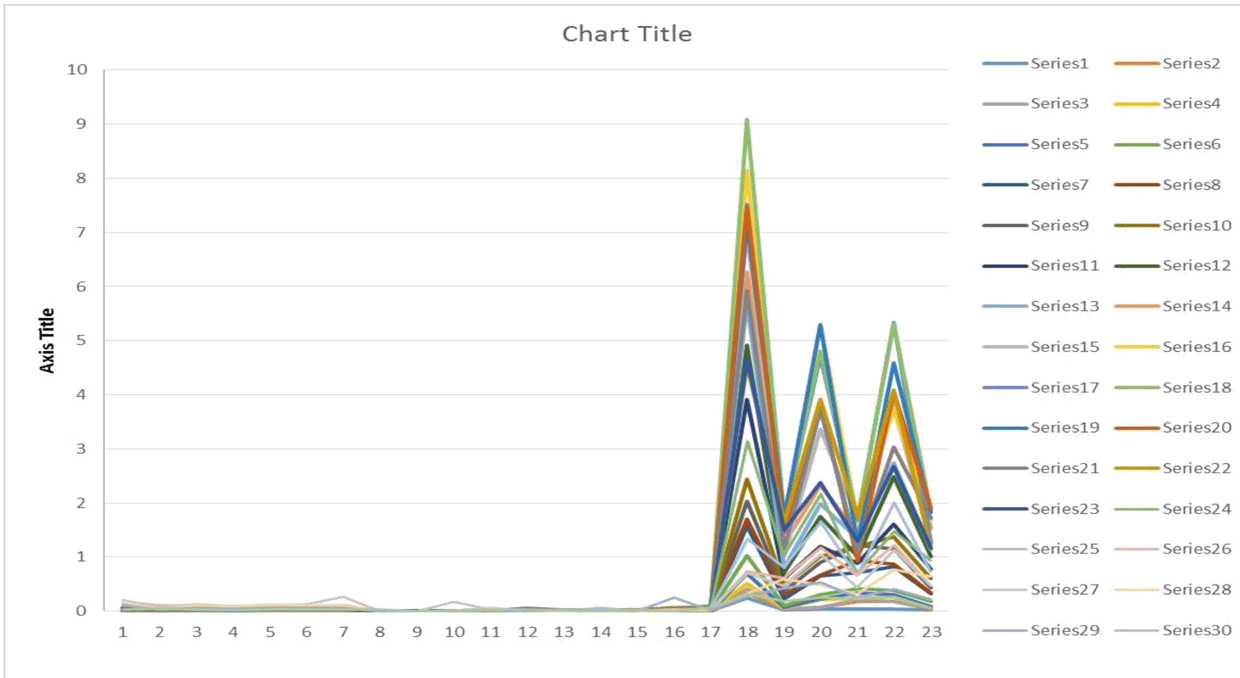


Fig. 5.6: VLF EM PROFILE No. L884

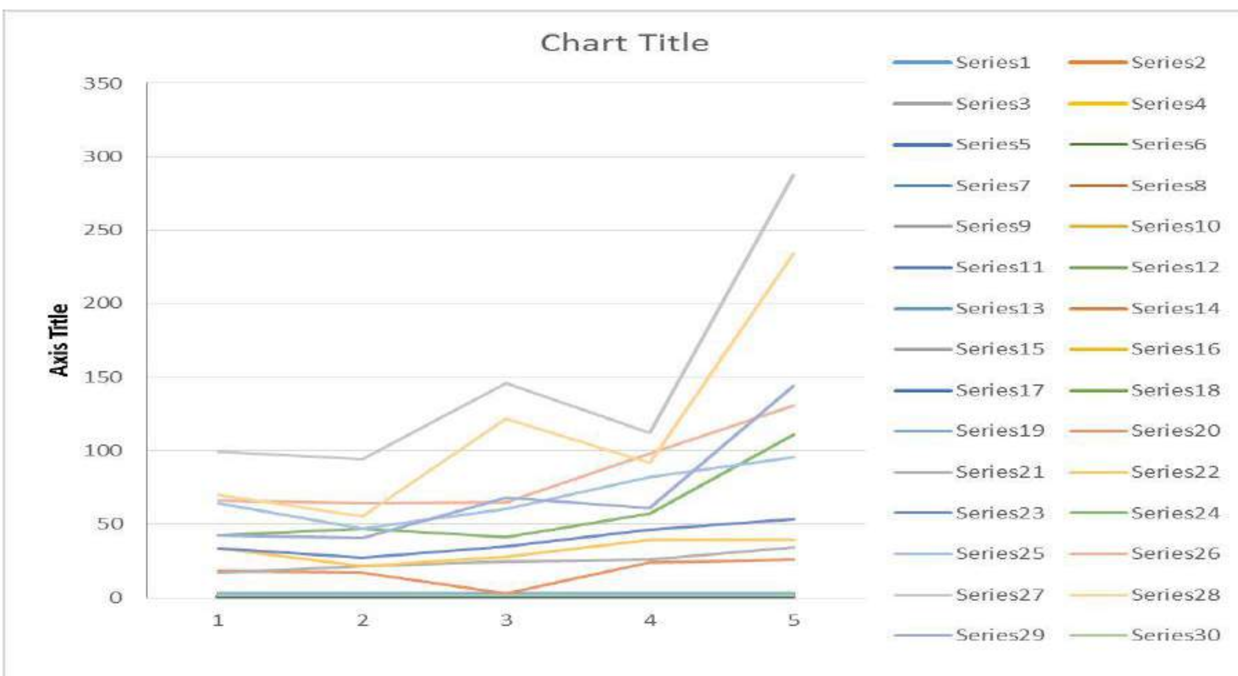


Fig. 5.7: VLF EM PROFILE No. L885

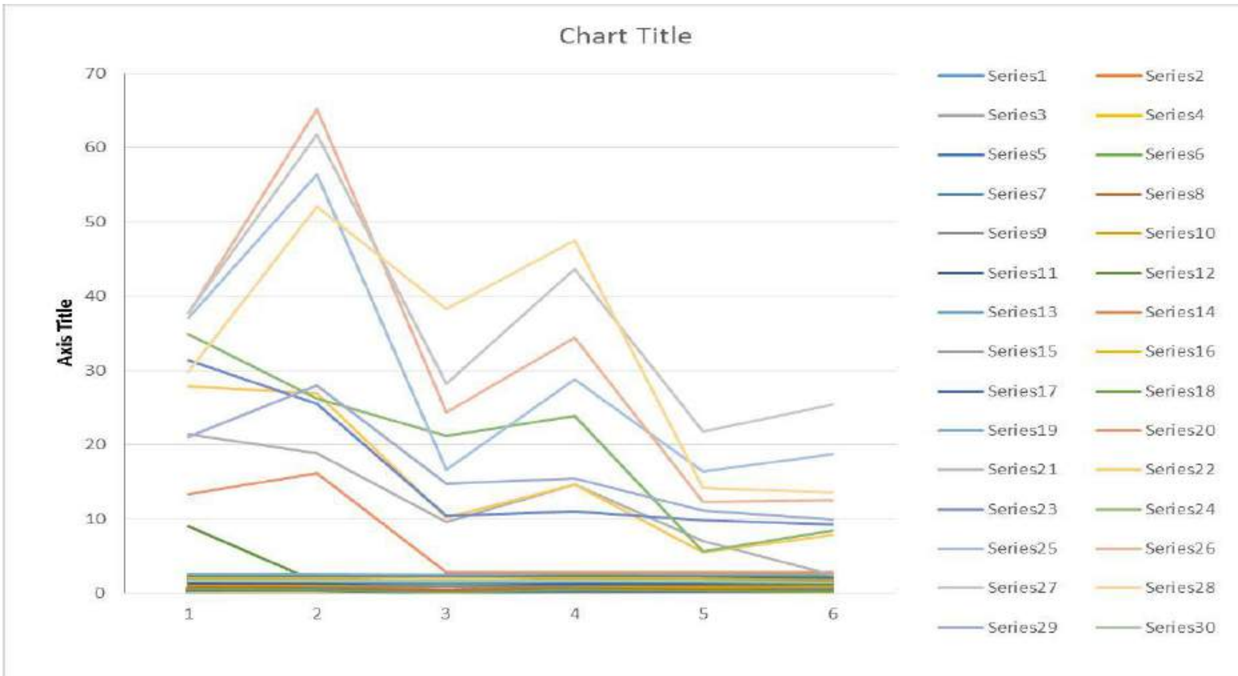


Fig. 5.8: VLF EM PROFILE No. L887

5.3 VERTICAL SECTIONS OF PROFILES

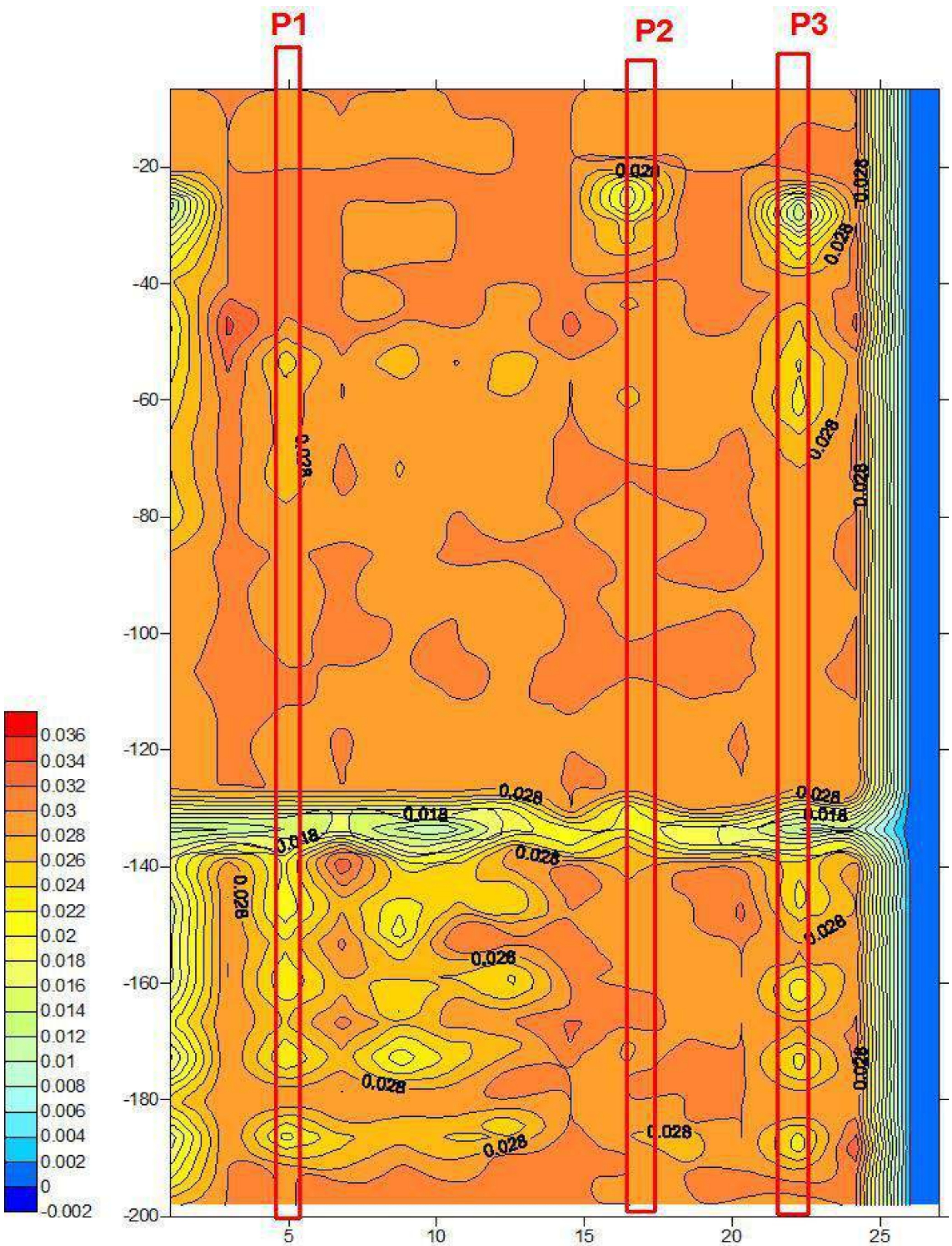


Fig. 5.9: Vertical Section of Profile L879

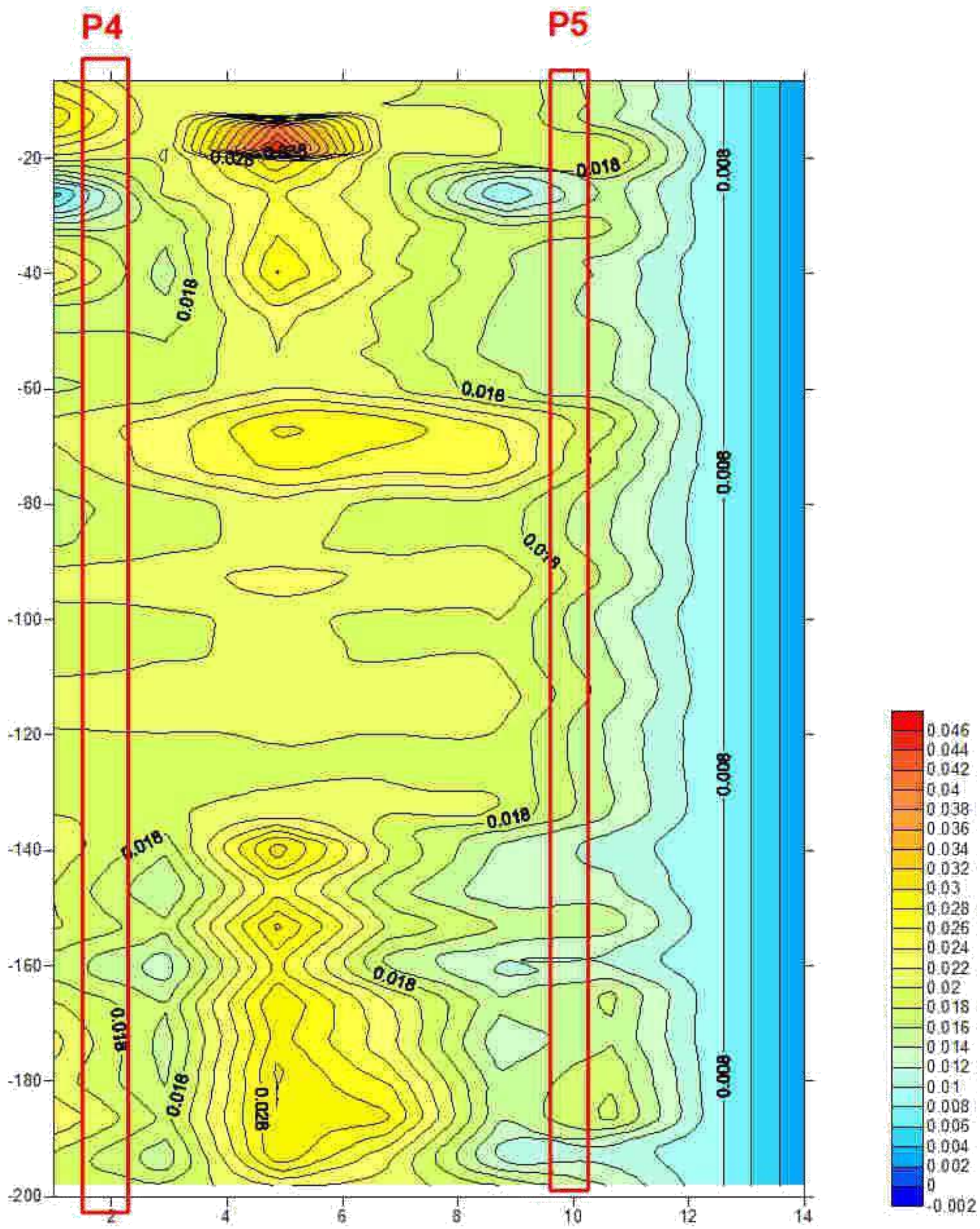


Fig. 5.10: Vertical Section of Profile L880

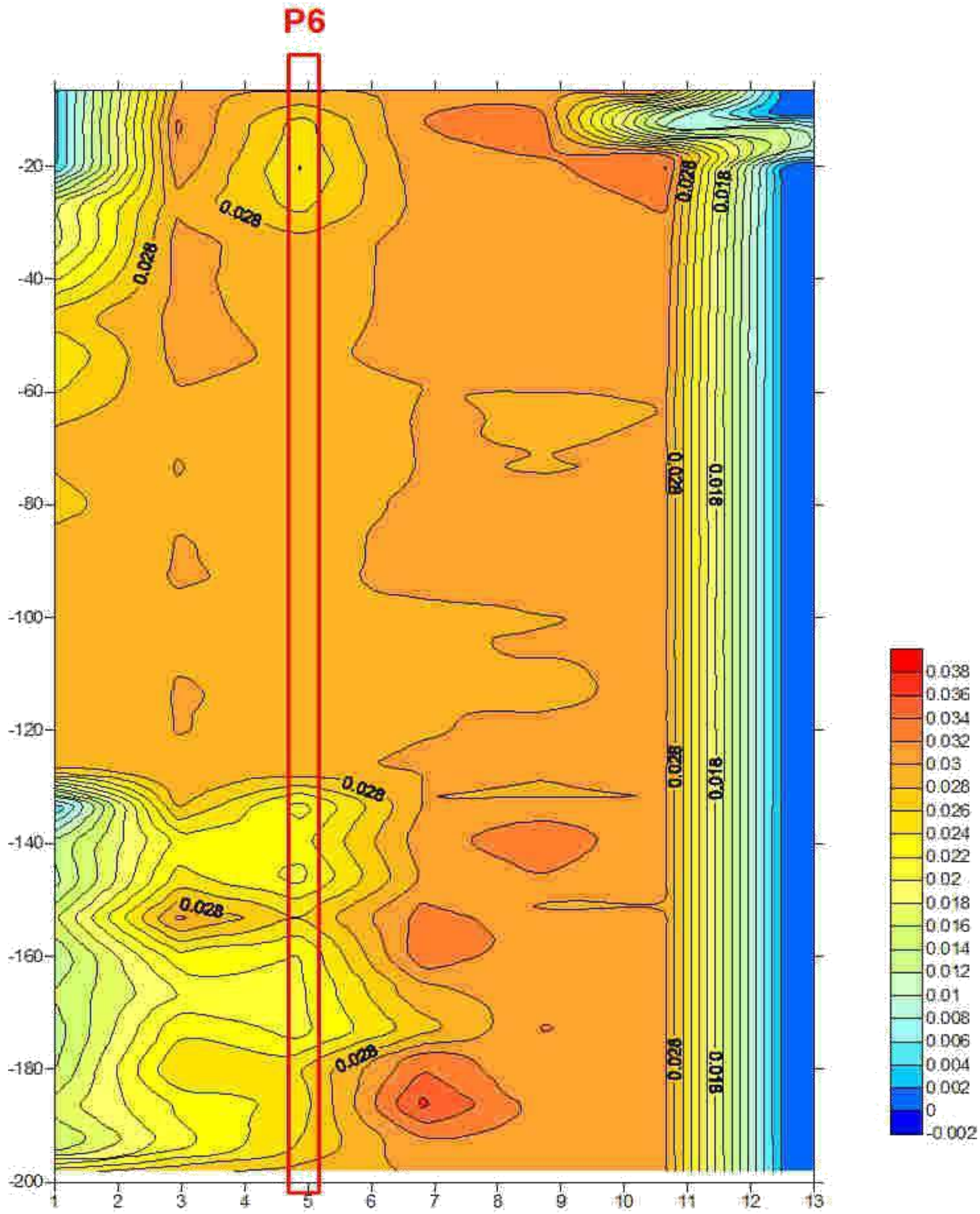


Fig. 5.11: Vertical Section of Profile L881

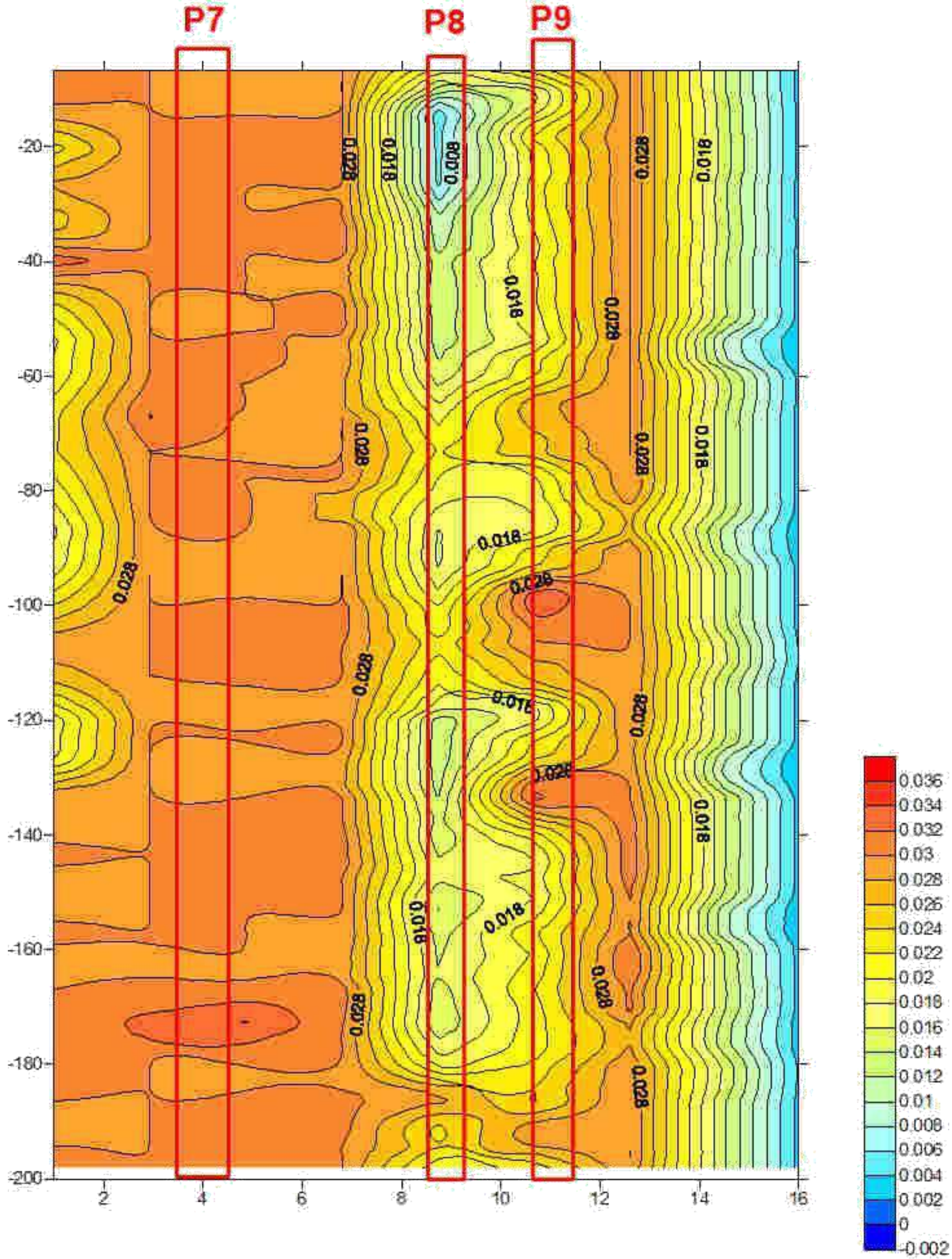


Fig. 5.12: Vertical Section of Profile L882

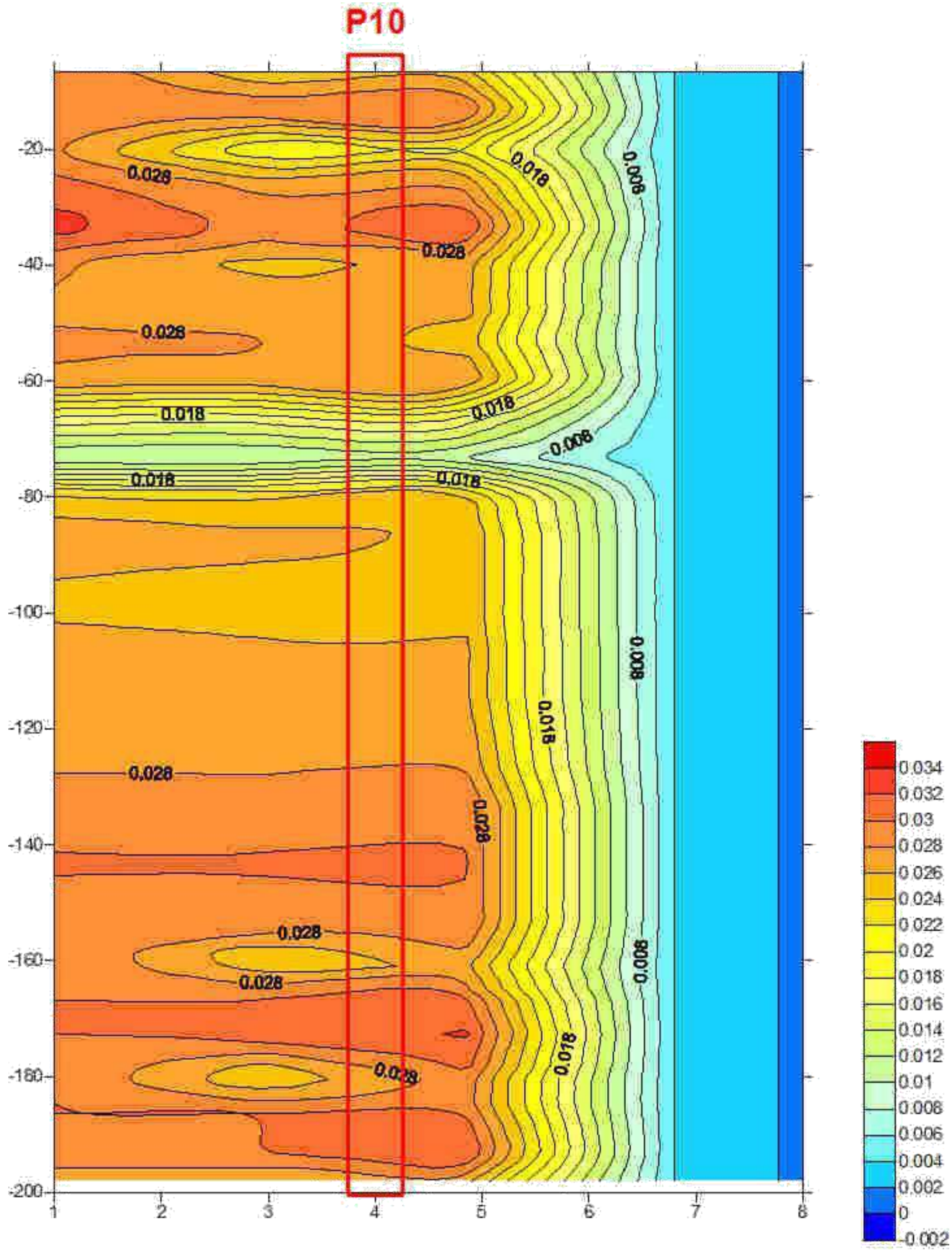


Fig. 5.13: Vertical Section of Profile L883

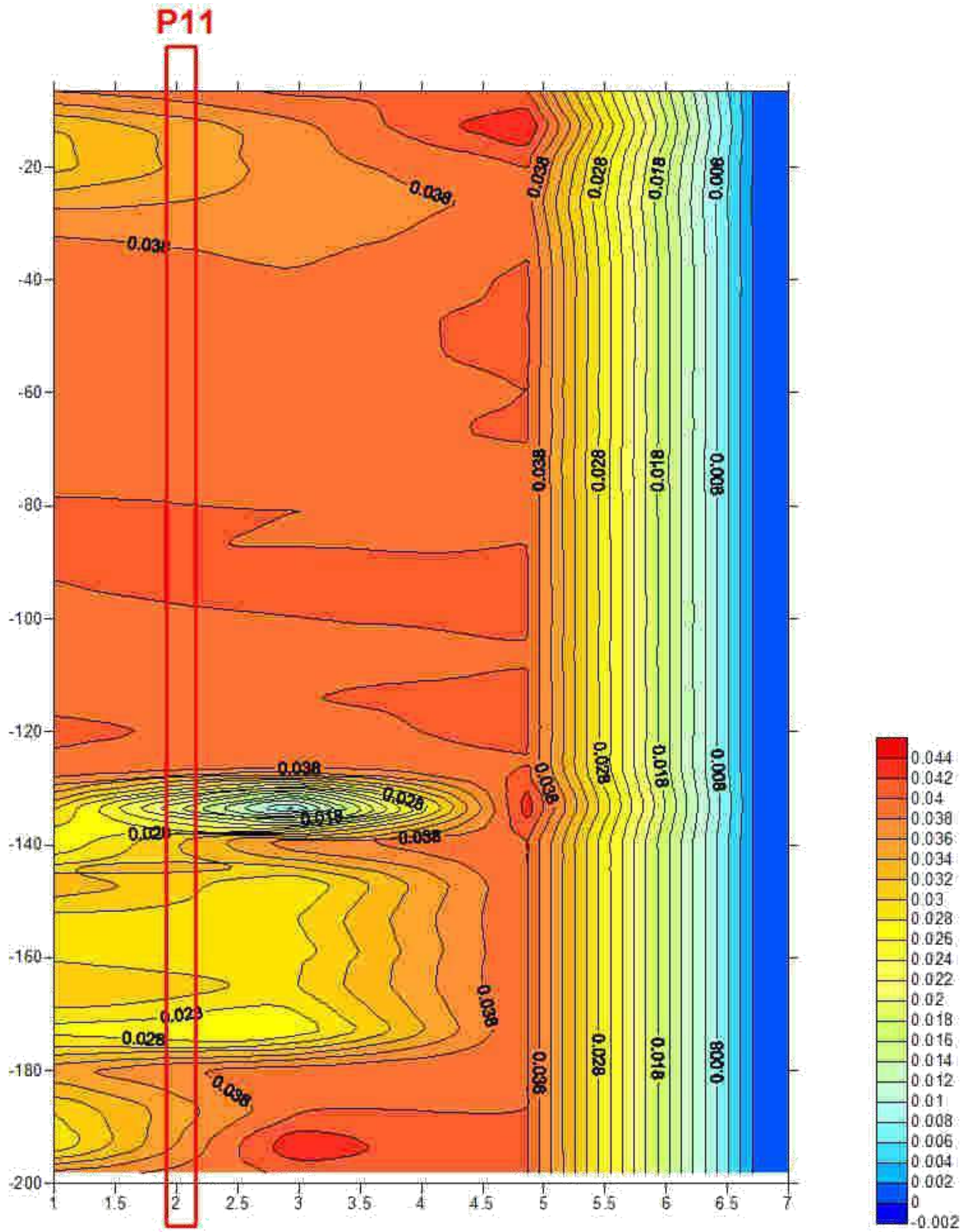


Fig. 5.14: Vertical Section of Profile L884

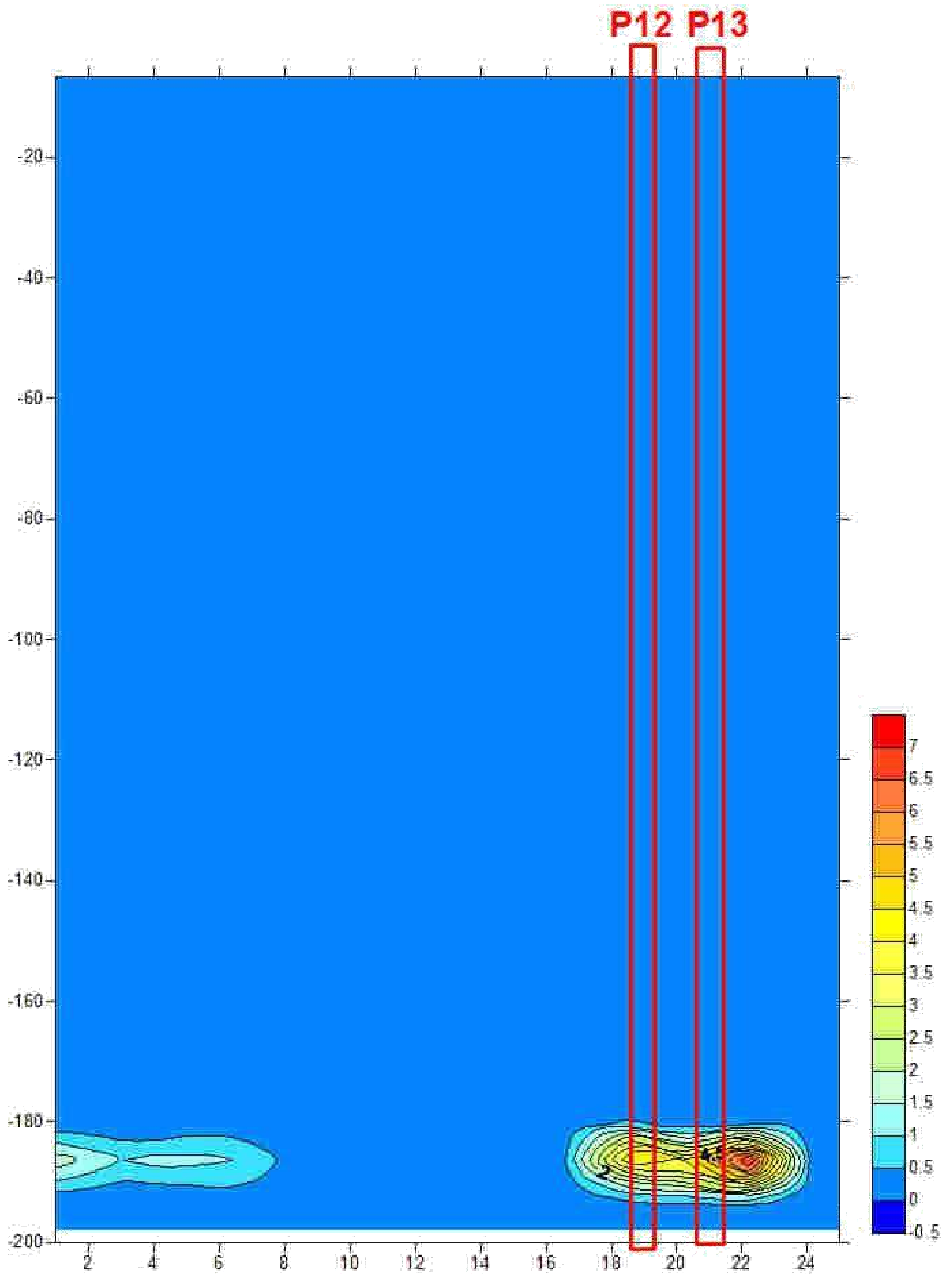


Fig. 5.15: Vertical Section of Profile L885

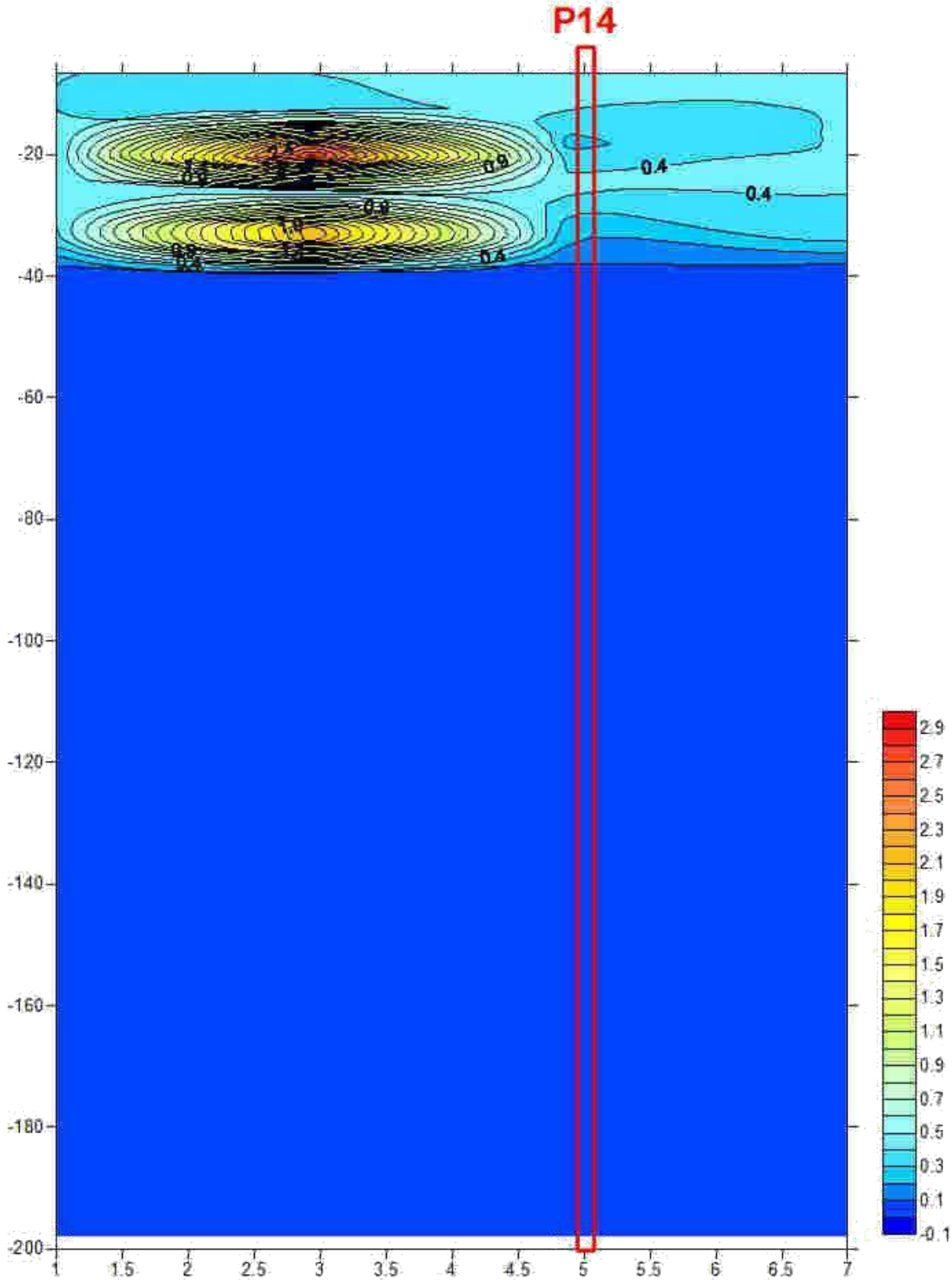


Fig. 5.16: Vertical Section of Profile L887

CHAPTER 6

CONCLUSION

Based on the analysis of hydrogeological and geophysical data the following conclusions are derived:

1. Few major fractures and many minor fractures are detected in the area. Therefore the area has good prospects for groundwater.

2. The recommended depth of drilling for recharge is around 30 to 40 meters.

3. The recommended depth of drilling for production is around 60 to 70 meters.

4. The recommended diameter of recharge well is 8 inches. If enough space for setting up drilling rig is not available then 5" inches diameter well is recommended.

5. To sustain the groundwater sources for a long time, it is necessary to implement rainwater harvesting system to artificially recharge the aquifers.

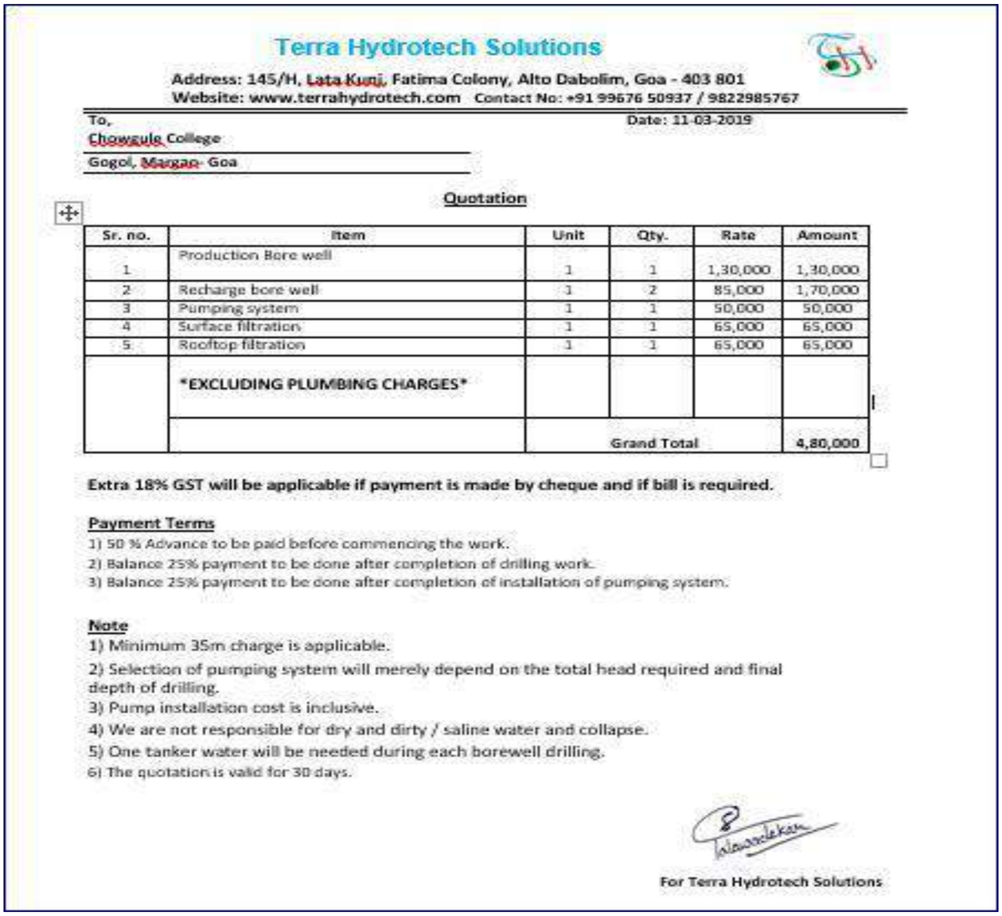
CHAPTER 7

RECOMMENDATION

The study area has sufficient groundwater reserve. Groundwater can be utilized as the primary source of water. This groundwater can be utilized to fulfil all the secondary needs of human settlement and for commercial use. To make the groundwater source sustainable it is recommended to compulsorily recharge the groundwater sources.

Rainwater should be collected, channelized, filtered, recharged, pumped and distributed to utilize it for fulfilling secondary water needs and surplus can be recharged to make groundwater resources sustainable. The filtration techniques used can be pebbles sand filter beds along with a bed of activated charcoal or stainless steel screen filtration techniques can be used.

QUOTATION FOR COST OF INSTALLING PROJECT



Terra Hydrotech Solutions

Address: 145/H, Lata Kunj, Fatima Colony, Alto Dabolim, Goa - 403 801
Website: www.terrahydrotech.com Contact No: +91 99676 50937 / 9822985767

To,
Chowgule College
Gogol, Margao- Goa

Date: 11-03-2019

Quotation

Sr. no.	Item	Unit	Qty.	Rate	Amount
1	Production Bore well	1	1	1,30,000	1,30,000
2	Recharge bore well	1	2	85,000	1,70,000
3	Pumping system	1	1	50,000	50,000
4	Surface filtration	1	1	65,000	65,000
5	Rooftop filtration	1	1	65,000	65,000
	EXCLUDING PLUMBING CHARGES				
			Grand Total		4,80,000

Extra 18% GST will be applicable if payment is made by cheque and if bill is required.

Payment Terms
1) 50 % Advance to be paid before commencing the work.
2) Balance 25% payment to be done after completion of drilling work.
3) Balance 25% payment to be done after completion of installation of pumping system.

Note
1) Minimum 35m charge is applicable.
2) Selection of pumping system will merely depend on the total head required and final depth of drilling.
3) Pump installation cost is inclusive.
4) We are not responsible for dry and dirty / saline water and collapse.
5) One tanker water will be needed during each borewell drilling.
6) The quotation is valid for 30 days.

For Terra Hydrotech Solutions

Fig: 7.1: Quotation for Cost of Installing Project

Plate No. 1: Data collection in the field (recharge points)

Plate No. 2: Data collection in the field (production point)

Plate No. 3: Data collection in the field (recharge/ production point)

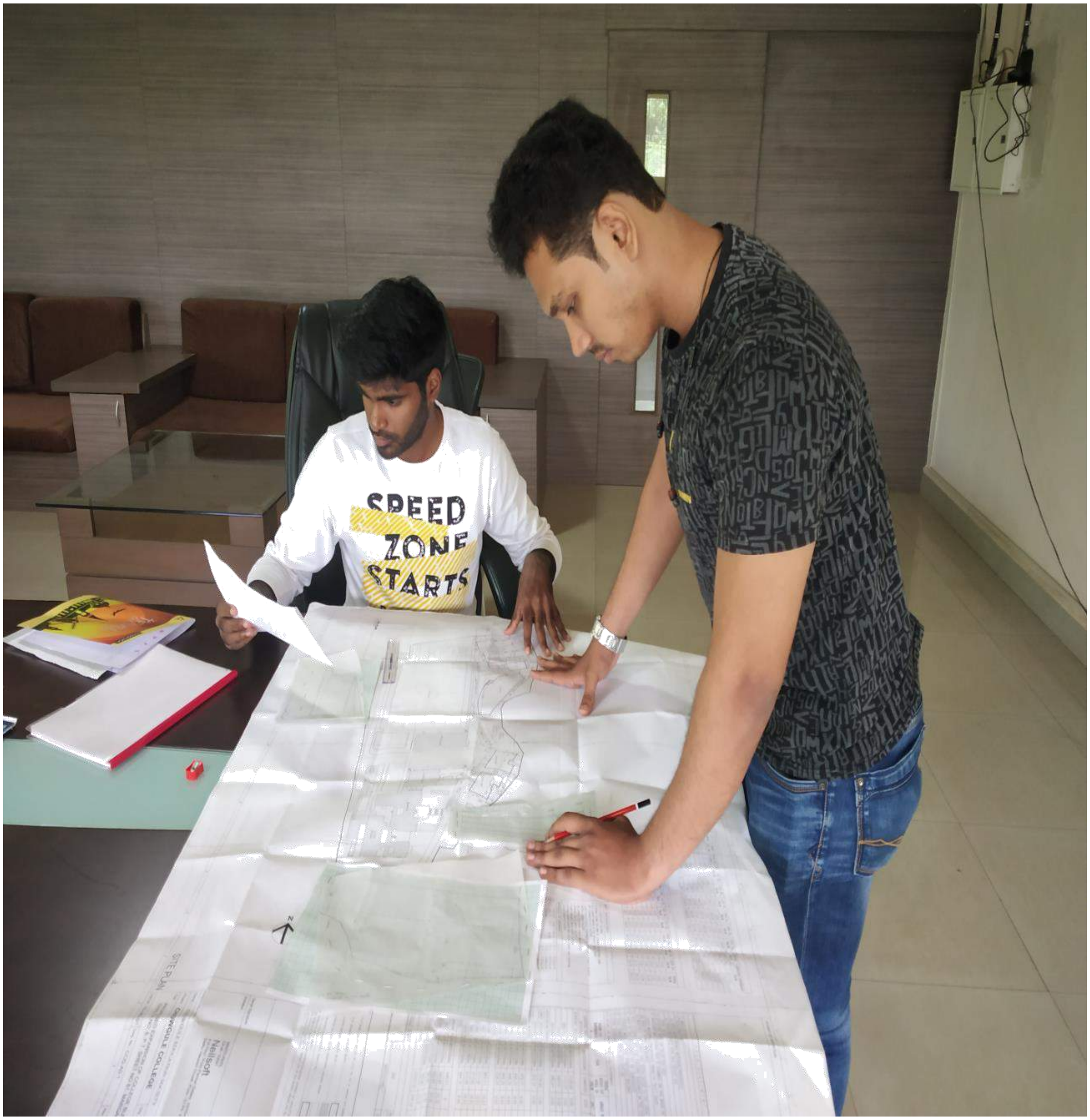


Plate No. 4: Data processing and compilation

Plate No. 5: Group Members

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