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Geophysical Studies of Time Variation of the Depth of Aquifer and its Thickness in Parts of Barend Tract, North West of Bangladesh

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GEOPHYSICAL STUDIES OF TIME VARIATION OF THE DEPTH OF AQUIFER AND ITS THICKNESS IN PARTS OF BARIND TRACT, NORTH-WEST OF BANGLADESH.

Mohammad Abdul Khaleque

THESIS

SUBMITTED TO RAJSHAHI UNIVERSITY, RAJSHAHI FOR THE AWARD OF THE DEGREE OF DOCTOR OF PHILOSOPHY IN APPLIED PHYSICS AND ELECTRONICS

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CERTIFICATE OF THE SUPERVISOR

I hereby certify that the thesis entitled "Geophysical studies of time variation of the depth of aquifer and its thickness in parts of Barind Tract, north-west of Bangladesh" submitted by Mohammad Abdul Khaleque has been composed by him under my supervision.

It has not formed the basis for any degree or award elsewhere to the best of my knowledge.

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(Mohammad Abdul Khaleque)

ABSTRACT

Groundwater is the supreme source of natural water supply, it is a precious and the most widely distributed renewable resources of the earth. Its role in modern development has increasingly been recognized. A shortage of groundwater, in areas of overdraft, stresses the significance of its reliable estimates and proper development, regulation and protection of supplies to ensure a perennial supply of this vital source.

The Barind Tract is one of the major physiographic unit of Bangladesh. This Tract lies in the north-western part of Greater Rajshahi District. The land of this Barind Tract has never been sincerely tested or any practical effort has never been made to confirm the feasibility for groundwater development in this region. Nevertheless, during the earlier part of eighties, under many programmes and projects, a good number of Deep Tube Wells (DTWs) have been sunk for the development of agriculture. But the performance of the DTWs were not satisfactory and some of them were used to face drying out during extreme low water times. Since 1984, it has been also observed that during the dry periods the discharge of the Shallow and Hand Tube Wells becomes minimum and in some cases it is completely nil. Out of the 13 thanas, comprising the Barind Tract, Nachole Thana and its surrounding areas are badly affected. Considering the above hydrogeological

problem geophysical investigation has been carried out in this area and an attempt has been made to studying the feasibility of groundwater sources and characteristics of groundwater aquifer; particularly its variation of depth and thickness during the course of the survey.

During the period of 1991 to 1993 nineteen geoelectrical measurements were carried out in the nine selected VES (Vertical Electrical Sounding) points covering the total study area and a distinct variation of aquifer level and its thickness was observed. In this regards, some hydrologic properties of aquifer e.g. porosity, permeability and specific yield is determined. Porosity of the aquifer materials ranges from 38 to 41 percent and the permeability of this formation is found 12 m/day from the pumping test result. But the permeability of the top thick clay formation (which ranges from 13 meter to 34 meter from the groundwater surface) is very low, in the range of $4x10^{-4}$ m/day which is very significant for the recharge estimation. Specific yield of the study area is found within 4.38 percent to 7.5 percent.

From the overall observation during the period of study it was found that the depth of aquifer level has been gradually declined and as a result the thickness of the aquifer is also reduced. The declination of aquifer level is found minimum in the north and north-western portion of the area, e.g. in Chatipur (VES- 1) and Paschim Mirzapur (VES-6), the respective net declination was 1.5 and 1.05 meter. While the value is maximum in the south to the south-eastern part, e.g. in Barenda (VES-8) it was 5.4 meter and in Vujoil(VES-4) it was about 2.0 meter. It is mentionable that the number of deep tube wells is minimum in the north-western part and maximum in the south-eastern part of the area. In addition to the above geoelectrical studies, a hydrograph has been prepared with the information of 21 years. It shows that, in the early eighties the fluctuation of groundwater level lie within 5 meter to 13 meter, wheares at present it is shifted below 10 meter, and as a result a permanant declination of water table is observed.

Considering the deterioration of aquifer condition, an additional effort i.e. the management of groundwater is studied for a period of 9 years. The result of this balance study also shows that the area has been suffering from an annual deficit of groundwater storage since 1987-88. In fine some specific suggestions are kept here for the immediate remedies and further development of present groundwater condition of the area.

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LIST OF SYMBOLS AND ABBREVIATIONS

A	Area of cross-section
a_j	Filter coefficient
F	Formation factor
I	Current
i	Current density
K	Geometric factor
mm	Milimeter
mg	Milligram
m/day	Meter per day
m/yr	Meter per year
mg/l	Milligram per liter
mcf	Million cubic feet
mcm	Million cubic meter
ohm-m	Ohm Meter
Ωm	Ohm Meter
ppm	Parts per million
R	Resistance of a specified layer
r	Variable distance
ρ	Resistivity
ρ_w	Resistivity of groundwater
µs/cm	Micro-siemen per centimeter
ϕ	Porosity
*	Convolution

LIST OF PUBLICATION IN THE SUPPORT OF THE THESIS

Khaleque, M. A., and Keramat, M., 1991, To study the geoelectrical parameter of Tanore Thana under the district of Rajshahi by electrical resistivity method, Accepted for publication in the Rajshahi University Studies.

Khaleque, M. A., and Keramat, M., 1991, Investigation of groundwater level by electrical resistivity method. Paper presented in 16th Annual Bangladesh Science Conference.

Keramat, M., and Khaleque, M. A.,1993, Study the variation of groundwater level of Rajshahi town and its adjoining area by electrical resistivity method, Communicated to the Journal of Association of Exploration Geophysicist, Osmania University, Hyderabad, India.

Keramat, M., and Khaleque, M. A., 1994; Application of geoelectrical method to study the aquifer response in Barind Tract of Rajshahi; The Bangladesh Journal of Scientific Research, Vol. 12(1).

CHAPTER ONE

INTRODUCTION

Chapter 1

1.0 INTRODUCTION

Water is essential for the existence of life. Our planet is unique in the sense that about 72% of the earth surface is covered with water, of which 97.2% in the oceans, 2.15% frozen and only the 0.65% is fresh water lies in the underground and also in the atmosphere as vapour. Thus the water occurs beneath the ground is termed as groundwater which is the largest available source of fresh water, suitable for human consumption.

Now a days, groundwater is considered as one of the most important resources in the development programme of the country. Bangladesh being an agricultural country, water plays a vital role for its economic development. Particularly for agricultural development, where surface water potential is seasonal and limited during irrigation season, groundwater is to be developed as an alternate source. But groundwater is also limited and there exists many constraints for its development. For this reason it is essential to determine the nature of subsurface condition and the quality of groundwater that can be withdrawn safely for different uses. The present work deals with such a problem of groundwater investigation and management. The study area is located in the Barind Tract of Greater Rajshahi District, north-west of Bangladesh.

The Barind Tract is one of the major physiographic units of Bangladesh constituting about 13 thanas of Greater Rajshahi District. At present many parts of the area suffer from problems of water scarcity. Once upon a time (before 1960) there was no tubewells and even dug wells in many of the villages of the area, particularly in the north-western part of the Barind Tract and the water demand was met up by the surface reservoirs like Ponds, Bill etc.

During the year 1967-68 under a programme of Technical Assistance from the Federal Republic of Germany, geophysical and hydrogeological investigation were carried out (Deppermann and Thiele, 1969) in order to develop a plan for groundwater extraction. The results of the investigation suggested that excluding the eastern and south-western part of the area, the irrigation projects of larger extent would yield no success.

After one decade, since 1979, a number of studies have been conducted by different organization in different discipline of groundwater resources of the area. Bangladesh Water Development Board (BWDB) had carried out a hydrogeological survey (Klinski, 1979) but it was restricted due to lack of data to cover all aspects of hydrogeology. The study by the BADC (Bangladesh Agricultural Development Corporation) to initiate the BIADP (Barind Integrated Area Development Project) contains lot of information about landuse and many other things (Assaduzzaman, 1982) but it was not a complete hydrogeological survey. The

Master Plan Organisation (MPO) of the Bangladesh Water Development Board (BWDB) initiated another survey named "Water Survey for the BIADP" and different aspects of the survey by different organisations (BWDB, 1990; BAEC,1989; BWDB,1989).

Besides, the area is also included in all of the major regional water plan projects. During the earlier part of eighties, an ambitious area development programme named BIADP (Barind Integrated Area Development Project) initiated a project for sinking and development of few thousands of Deep Tube Wells (DTWs) to provide irrigation facilities to the local farmlands during the dry months. Most of these deep tubewells of the project area are sunk within 100 to 170 feet and in few places it is about 200 feet while the Hand Tube Wells (HTWs) supplied by the Public Health Engineering Department have sunk also within 100 to 160 feet, that is, in the same hydraulic gradient. Now it is evident that during dry season, whenever deep tubewells are in operation, the discharge of the Hand and Shallow tubewells become nil. Before the initiation of the project a large number of Shallow Tube Wells (STWs) together with a small number of DTWs were in operation in the area. But the performance of the tubewells was not satisfactory and used to face drying out during extreme low water times. The water table in the area is deep compared to the other parts of the country and gradually declining further.

The situation is further aggravated by the river Padma which was the main surface water source of the area. Once upon a time the area is used to get horizontal percolation from the river beds during the dry season. Moreover the smaller distributaries of the area used to be fed by the head water from the river Ganges. Now most of them become dry during the dry periods and river stages go down compared to the groundwater level and results into loss of water from groundwater storage as base flow at higher rate.

The decline in the groundwater level and decrease in the lean period flow of the rivers is bringing in some major ecological changes in the region. Some parts, particularly the high Barind area, are showing evidences of desertification. Although BIADP is aimed to overcome this adversities, has generated an intellectual debate among the environmental scientist of the country and most of them are against large scale abstraction of groundwater from the region. According to them, such a large scale abstraction from an area with minimum rainfall, persistent draught and very low surface water potentiality could bring in severe changes in the ecological balance of the area. This effect may include deforestation, permanent decline in the water table, reduced base flow to the streams and even land subsidence.

Considering the above intricate problem the present project is designed with the following objectives:

(a) To detect the aquifer location; its hydrogeologic properties and thickness by geoelectric exploration.

(b) To determine the water quality as relates to present investigations.

(c) To estimate the recharge of groundwater by different techniques.

(d) To compute the total annual discharge.

(e) To study the management of groundwater.

1.1 FORMS OF SUBSURFACE WATER

Groundwater may be defined as the subsurface water in soils and rocks that are fully saturated. It is widely distributed under the ground and is a replenishable resource unlike other natural resources of the earth. The problems in groundwater investigation are the zone of occurrence and recharge. The subsurface occurrence of groundwater may be divided into two great zones; zone of aeration and zone of saturation. The zone of aeration consists of interstices occupied partially by water and partially by air while the zone of saturation are filled with water under hydrostatic pressure. On most of the land masses of the earth, a single zone of aeration overlies a single zone of saturation and extends upward to the ground surface, as shown in Figure 1.1.

Zone of Aeration

The water of the zone of aeration includes stored water and moving water. This general zone may be further subdivided into the soil water zone, intermediate vadose zone, and the capillary zone.

Soil-Water Zone

Water in this zone exists at less than saturation except temporarily when excessive water reaches the ground surface as from rainfall or irrigation. The zone extends from the ground surface down through the major root zone. Its thickness varies with soil type and vegetation.

Intermediate Vadose Zone

The intermediate vadose zone extends from the lower edge of the soil-water zone to the upper limit of the capillary zone (Figure 1.1). The thickness may vary from zero, where the bounding zones merge with a high water table approaching ground surface, to more than 100 meter under deep water table conditions. The zone serves primarily as a region connecting the zone near ground surface with that near the water table through which water moving vertically downward must pass. Non-moving vadose water is held in place by hygroscopic and capillary forces. Temporary excesses of water migrate downward as gravitational water (Todd, 1980).

Capillary Zone

The capillary fringes extends from the water table up to the limit of capillary rise of water. The transition to the capillary fringe is rather abrupt in coarse-grained sediments, but is very gradual in silts and clays.

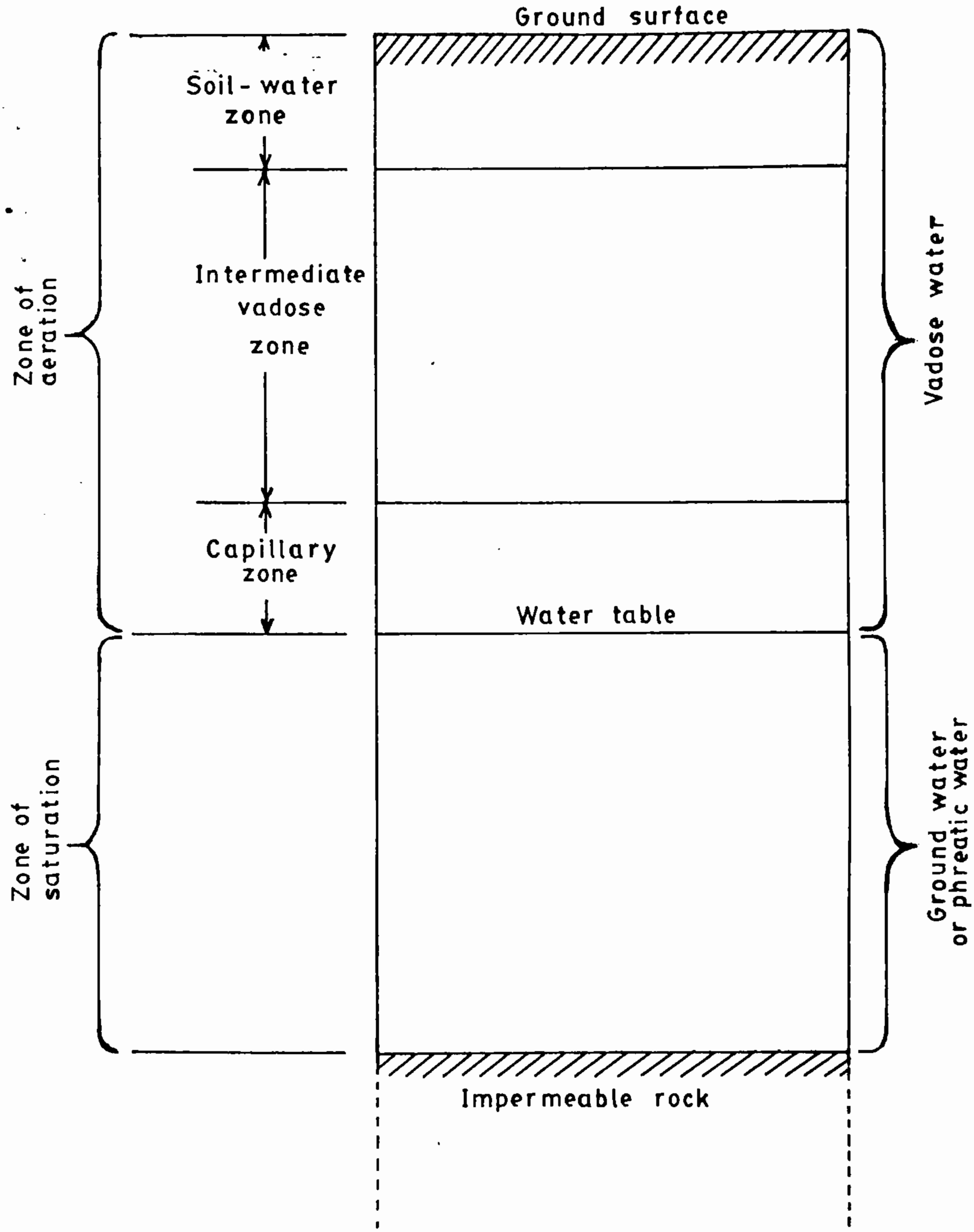

Fig. 1-1 Divisions of subsurface water.

Zone of Saturation

In the zone of saturation, groundwater fills all of the interstices; hence, the effective porosity provides a direct measure of the water contained per unit volume. A portion of the water can be removed from subsurface strata by drainage or by pumping of a well; however, molecular and surface tension forces hold the remainder of the water in place. All earth materials from soils to rocks have pore spaces. Although these pores are completely saturated with water below the water table, from the groundwater utilization aspect only such material through which water moves easily and hence can be extracted with ease are significant. On this basis the saturated formations are classified into four categories:

1. Aquifer,
2. Aquitard,
3. Aquiclude, and
4. Aquifuge.

Aquifer

An aquifer is a saturated formation of earth material which not only stores water but yields it in sufficient quantity. Thus an aquifer transmits water relatively easily due to its high permeability. Unconsolidated deposits of sand and gravel form good aquifers.

Aquitard

An aquitard is a geologic formation of rather impervious and semiconfining nature which transmits water at a very slow rate as compared to an aquifer, e.g.clay bed interbedded with sand beds.

Aquiclude

This geologic formation is essentially impermeable to the flow of water. It may be considered as closed to water movement even though it may contain large amounts of water due to its high porosity. Clay is an example of aquiclude.

Aquifuge

It is a geologic formation which is neither porous nor permeable. There are no interconnected openings and hence it cannot transmit water. Massive compact rock without any fractures is an aquifuge.

1.2 GEOLOGIC FORMATION AS AQUIFER

A geologic formation that will yield significant quantities of water has been defined as an aquifer. The word aquifer comes from the two latin words, aqua(water) and ferre(to carry). The aquifer literally carries water- underground. The identification of a geologic formation as a potential aquifer for groundwater development is a specialized job requiring the services of a trained hydrogeologist. Many types of formations serve as aquifers (Blank and Schroeder, 1973).

The geologic formations of importance for possible use as an aquifer can be broadly classified as (i) Unconsolidated deposits and (ii) Consolidated rocks. Unconsolidated deposits of sand and gravel form the most important aquifer. The aquifer characteristics vary for different geologic formation.

Alluvial Deposits

Probably 90 percent of all developed aquifers consist of unconsolidated rocks, chiefly gravel and sand. They occur as fluvial alluvial deposits, abandoned channel sediments, coastal alluvium and as lake and glacial deposits. The yield is generally good and may be of the order of 50-100 m^3/hr.

Sandstone

Among consolidated rocks, rocks with primary porosity such as sandstones are generally good aquifers. The state of weathering of rocks and occurrence of secondary openings such as joints and fractures enhance the yields. Normally the yield from these aquifers is less than that of alluvial deposits and typically may have a value of 20-50 m^3/hr (Subramanya, 1990).

Limestone

Limestones contain numerous secondary openings in the form of cavities formed by the solution of action of flowing subsurface water. Often these form highly productive aquifers.

Volcanic Rock

Volcanic rock can form highly permeable aquifers; basalt flows in particular often display such characteristics. The types of openings contributing to the permeability of basalt aquifers include, interstitial spaces in clinkery lava at the tops of flows, cavities between adjacent lava beds, fissures resulting from faulting and cracking after rocks have cooled, and holes left by the burning of trees overwhelmed by lava (Maxey and Hackett, 1963).

Igneous and Metamorphic Rocks

Igneous and metamorphic rocks with considerable weathered and fractured horizons offer good potentialities as aquifers. Since weathered and fractured horizons are restricted in their thickness these aquifers have limited thickness. Also the average permeability of these rocks decreases with depth. The yield is fairly low, being of the order of 5-10 m^3/hr.

Clay

Clay and coarser materials mixed with clay are generally porous, but their pores are so small that they may be regarded as relatively impermeable. Clayey soils can provide small domestic water supplies from shallow, large-diameter wells.

1.3 TYPES OF AQUIFER

Most aquifers are of large areal extent and may be visualized as underground storage reservoirs. Water enter the reservoir from natural or artificial recharge and it flows out under the action of gravity or is extracted by wells. Aquifers vary in depth, lateral extent, and thickness but in general aquifers may be classified as unconfined or confined, depending on the presence or absence of water table.

Unconfined Aquifer

An unconfined aquifer is one in which a water table serves as the upper surface of the zone of saturation (Figure 1.2a). It is also known as a free, phreatic or non-artesian aquifer. An unconfined aquifer is open to infiltration of water directly from the ground surface. The water table varies in undulating form and in slope, depending on areas of recharge and discharge, pumpage from wells, and permeability. Rises and falls in the water table corresponds to changes in the volume of water in storage within an aquifer. A well driven into an unconfined aquifer will indicate a static water level corresponding to the water table level at that point.

Perched groundwater represents a special case of an unconfined aquifer in which the underlying impermeable or semi-permeable bed is not continuous over a very large area and is situated at some height above the main groundwater body. The most common occurrence of perched aquifers is probably where an impermeable bed intersects the side of a velly (Price, 1985). In many areas the first unconfined groundwater encountered in drilling a borehole is of this perched type and constitutes a more or less isolated body of water whose position is controlled by structure or stratigraphy (Davis and De Wiest, 1966).

In addition, water percolating through the zone of aeration after heavy rainfall may also be regarded as a temporary perched water body, like clay lenses in sedimentary deposits (Figure 1.2b). Wells tapping these sources is of limited extent and the yield from such a situation is very small.

Confined Aquifer

A confined aquifers, also known as artesian aquifers, which is confined under pressure greater than atmospheric by overlying relatively impermeable strata. Hence the piezometric level will be much higher than the top level of the aquifer. At some locations: the piezometric level can attain a level higher than the land surface and a well driven into the aquifer at such a location will flow freely without the aid of any pump. Water enters a confined aquifer in an area where the confining bed rises to the surface; where the confining bed ends underground, the aquifer becomes unconfined. A region supplying water to a confined aquifer is known as a recharge area. Rises and falls of water in wells penetrating confined aquifers result primarily from changes in pressure rather than changes in storage volumes.

The piezometric surface, or potentiometric surface, of a confined aquifer is an imaginary surface coinciding with the hydrostatic pressure level of the water in the aquifer (Figure 1.2a). The water level in a well penetrating a confined aquifer defines the elevation of the piezometric surface at that point. It should be noted that a confined aquifer becomes an unconfined aquifer when the piezometric surface falls below the bottom of the upper confining bed. Also, quite commonly an unconfined aquifer exists above a confined one as shown in Figure 1.2a.

Leaky Aquifer

Aquifers that are completely confined or unconfined occur less frequently than do leaky, or semi-confined, aquifers. These are a common feature in alluvial valleys, plains or former lake basins where a permeable stratum is overlain or underlain by a semipervious aquitard, or semi-confining layer (Figure 1.2c). Pumping from a well in a leaky aquifer removes water in two ways: by horizontal flow within the aquifer and by vertical flow through the aquitard into the aquifer.

1.4 METHODS OF DETECTION OF AQUIFER

Groundwater properly designates all interstitial water below the water table, but only the superficial portion of groundwater, principally within 1000 ft. of the ground surface has been studied and exploited by those interested in water supply. A variety of techniques can provide information concerning its occurrence and under certain conditions-even its quality from surface or above surface locations. They are as follows.

a) Geologic method

b) Hydrologic method

c) Remote sensing method

d) Geophysical method

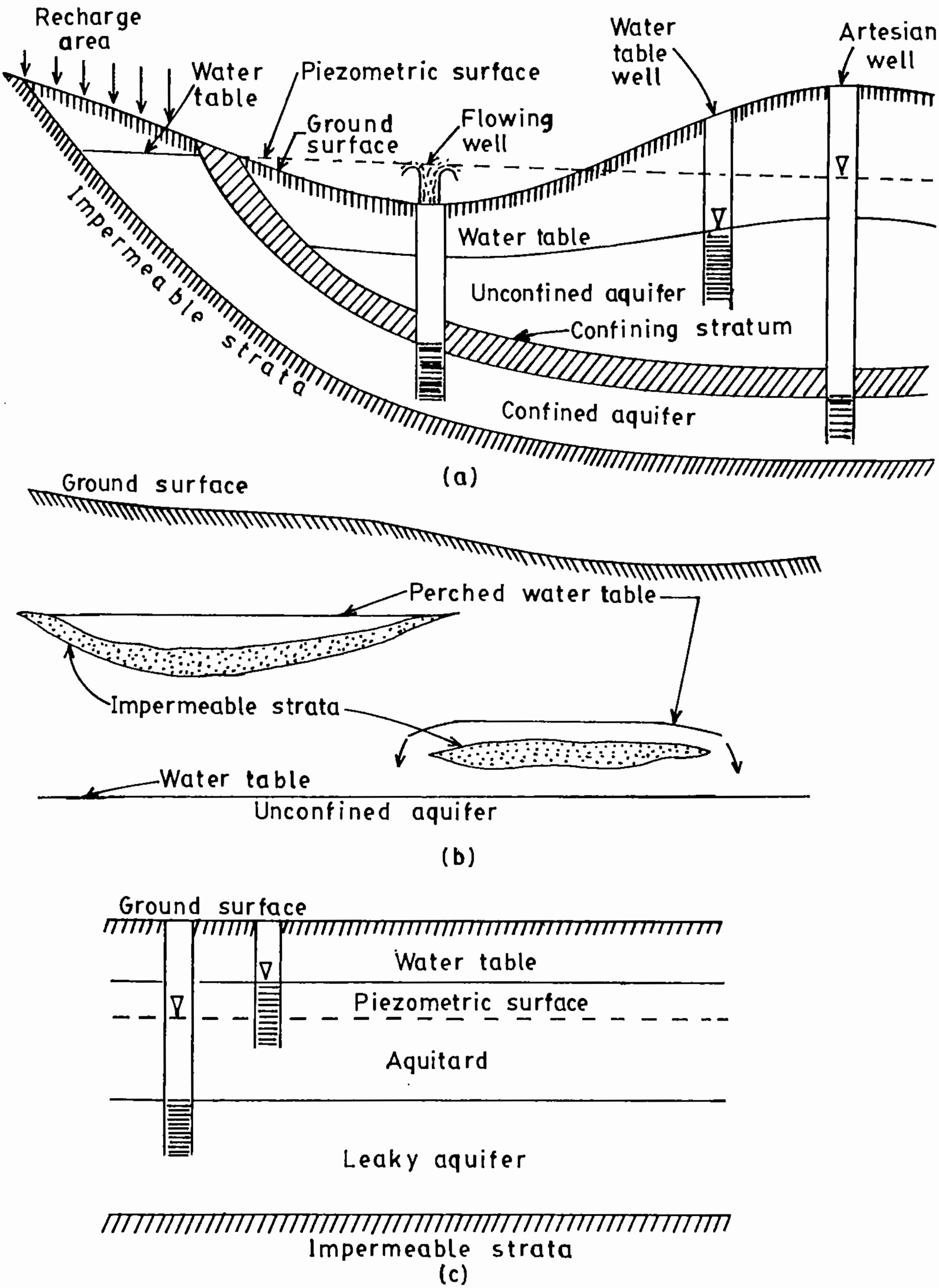

Fig. 1.2. (a) Schematic cross section illustrating unconfined and confined aquifers, (b) Sketch of perched water tables and (c) Sketch of a Leaky aquifer. [After D. K. Todd].

1.4.1 Geologic Method

Geologic studies enable large areas to be rapidly and economically appraised on a preliminary basis to their potential for groundwater development. A geologic investigation begins with the collection, analysis, and hydrogeologic interpretation of existing topographic maps, aerial photographs, geologic maps and logs and other pertinent records. The geologist utilizes petrography, stratigraphy, structural geology, geomorphology, and to a lesser extent other geologic specialization in the search for subsurface water.

1.4.2 Hydrologic Method

Hydrologic method of prospecting for groundwater include studies of total water available for recharge, ease of recharge, and the location and quantity of groundwater discharged at the surface. The total quantity of water available for recharge includes both natural precipitation and surface water in large perennial streams. In general the opportunity for finding the subsurface water is related more or less directly to the recharge available. However impermeable surfaces such as shale, clay, and quartzite prevent adequate groundwater recharge.

The presence of recoverable groundwater may be indicated roughly by the type of plants. The natural discharge is also an indication of the maximum quantity of recoverable water in the area. For the best result hydrologic and geologic exploration should proceed altogether. A region that is hydrologically favourable may not be geologically favourable for groundwater development, and the reverse is commonly true.

1.4.3 Remote Sensing Method

Photographs of the earth taken from satellite at various electromagnetic wavelengths can provide useful information regarding groundwater conditions (Bowden and Pruit(eds.),1975). Observable patterns, colours, and relief make it possible to differentiate between rock and soil types and indicate their permeability and aerial distribution and hence areas of groundwater recharge and discharge (Ray, 1960; Avery, 1977).

1.4.4 Geophysical Methods

Geophysical methods, developed in the last sixty years have proved useful for locating and analyzing groundwater. The geophysical work is, in general, much more expensive than geologic and hydrologic reconnaissance so that the decision whether or not to use geophysics is most often a questions of economics. If the exploration project is economically important enough and if the geologic framework of the area is favourable geophysics should by all means, be utilized. The most useful applications of all geophysical techniques, however, are in the interpretation of geologic structure and stratigraphy, thus eliminating the need of an extensive and expensive drilling program.

Geophysically, the location of groundwater may be determined in three ways :(i) direct, (ii) structural and (iii) stratigraphy.

(i) Direct methods are the subsurface geophysical methods that are largely confined to well-logging. Geophysical Logging involves lowering sensing devices in a borehole and recording a physical parameter that may be interpreted in terms of formation characteristics such as groundwater quantity, quality, and movement or physical structure of the borehole (Jones and Skibitzke, 1956; Keys and Mac Carary, 1971; Patten and Bennett, 1963).

(ii) The structural approach means the mapping of keys beds that bears a certain structural relation to the water bearing bed, i.e., mapping of synclines, erosional troughs, or structurallows.

(iii) The stratigraphic method, is a surface geophysical methods which implies locating water-bearing formations through distinguishing physical properties imparted by the presence of water, such as high seismic velocity or increased or decreased electrical conductivity. Although geophysical exploration was mainly developed, and has been most widely used in the search for oil and mineral; much of the knowledge thus gained, and many of the procedures (Zohdy,1974) employed apply equally well in the groundwater field.

Different geophysical methods are employed for groundwater exploration. The four major methods are seismic, magnetic, gravity and electrical resistivity. Among this four methods, the electrical resistivity method is widely used in groundwater investigation.

CHAPTER TWO

GENERAL DESCRIPTION OF THE INVESTIGATED AREA

Chapter 2

2.0 GENERAL DESCRIPTION OF THE INVESTIGATED AREA

2.1 LOCATION AND EXTENT

The study area is located in the Barind region which lies within the Greater Rajshahi District (Figure 2.1). It is one of the thana of newly Chapayee Nawabganj District named by Nachole. The thana come into existance in 1918. Once upon a time some travellers came to the present area of the thana. The area was hazaradous for which the travellers named it "Na-chol" (Unsuitable for movement). Some of the local people are in the opinion that present name of the thana has been derived from that word "Na-chol". It lies between 24°38′ and 24°51′ north latitude and 88°15′ and 88°21′ east longitude. It is bounded in the north by Gomastapur thana, in the south by Chapayee Nawabganj and Tanore thana, in the east by Niamatpur thana and in the west by Shibganj thana (Figure 2.2). It comprises a total area of 283.60 sq.Km.(109.50 sq.miles) including an area of 0.7 sq.Km. by the river Mahananda.

2.2 GEOGRAPHY

2.2.1 Landform and Topography

Two distinct landforms characterises the study area -the Barind Tract and the flood plains of the river Ganges and Mahananda. The Barind Tract itself is divided into two distinct land types-the

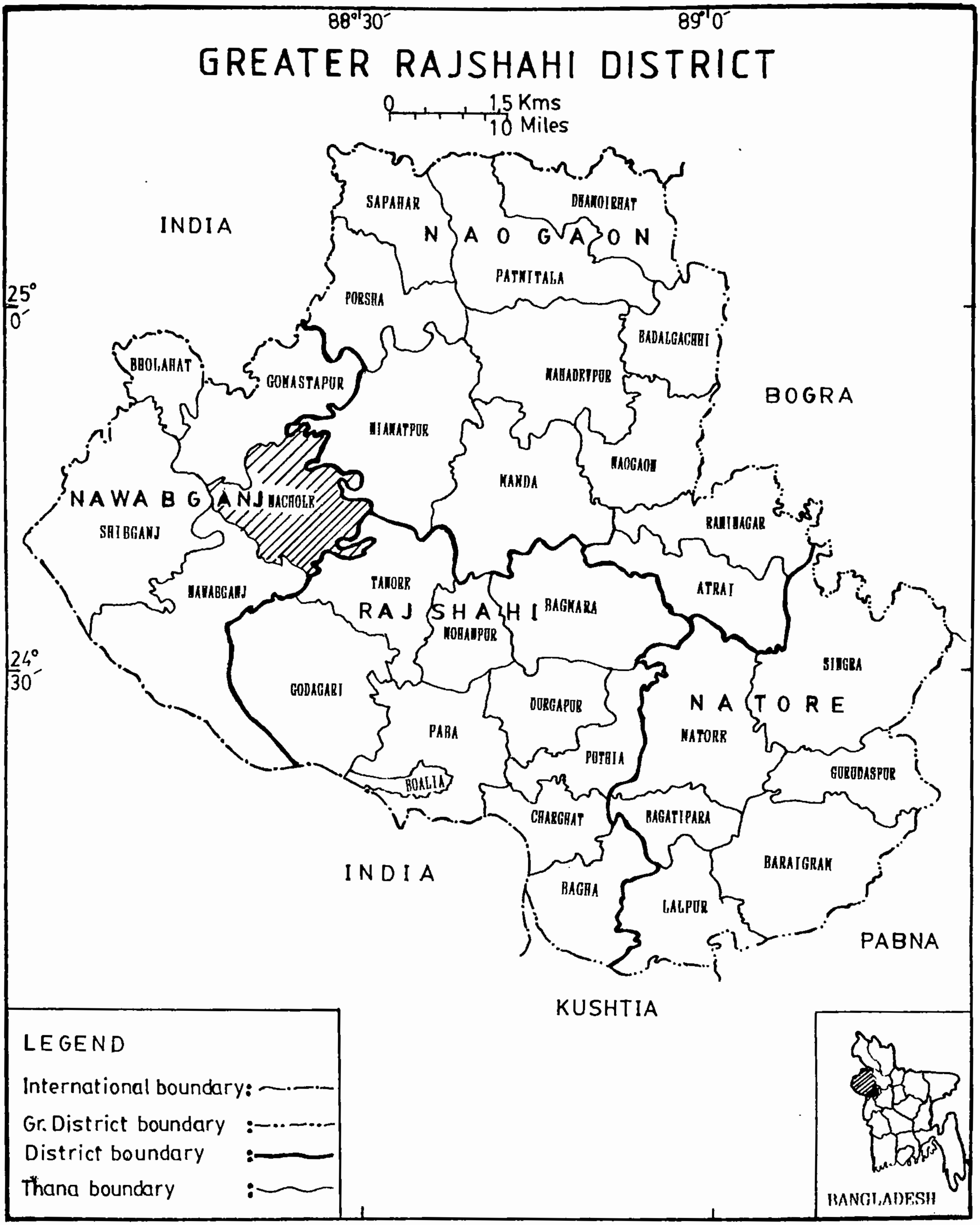

Fig. 2.1 Key map of the study area.

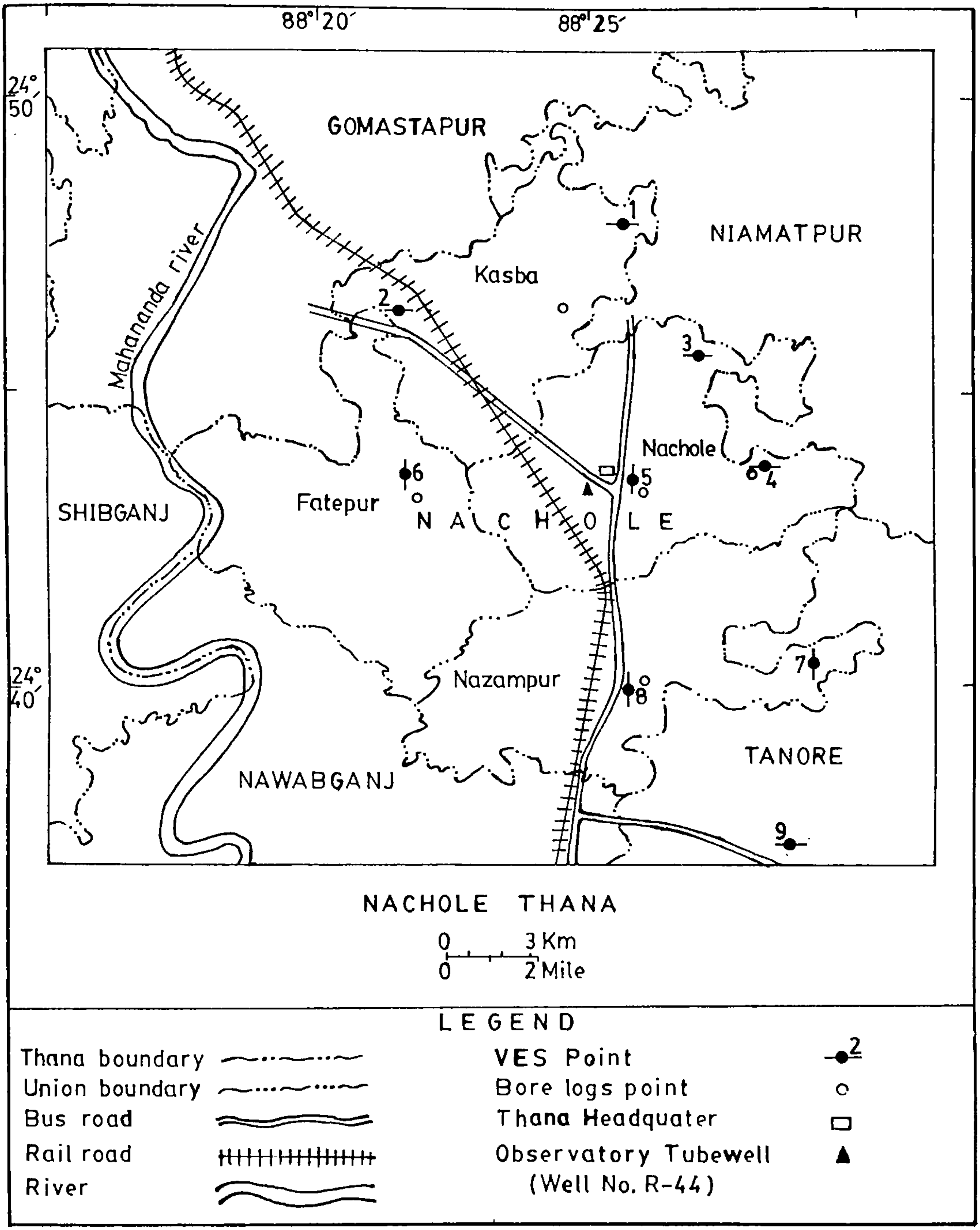

Fig.2.2. Location map of the study area.

dissected undulated high Barind which occupies about the three-fourth of the total study area and the level Barind. The flood plain comprises only 9.5% of the total area. Dissection by valley occur both at a short and long distances. In the dissected areas top of the landscape i.e. the summits are level, the slopes and valley sides are terraced, locally rounded dome shaped summits occur due to closer dissection.

The elevation of the area from the mean sea level ranges from a maximum of 38 meter in the north-west to a minimum of 32 meter in the east. The physiograpy of the area was studied in detail by Morgan and McIntyre (1959).

2.2.2 Population

According to 1981 population cencus, the total population of the study area is 74,860, of which 38,245 is male and 36,615 is female. The density of population has since considerably increased. There are 12,245 households in the area of which 12,152 (about 99.2%) are dwelling units and the rest are institutional & business/industrial units.

About 38.2% of the total dwelling households depend on tubewell, 61.2% on ponds and shallow well and 0.5% on river as a source of drinking water.

2.2.3 Drainage

The Barind Tract is drained by an intricate network of rather narrow, tightly entrenched, usually streamles valleys. The Atrai, the Little Jamuna and the Shib collect most of their drainage water in the east while the Mahananda and the Ganges collect their drianage water from the west. All these rivers have long history of migration and formation of flood plains.

Besides the main streams their exists a network of minor tributaries and distributaries along with numerous canals. Most of these become dry in the dry months. There are some standing surface water bodies like ponds. Another type of surface water body of the area is the low lying swampy lands locally known as Beels. Some of them are quiet big and perennial (Sparrso, 1989).

2.2.4 Climate

Barind Tract has a tropical monsoon climate. There are three distinct season in the area - winter (November to February) which is cool and almost dry; premonsoon (March to May) which is hot and has periodic thunderous shower; and monsoon or rainy season (June to October) which is warm, humid and 80% or more of the annual precipitation occurs during this time. The highest temperature of the year is recorded in the premonson period, at times exceeding 45°c whereas the minimum winter temperature is less than 10°c. Winds are ordinarily light through out the year but stroms are common in premonsoon time. The study area is in the high evaporation zone, relative humidity varies from 60% in winter to more than 85% in monsoon.

2.2.5 Rainfall

One of the major factor affecting the groundwater and agriculture pattern of the area is unequal seasonal distribution of rainfall. About 80% of the total rainfall occurs during monsoon (June to

October). The rest 20% falls during the other season. The annual rainfall for the last 22 years (1972 to 1993) in the study area is given in Table 2.1. The average annual rainfall of the above 22 years is about 1443 mm which is relatively lower than the other parts of the country.

Table 2.1. Annual rainfall records of the study area during the period 1972 to 1993.

Year	Rainfall in (mm)	Year	Rainfall in (mm)
1972	1410.97	1983	1328.42
1973	1367.03	1984	1329.69
1974	1834.89	1985	1343.66
1975	739.14	1986	1729.99
1976	1082.04	1987	1558.79
1977	2063.24	1988	1848.80
1978	1317.49	1989	1279.30
1979	1419.60	1990	1564.20
1980	1558.54	1991	1572.20
1981	1812.54	1992	1342.30
1982	796.29	1993	1410.05

2.2.8 Vegitation

Old river-beds, ponds and marches, and streams, with sluggish current have a copious vegitations of vallisnenia and other plants. Lands subjected to inundation have usually a coverings of Tamarisk and reedy grass. There are no forests. Usually the higher grounds are covered with bamboos and grass. Imperata arundinacea and Andopogon ociculutus are among them. The banyan, pipal and semul may be seen.

In the villages palms are grown widely and Khejur or date-palm trees are grown generally in the southern parts. Besides these, numerous species of the babul (Acacia arabia) or gum trees are found through out the study area (Siddiqui, 1976).

2.3 GEOLOGY

2.3.1 Regional Geologic Setting

Bangladesh is situated in the eastern part of the Bengal Basin, a partly geo-synclinal sedimentation area which is still in course of settlement. The Basin is bounded to the west by the Rajmahal Hills, to the north by the Shilong Plateau of Assam, and to the east by the Tripura Hills.

2.3.2 Structure and Tectonics

The Barind Tract comprises a part of the Bengal Basin, one of the major sedimentary basin of the world. The Bengal Basin is divided into two major tectonic units - the western stable shelf and the eastern mobile foredeep flank. The Barind is situated in the stable shelf region (Guha, 1978). Figure 2.3 shows the tectonic classification of the Bengal Basin.

The Barind Tract is devoid of any major visible surface structure whereas it is delineated and underlain by a number of major subsurface faults. The area is tectonically active and evidences of recent tectonic activities are found in different places (Morgan & McIntyre, 1959; Khandoker, 1987 & 1989).

The Barind Tract is bounded in the west by the Maldah - Kishanganj Fault in the south by the Padma Fault, in the east by the Dhubri-Jamuna Fault and the Karatoya Fault. The western extension of the Dauki Fault, a major structural unit of the region, cuts across the area. All the Faults are subsurface and some of them are basement faults.

2.3.3 Sedimentology

The geology of the Rajshahi Barind Tract is of Quaternary age. It is essentially composed of fluvial sediments mainly deposited by the Ganges-Brahmaputra system. The nature and distribution of the surface sediments within the area have been well described by Morgan and McIntyre (1959). From the hydrological point of view, the surface sediments is the oldest exposed sedimentary sequence of the area and is of Pleistocene age. At the surface the Barind sediments consists of unconsolidated red to yellow lateritic clays (Modhupur clay) which towards the depth, merge into gray clay.

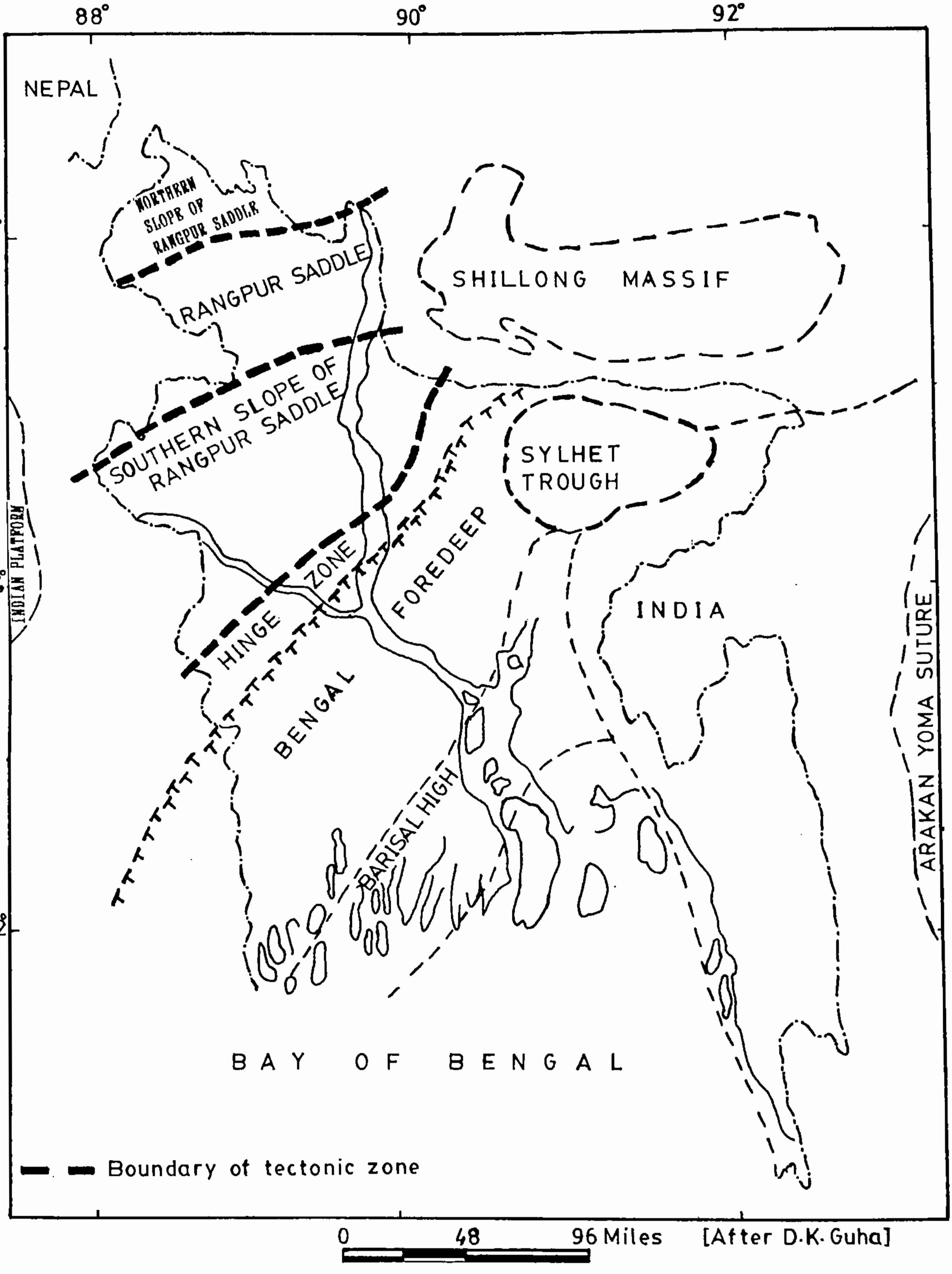

Fig. 2.3 Tectonic Map of Bangladesh.

The formation was most probably laid down in a deltaic environment. The clays of the unit are yellowish-gray in colour and the persistent weathering of the iron rich sediments has produced the characteristic red colour and hence locally know as red clay. The clay thickness varies from 6 meter in the south-west to over 30 meter in the north-west.

CHAPTER THREE

GEOELECTRICAL RESISTIVITY METHOD

Chapter 3

3.0 GEOELECTRICAL RESISTIVITY METHOD

The early chronology of applications of electrical methods of exploration has been carefully preserved in different literature (Kelly,1950; Kunetz,1966; Van Nostrand and Cook,1966). From those preservations and others, it seems that the electrical methods actually began with Robert W. Fox's 1830 observation of self potentials associated with copper vein deposits in cornwall.

The first practical approach to utilizing active electrical methods, wherein the earth is energized via a controlled source and the resulting artificial potentials are measured, was due to Schlumberger in 1912. At that time he introduced the direct-current equipotential line method (Schulumberger,1920).

The concept of apparent resistivity was introduced in about 1915 by both Wenner (1912) and by Schlumberger(1920). The theoritical basis for the electrical resistivity method became more firmly grounded with the forward solutions developed for horizontally layered earths by Stefanesco et al (1930), and others. This work culminated in the publication of an album of curves for the Schlumberger array (Compagnie General de Geophysique,1955) and for the Wenner array by Mooney and Wetzel(1956). Until recently, matching of observed and theoritical curves using such albums was the standard method of interpreting resistivity data over horizontally layered earths.

Langer (1933) and Slichter (1933) were the first to develop formulation of the inverse problem in resistivity sounding of horizontally layered structures. Koefoed (1968) and Ghosh (1971) did much to make inversion practial. Zohdy (1975) developed a method of direct interpretation with which he obtained good results.

3.1 ELECTRICAL PROPERTIES OF ROCKS

All rocks at the earth's surface are porous. Under any reasonable circumstances these pores are partly or completely filled with water. This water usually carries some salt in solution, so that the water content of a rock has a far greater capacity for carrying current than does the solid matrix of the rock, unless highly conducting minerals are present. For most rocks near the earth's surface, conduction will be electrolytic.

The resistivity of a water bearing rock will depend on the amount of water present, the salinity of this water and the way in which the water is distributed in the rock. The electrical properties of a water-bearing rock should be describable in the same terms as the electrical properties of an electrolyte.

The resistivity of a water-bearing rock decreases with increasing water content. In fully saturated rocks water content may be equated with porosity, but in partially desaturated rocks, the effect of desaturation on resistivity must be considered. For example, in such rocks, where ρ is the resistivity when fully saturated with water of resistivity ρ_w , the ratio $F = \rho/\rho_w$ for a particular formation tends to be constant and is known as the formation factor. There is also a relationship between the formation factor F and the porosity ϕ having the general form

$$F = a/\phi^m \qquad (3.1)$$

where a and m are constants, their values being governed by the nature of the formation. Since m has a value not far from 2, the formation factor varies more or less inversely as the square of the porosity (Griffiths and King, 1981).

Unlike the other rock-forming minerals, which are in themselves non-conductors, conduction takes place through clays by way of the weakly bonded surface ions. Equation (3.1) above does not therefore apply to porous rocks containing any appreciable amount of clay minerals.

3.2 THEORITICAL FOUNDATION

Geoelectric exploration consists of exceedingly diverse principles and techniques and utilizes both stationary and variable currents produced either artificially or by natural process. One of the most widely used methods of geoelectric exploration is known as the resistivity method. In this method, a current (direct or very low frequency) is introduced into the ground by two or more electrodes and the potential difference is measured between two points (probes) suitably chosen with respect to the current electrodes. The potential difference for unit current sent through the ground is a measure of the electrical resistance of the ground between the probes. The resistance is a function of the geometrical configuration of the electrodes and the electrical parameters of the ground. From a knowledge of the potential drop, current and electrode spacings, the ground resistivity can be easily calculated.

For a quantitative treatment, let us consider a homogeneous isotropic earth layer of resistivity ρ, length l, resistance R and cross sectional area A, through which a current I is flowing. The potential difference across the ends is given by Ohm's law:

$$\Delta V = RI \qquad (3.2)$$

By definition, $R = \rho l/A$, the above equation (3.2) can be rewritten as:

$$\Delta V = \rho l I/A$$

or $$\Delta V/l = \rho I/A$$

or $$\text{grad } V = \rho i \qquad (3.3)$$

where grad V stands for the potential gradient, and i is the current density.

The next step in the development of the theory is to derive the potential in a homogeneous medium due to a point source of the current. Now consider a semi-infinite conducting layer of uniform resistivity bounded by the ground surface and let a current of strength +I enter at point A on the ground surface (Figure 3.1). This current will flow away radially from the point of entry and at any instant its distribution will be uniform over a hemispherical surface of the underground of resistivity ρ. At a distance r, away from the current source, the current density i, would be :

$$i = I/2\pi r^2 \qquad (3.4)$$

The potential gradient $-\delta v/\delta r$ associated with the current is given by equation (3.3) which when using equation (3.4) can be written as:

$$-\delta v/\delta r = \rho i = \rho I/2\pi r^2 \qquad (3.5)$$

The negative sign indicates here to express the fact that potential increases in the opposite direction to the current flow. The potential at a distance r (e.g. at point P in Figure 3.1) is obtained by integrating equation (3.5) and is :

$$V = I\rho/2\pi r \qquad (3.6)$$

This is the basic equation which enables the calculation of the potential distribution in a homogeneous conducting semi-infinite medium. Figure 3.2 shows the distribution of the potential and the lines of current flow in the vertical section of a homogeneous conducting underground medium due to a pair of current electrodes (Sharma, 1978).

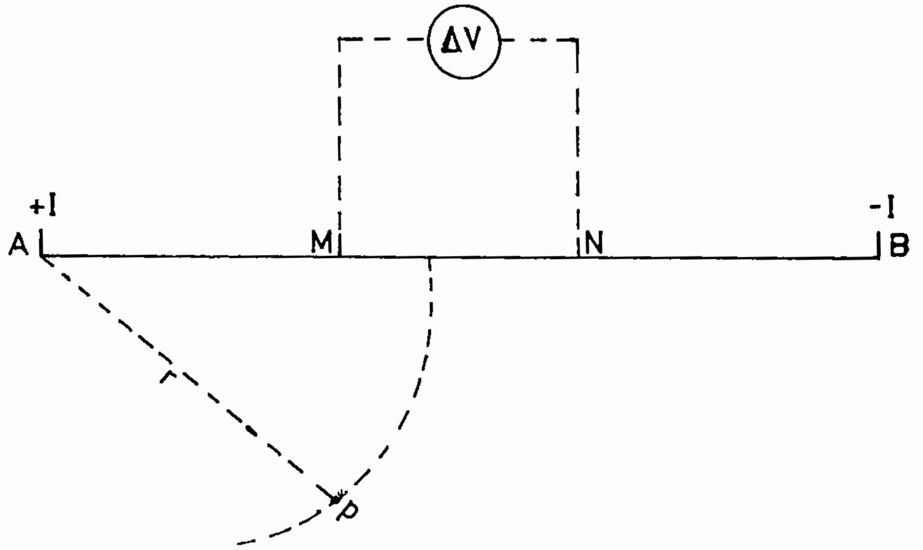

Fig. 3.1. Method of calculating potential distribution due to a current source in a homogeneous medium.(After Todd, 1980).

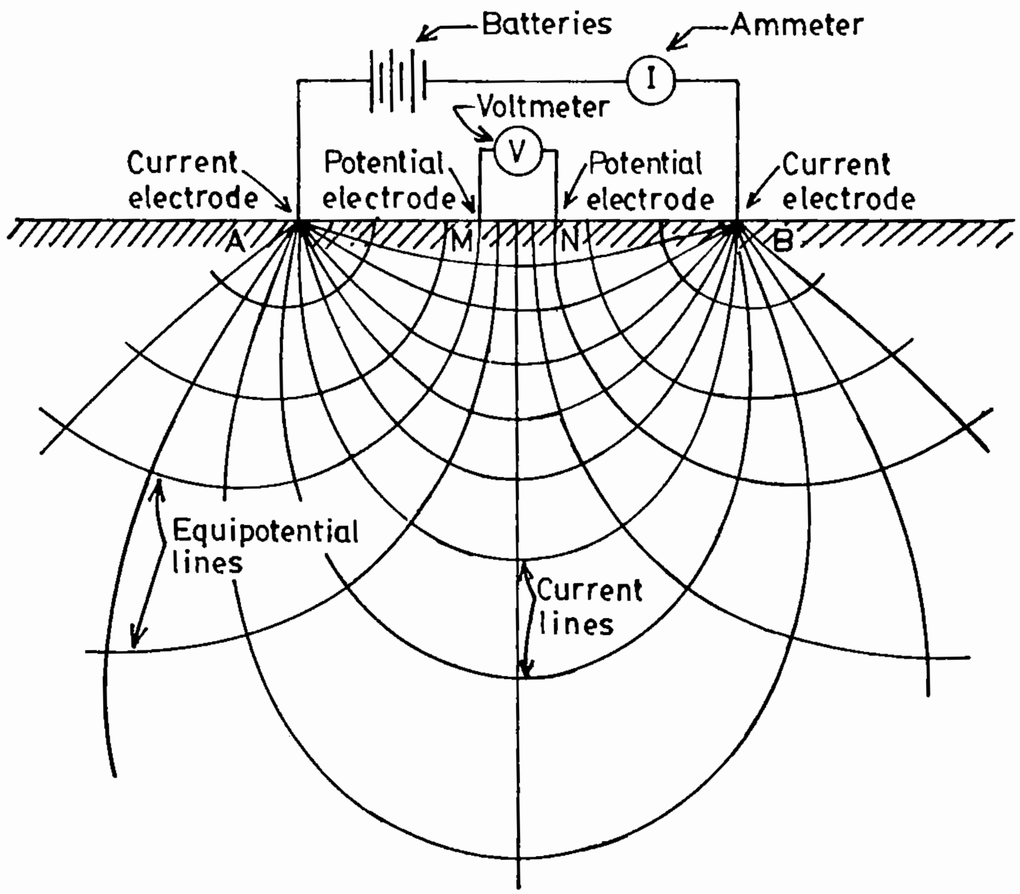

Fig. 3.2. Electrical circuit for resistivity determination and electrical field for a homogeneous subsurface stratum.(After Todd, 1980).

3.3 RESISTIVITY MEASUREMENT

From equation (3.6) it is easy to see that the potential difference between points M and N (Figure 3.1) caused by current +I at the "source" (entry point A) is :

$$V_A = (I\rho/2\pi).(1/AM - 1/AN) \qquad (3.7)$$

In the same manner, the potential difference between M and N caused by -I current at the "sink" (exit point B) is :

$$V_B = (-I\rho/2\pi).(1/BM - 1/BN) \qquad (3.8)$$

The total potential difference V between M and N is, therefore given by the sum of the right hand side of equations (3.7) and (3.8):

$$V = (I\rho/2\pi).(1/AM - 1/BM - 1/AN + 1/BN)$$

or $$\rho = (2\pi V/I).\{1/ 1/AM - 1/BM - 1/AN + 1/BN)\}$$

or $$\rho = (2\pi V/I).K \qquad (3.9)$$

here K denotes the geometric factor of an electrode configuration. For field practice a number of different electrode configurations have been proposed. Several commonly used linear array type arrangements are; (i) Wenner array, (ii) Lee-partition array, (iii) Schlumberger array, and (iv) Dipole-Dipole arrya. Regardless of the specific electrode spread employed, there are really only two basic procedures in resistivity work. The particular procedure to be used depends on whether one is intersted in resistivity variations with depth or with lateral extent. The first is called electric sounding and the second electric profiling.

3.4 INTERPRETATION TECHNIQUES

The interpretation of field observation in terms of layer parameters (e.g. resistivity and thickness) is the basic task of a geoelectrical survey. The field data obtained in the form of an apparent resistivity curve (ρ_a), is interpreted in terms of basic theory and the results are then correlated with available geohydrological information to arrive at a realistic picture of the subsurface structure. The first step is thus termed as physical interpretation and the subsequent procedure as geological interpretation.

Interpretation are broadly classified into qualitative and quantitative. The qualitative interpretation involves the study of the types of the curves, preparation of apparent resistivity maps and section. Quantitative interpretation is made as indirect and direct depending upon the manner in which the parameters of the subsurface are deduced from the field observations.

Indirect Method

In this method the field curve is compared with a set of precalculated master curves (Compagnie General de Geophysique, 1963; Orellana and Mooney, 1966; Rijkswaterstaat, The

Netherlands, 1975) for known geological condition of the earth. A match of the curves is interpreted as a match of the parameters. There are four approaches which may be used in interpreting multiple layer resistivity sounding data (Keller and Frischkneeht,1982):

1. Complete curve matching, *2.* Partial curve matching, 3. Equivalent curve matching, and *4.* Observation of the position of the maxima and minima on the field data.

Out of these methods, the partial curve matching technique is widely used for preliminary interpretation. This semi-empirical method is also termed as "Auxiliary Point Method".

Direct Method

Direct methods is such a method in which attempts have been made to determine the layer distribution directly from field measurements, by taking the help of certain mathematical process. The foundation of the direct method was laid by Langer (1933) and subsequently it has been widely investigated by different authors (Slichter, 1933; Pekeris, 1940; Vozoff, 1958; Koefoed, 1968; Meinardus, 1970; Kunetz and Rocroi, 1970) by means of different numerical or graphical procedures.

In direct method sampling and filter theory (Ghosh,1970) is applied in deriving the resistivity transform function T, related to the kernel, from the apparent resistivity curve and the layer parameters could then be obtained from the T curve. The direct interpretation system (Koefoed, 1968, 1970) splits up into three steps:

1. The determination of sample values of the resistivity transform from the observed apparent resistivity values.

2. The determination of the layer parameters of the top layer from the early part of the resistivity transform curve.

3. The reduction of the resistivity transform curve to a lower boundary plane. Steps (2) and (3) are iterated until the transform curve has been exhausted.

The resistivity field curve is sampled at a regular interval in a factor of 10 of log paper used. The sampled values are then replaced by functions of the form sinx/x called sinc function. The sum of the resistivity transform of each of these sinc functions give the total transform of the whole apparent resistivity curve.

For simplification in application the digital approach is followed. This involves determining the filter coefficient of the sinc response and a running weighted average of that filter operators with the input (i.e the resistivity sample values) yield the output (i.e. the transform values). This is described by the following digitalized convolution process,

$$T_m = \sum_{-\infty}^{\infty} a_j * R_{m-j} \qquad (3.10)$$

where T_m = resistivity transform at sample point m

R_m = apparent resistivity value at sample point m

a_j = filter coefficients; number determined by the length of filter to be used

Different sets of filter coefficients are to be used for the Schlumberger and Wenner arrangement. The short filter with 9 points (Table 3.1) is most commonly used because of its high accuracy.

Table 3.1 The short Schlumberger filter coefficients.

a_{-2}	a_{-1}	a_0	a_1	a_2	a_3	a_4	a_5	a_6
-0.0723	0.3999	0.3492	0.1675	0.0858	0.0358	0.0198	0.0067	0.0076

Hence the above equation becomes:

$$T_m = \sum_{-2}^{6} a_j * R_{m-j} \qquad (3.11)$$

The early part of the resistivity transform gives the top layer parameters. To this end the reduction of the resistivity transform to a lower boundary plane is made that corresponds to a layer distribution by removing the top layer. This reduction to a lower boundary plane is based upon the following equation (Koefoed,1970).

$$T_{n-1} = (T_n - v_1)/(1 - T_n v_1/\rho_1^2) \qquad (3.12)$$

where $$v_1 = \rho_1 (1 - e^{-2\lambda t_1})/(1 + e^{-2\lambda t_1}) \qquad (3.13)$$

In equation (3.12) and (3.13) T_n is the resistivity transform corresponding with the original layer distribution,T_{n-1} is the resistivity transform reduced to the lower boundary plane and ρ_1 and t_1 are the resistivity and thickness of the top layer. The layer distribution is now obtained in the following way:

i) by fitting the first part of the resistivity transform T_n to a two-layer curve, the values of ρ_1 and t_1 are obtained;

ii) from the values of ρ_1 and t_1 and with the equation (3.12) and (3.13), the resistivity transform T_{n-1} is easly obtained.

iii) steps (i) and (ii) are repeated now on the function T_{n-1} and so on until a reduced resistivity transform is obtained which is fully fitted by a two layer curve.

As concerns step (ii), the evaluation of T_{n-1} can be carried out by the graphical procedure suggested by Koefoed (1970) or alternatively, by a numerical computation procedure (Patella, 1975) directly on equation (3.13) and (3.14). The later one i.e. the Patella´s computational procedure is adopted for the present interpretation. Figure 3.3 to 3.5 shows an example of stepwise interpretation procedure.

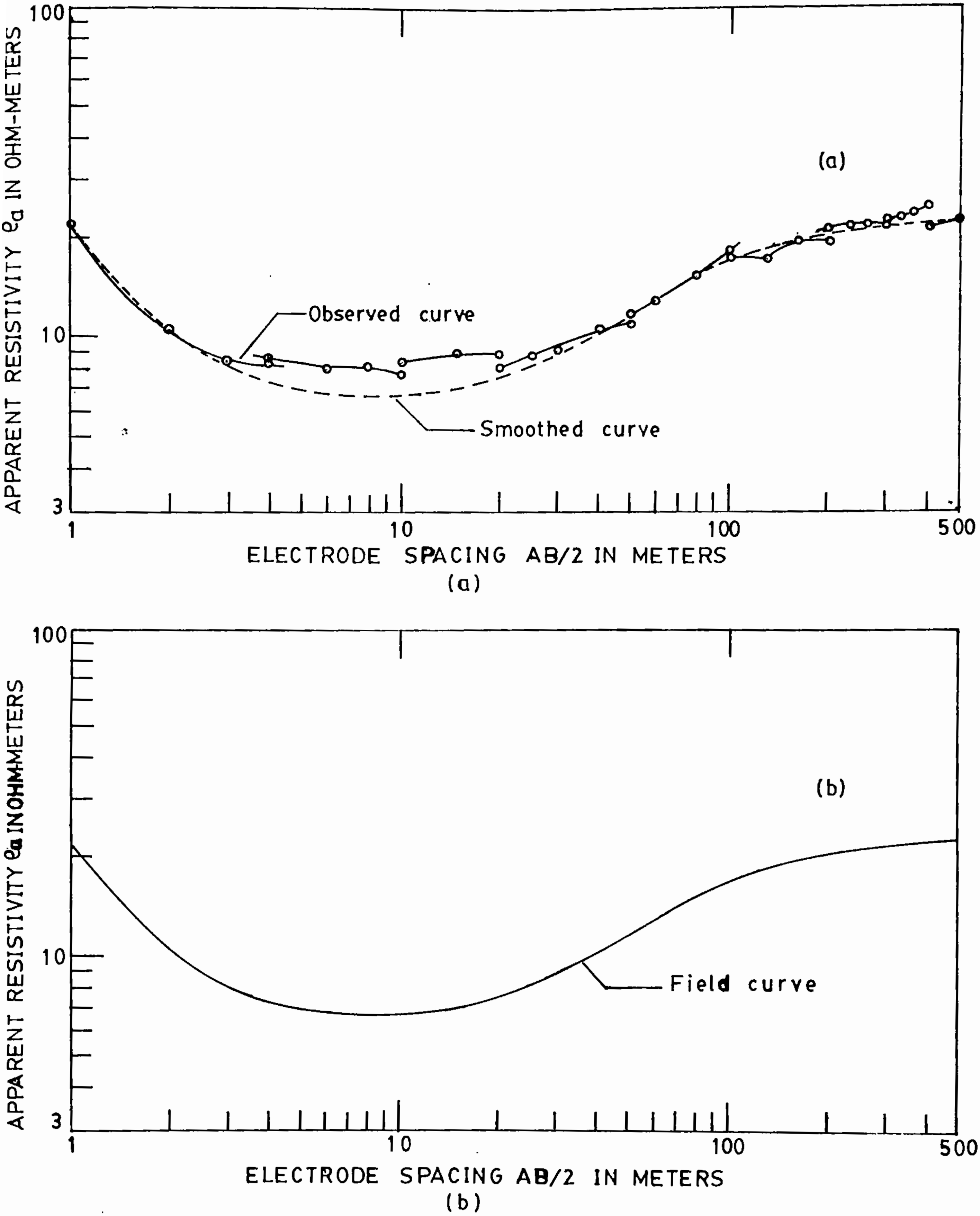

Fig.3.3 (a) Correct displacements on a Schlumberger sounding curve and method of smoothing, (b) Final field curve after smoothing. This observed curve is taken from the location Barenda (VES No.-8, May, 1993).

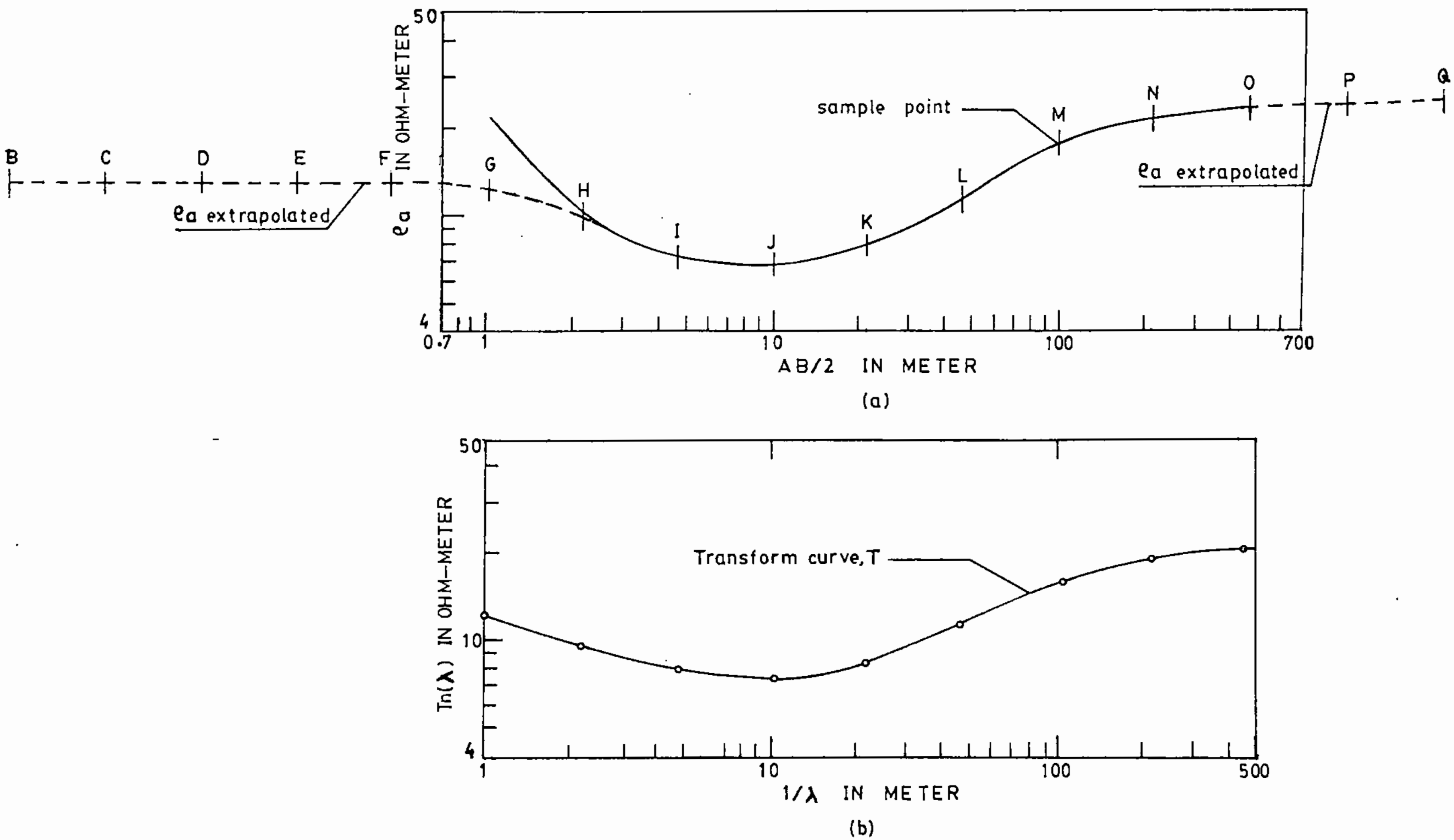

Fig. 3.4 Derivation of the resistivity transform from the sampled values of the apparent resistivity field curve, (a) sampling of ρ_a curve (b) resultant T curve, of the example of Figure-3.3

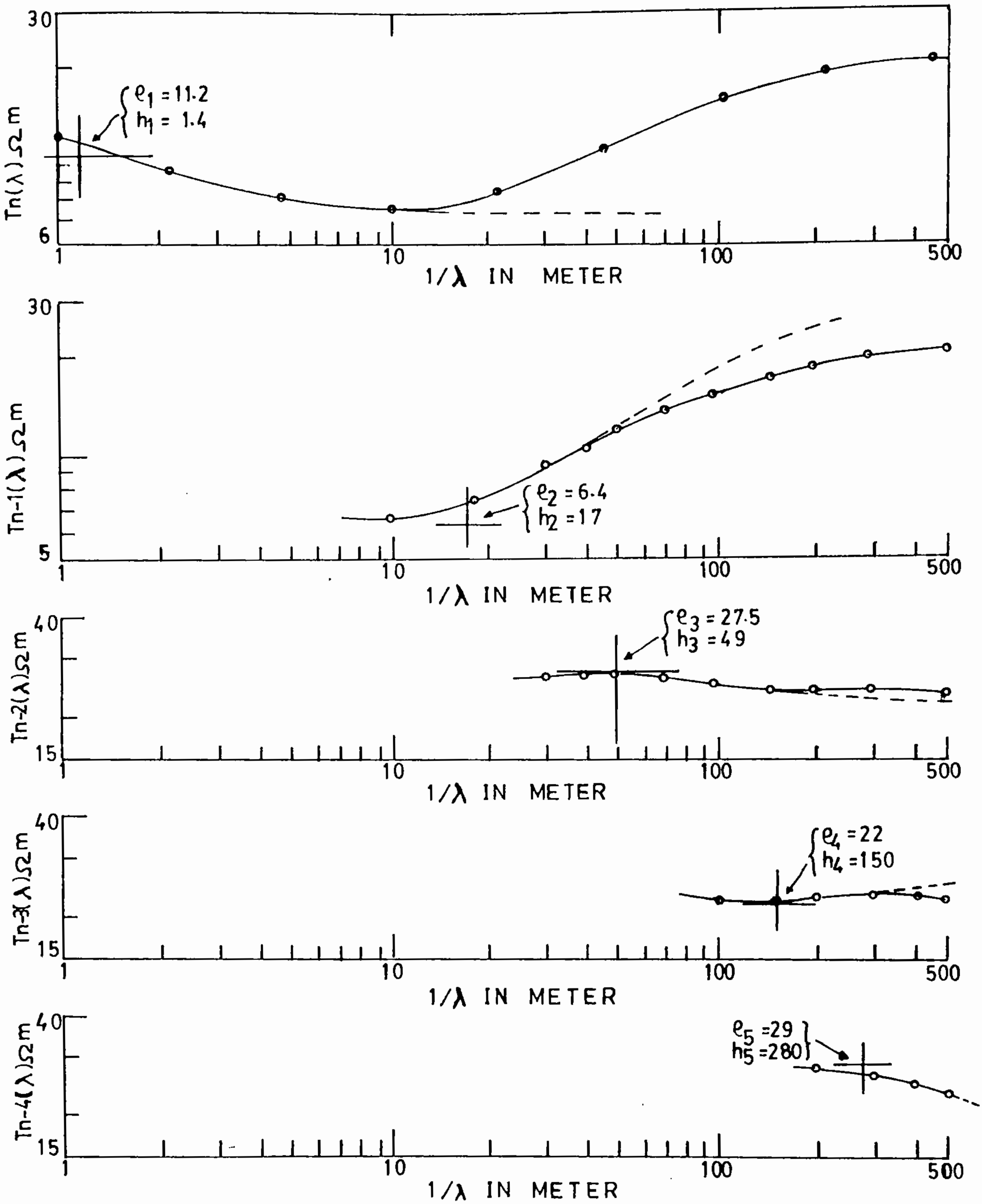

Fig. 3.5 Determination of the layer distribution from the resistivity transform of the example of fig. 3.4

CHAPTER FOUR

ELECTRICAL RESISTIVITY SURVEY

Chapter 4

4.0 ELECTRICAL RESISTIVITY SURVEY

Whatever the geophysical method being used to solve a particular problem the aim will be to acquire information quickly and cheaply consistent with obtaining enough data of sufficient accuracy for an adequate interpretation to be made. The choice of the method will depend to a considerable extent on the geology, and nature of the problem involved.

In hydrogeology a very wide range of problem is met, demanding for their solution anything from a few depth sounding to a long and detailed survey. Major investigations are likely to involve also drilling, borehole logging and the use of other geophysical methods. In some instances the resistivity survey may only be used to determine the geometry of a known aquifer, that is, its depth and thickness, lateral extent and the degree, and nature of any faulting.

4.1 DATA ACQUISITION

The present electrical resistivity survey is carried out in Nachole thana and its surrounding area which is a part of the Barind Tract of Greater Rajshahi. Vertical Electrical Sounding (VES) employing Schlumberger configuration were conducted at different locations. The study area, Nachole thana is consists of four union and the locations are so chosen that at least one sounding has been made in each union. A total of nine (9) locations are selected (Figure 2.2). Each location is treated as a separate VES (Vertical Electrical Sounding) number, such as VES No. 1, 2, 3, 4, 5, 6, 7, 8, and 9, are represents the location, Chatipur, Kachra, Amjoan, Vujoil, Nachole, Paschim Mirzapur, Diara, Barenda, and Mundumala respectively. The location Mundumala (VES-9) is located in the neighbouring Tanore thana which is south-east of Nachole thana as shown in the Figure 2.2.

Field work was carried out at least once in a year during the period (1991-93) of the field programme. The field work of the present investigation was accomplished with the help of concerned final year student and one Laboratory Assistant of the Department of Applied Physics & Electronics. Equipment and its accessories were supplied from the department but transportation and other field expenditure had financed by the U.G.C.(University Grant Commission). The field work was started in March 1991. In the first year nine (9) sounding points are covered. In 1992 the field work was frequently interrupted by rain and it was not possible to carry out the field work after only two sounding. Due to that reason, an additional field programme was made in January 1993. All these above field work were made with the maximum current electrode separation of 260 meter.

Finally in view of searching deeper aquifers, in May 1993, five(5) stations have been selected covering the whole study area for Vertical Electrical Sounding (VES) with the current electrode spacings (AB/2) of 500 meter.

4.2 INTERPRETATION

The resistivity sounding curves were primarily interpreted by the semi-empirical Auxiliary Point Method. Finally the field curves were interpreted by the direct interpretation method. This method essentially based upon the successive reduction of the kernel function (or resistivity transform related to kernel) to lower boundary plane. The interpretation technique employed in the present geoelectrical studies are described in details in the earlier chapter.

In the first year of field programme, a total of 9(nine) sounding have been made. Out of the 9(nine), five sounding points are finally selected for the study of time variation of the depth and thickness of aquifer. However, the field data of the remaining four sounding (VES-2, VES-3, VES-7, and VES-9) have been also interpreted.

VES-2(Kachra): This VES point is located in the north-western portion of the study area. The field curve is complicated and multilayered one. Interpretation of this curve gives a total of seven layer's information within the depth of only 90 meter, where the first four layer occurred within the depth of only 15 meter, i.e. above the water table as to local geology. Practically it happened due to the seasonwise temperature variation. The resistivity of the layer varies from 21 ohm-m to 112 ohm-m. The interpreted curve is shown in the Figure 4.1(a).

VES-3(Amjoan): The sounding point is situated in the north-eastern part of the investigated area. The shape of the field curve is almost H-type. A total of 6(six) layer is obtained, where the top three layer is found within the depth of 9(nine) meter as is observed earlier in VES-2. The resistivity of the five layer ranges from 13 ohm-m to 68 ohm-m. The sixth layer has a resistivity of 340 ohm-m which is comparatively high indicating a hard layer. The interpreted field curve is shown in the Figure 4.1(b).

VES-7(Diara): This sounding is made in the south-eastern part of the study area. The field curve is a multilayered and almost QA-type in shape. Interpretation of this curve gives 6(six) layer and the first three layers are occurred within 90 meter depth due to moisturisation of soil. The resistivity ranges a low value (9.6 ohm-m to 75 ohm-m) excepting the sixth layer of resistivity 262.5 ohm-m showing a reasonably hard layer. The interpreted curve is shown in the Figure 4.2(a).

VES-9(Mundumala): The last sounding point VES-9 is located in the neighbouring Tanore thana as shown in the study area (Figure 2.2). The shape of the field curve is HA-type. Four layer parameters are obtained from its interpreted curve. The resistivity of first three layer ranges within only 12 ohm-m to 22 ohm-m while the fourth layer attains a resistivity of 154 ohm-m of undetermined thickness. Figure 4.2(b) shows its interpreted field curve. The interpreted result of the above four sounding points(VES-2, VES-3, VES-7 and VES-9) are arranged in a tabular form as shown below in Table 4.1.

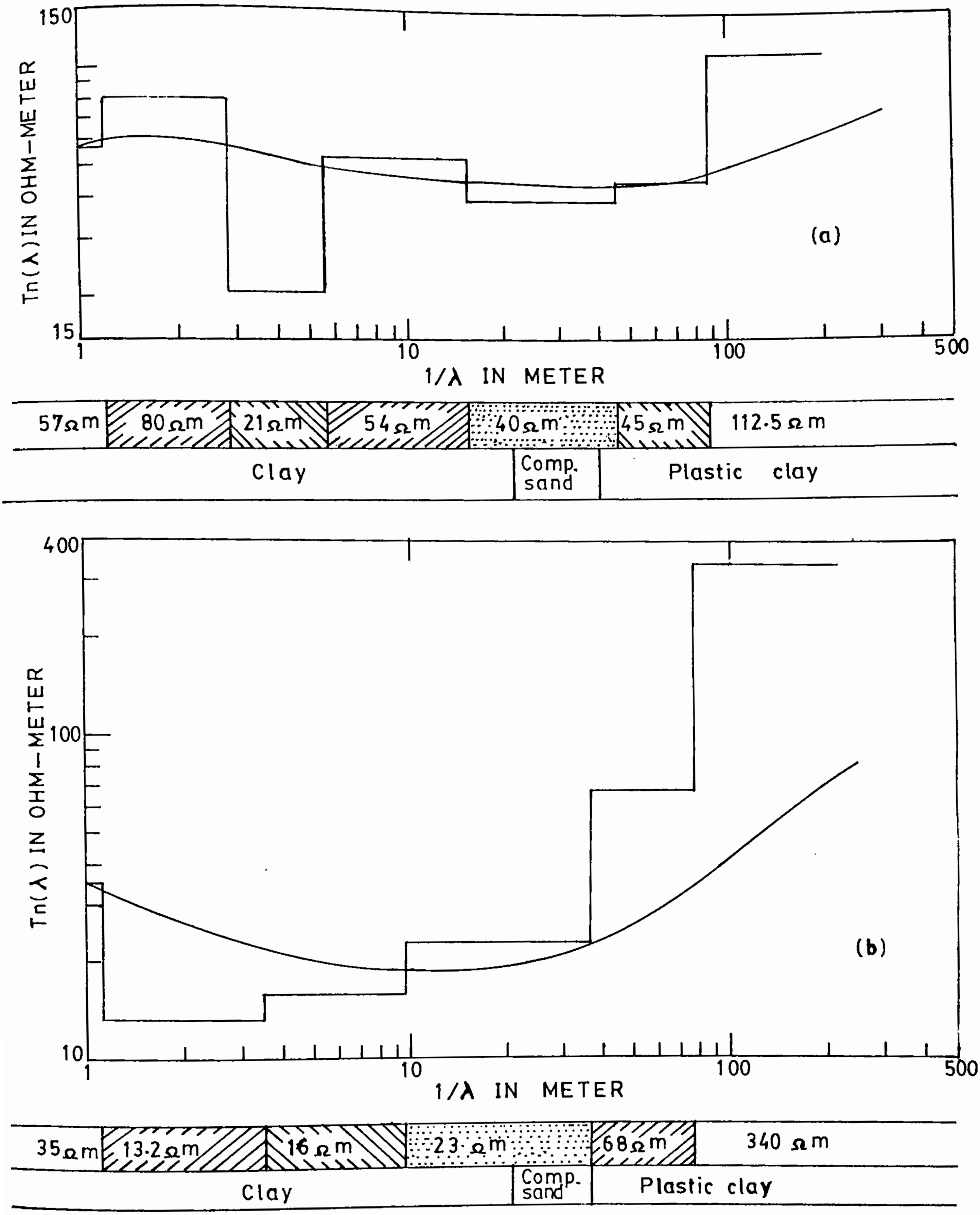

Fig.4.1 Interpreted field curves of; (a)VES-2 and (b)VES-3 during the period of March 1991.

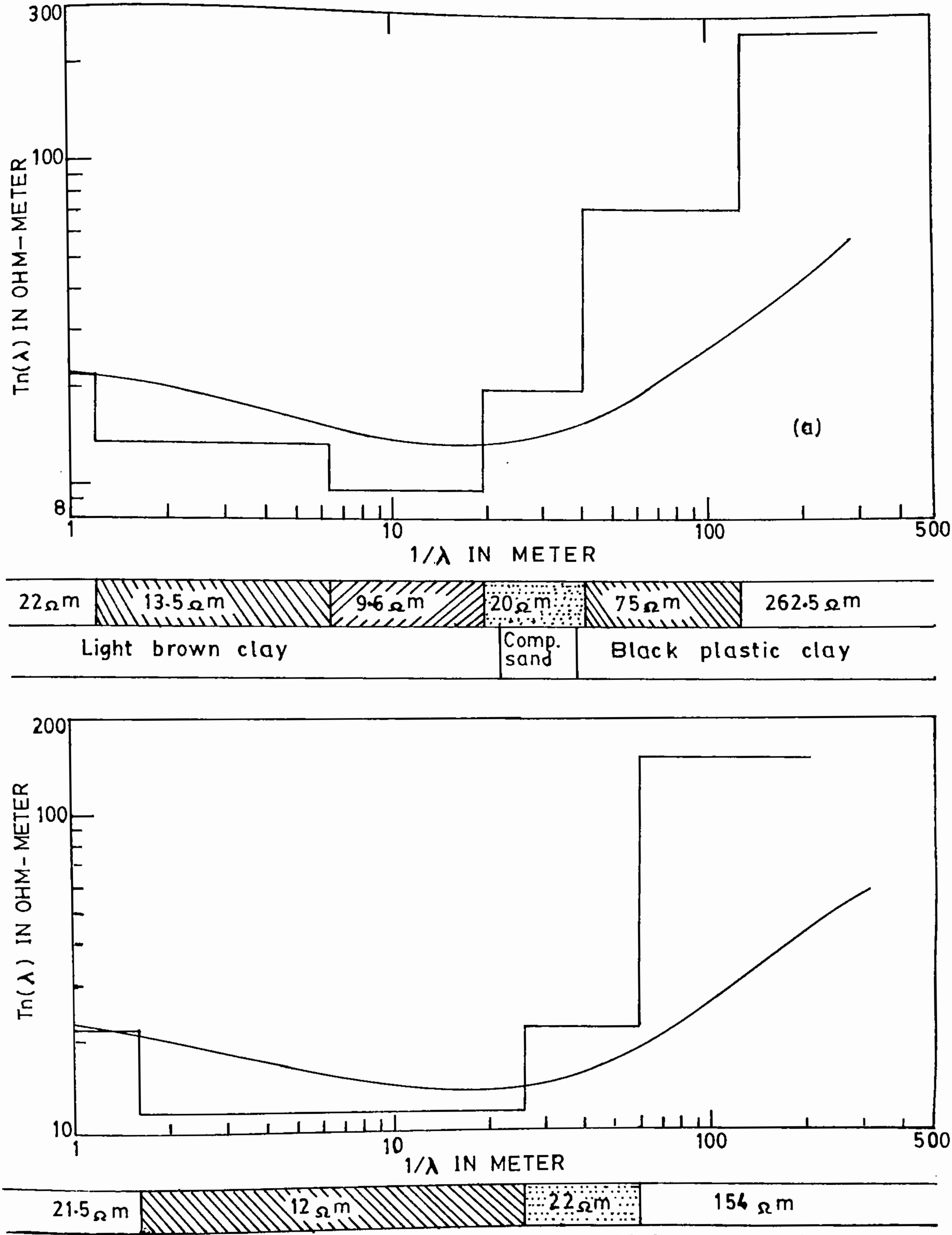

Fig.4.2 Interpreted field curves of; (a)VES-7 and (b)VES-9 during the period of March 1991.

Table 4.1 Interpreted results of VES-2, VES-3, VES-7 & VES-9 during the first field (March, 1991).

Location of VES point							
Kachra(VES-2)		Amjoan(VES-3)		Diara(VES-7)		Mundumala(VES-9)	
ρ_1 to ρ_7 Ωm	h_1 to h_7 m.	ρ_1 to ρ_6 Ωm	h_1 to h_6 m.	ρ_1 to ρ_6 Ωm	h_1 to h_6 m.	ρ_1 to ρ_4 Ωm	h_1 to h_4 m.
57	1.20	35	1.1	22	1.2	21.5	1.6
80	1.65	13.2	2.4	13.5	5.2	12	24.0
21	2.80	16.0	6.0	9.6	13.0	22	34.0
54	10.0	23	27.0	20.0	21.5	154	**
40.0	30.0	68	40.0	75	88.0		
45	43.0	34	**	262.5	**		
112.5	**						

** Undetermined thickness

As mentioned earlier, that five sounding points are finally selected for time variation. These five points are Chatipur(VES-1), Vujoil(VES-4), Nachole(VES-5), Paschim Mirzapur (VES-6) and Barenda(VES-8).

During the entire period of the field programme (1991-93), it has been tried to carry out the field work in four times but due to different circumstances it was not possible absolutely excluding the location Vujoil(VES-4) and Barenda(VES-8). The interpreted field curve of these five stations are described below.

Chatipur(VES-1): This sounding station is located in the top north of the study area. The surface throughout the sounding profile is to some extent high land. The first field data is taken during March, 1991. Interpretation of this first field curve gives a subsurface information of five layer parameters within a depth of 54 meter. The first two layers are confined within 3.9 meter depth from ground surface. The resistivity value is comparatively low, ranges from 9.0 ohm-m to 80 ohm-m. The interpreted curve is shown in the Figure 4.3(a).

In 1992 the second field data is collected but its interpretation could not be possible due to inconsistence of data.

The third field has been made during January in 1993. The interpreted field curve is shown in the Figure 4.3(b). Interpreted result of this field curve gives five layer information as observed in the first field but of different resistivities and thickness (Table 4.2). The resistivity value ranges from 7 ohm-m to 38 ohm-m.

In 1993 another and fourth field data is taken at the end of the month May of the year which is extremely dry. It has been

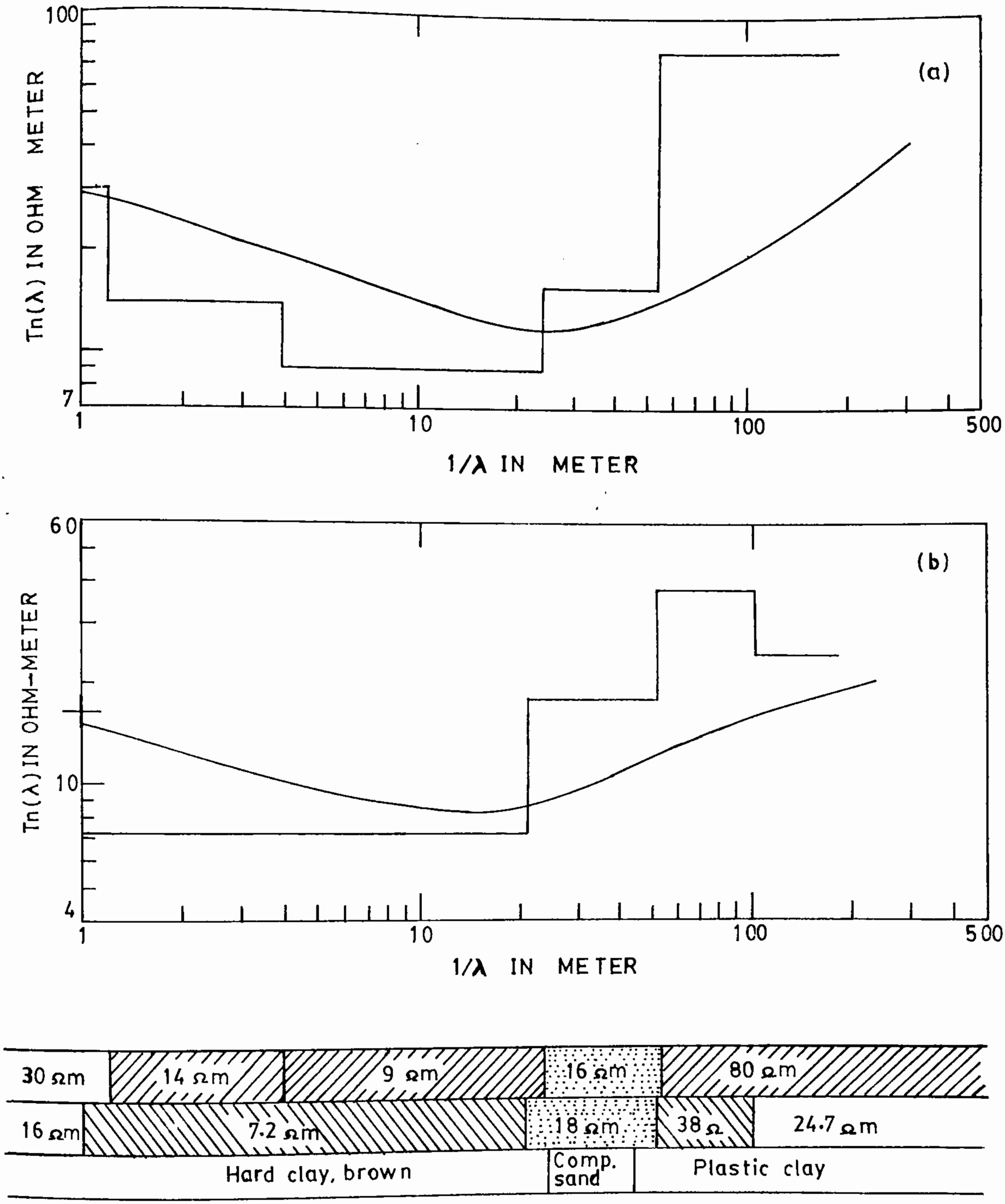

Fig.4.3 Interpreted field curves of VES-1; (a)March 1991, (b)January 1993.

already mentioned that the fourth field is made with the larger electrode spacing (AB/2=500 meter) for searching the deeper aquifer. In spite of increasing the electrode spacing the layer distribution found is the same but of greater thickness of fourth layer. The resistivity of the layers ranges from 7.8 ohm-m to 43 ohm-m. The interpreted field curve is shown in the Figure 4.3(c).

Vujoil(VES-4): This sounding point is situated in the eastern part of the study area. The plane is almost low level Barind. All of the four sounding are made possible in this location. The first three field is covered with the usual electrode spacing(AB/2=130 m) while the fourth and last field is made with the larger electrode spacing(AB/2=500 meter). The interpreted curves of four different periods (March, 1991; June, 1992; January, 1993; May, 1993) are shown accordingly in Figure 4.4 (a),(b),(c) and (d). Five layer parameters are found excepting in the second field observation. The top formation consisting first two layers of resistivity ranges from 6 ohm-m to 17 ohm-m lies within the depth of 12 meter from ground surface. The resistivity of the middle layer is increasing but in the deeper layer it is again decreasing.

Nachole(VES-5): This point locates near to the head quater of Nachole thana. The profile is almost plane but the land surface is low in comparison to its surroundings. The field data of first sounding could not be interpreted due to inconsistency of data and in June 1992 the second field work was interrupted by rain. So only the third and fourth sounding are possible here.

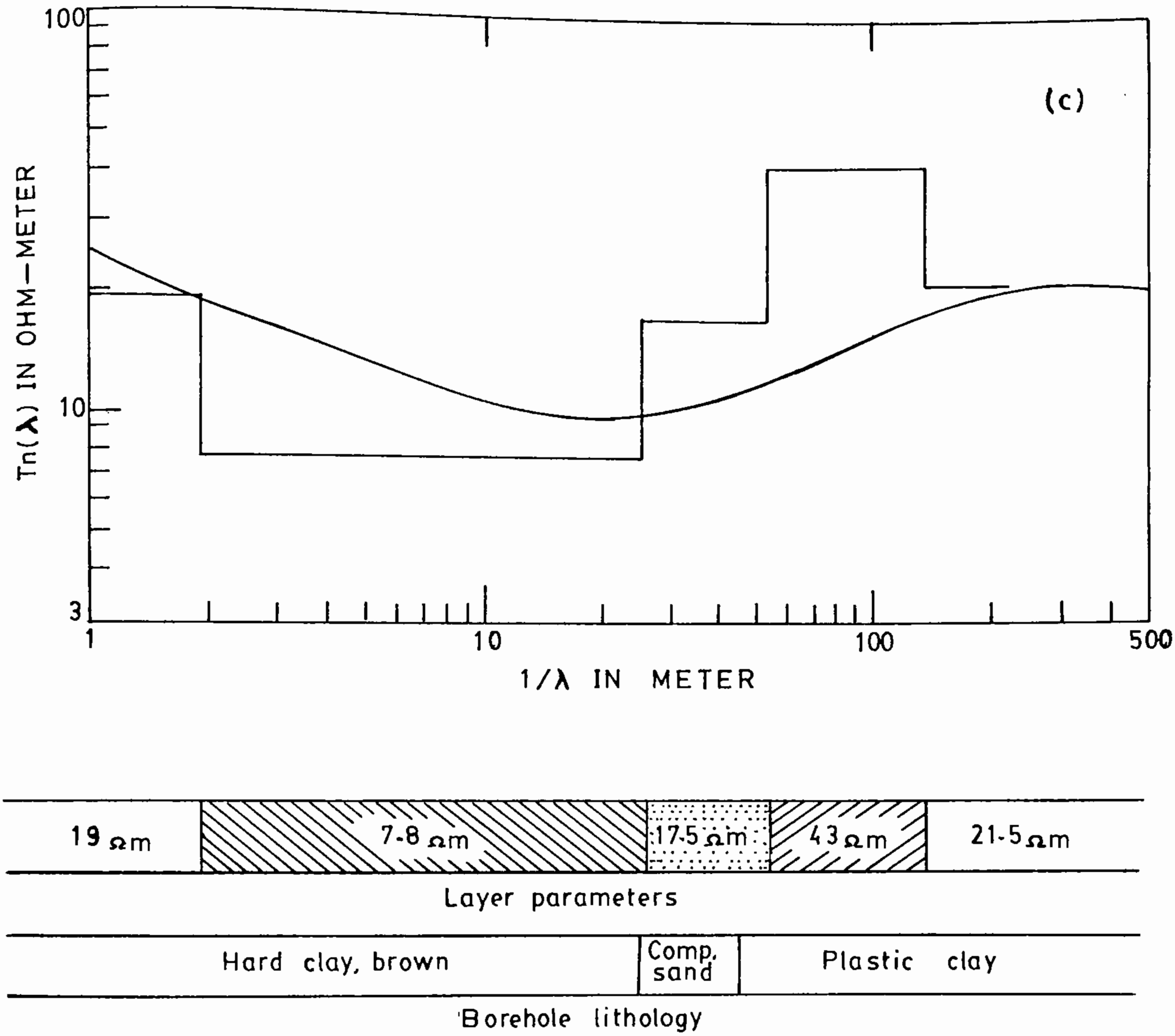

Fig.4.3 (c) Interpreted field curve of VES-1 during May 1993.

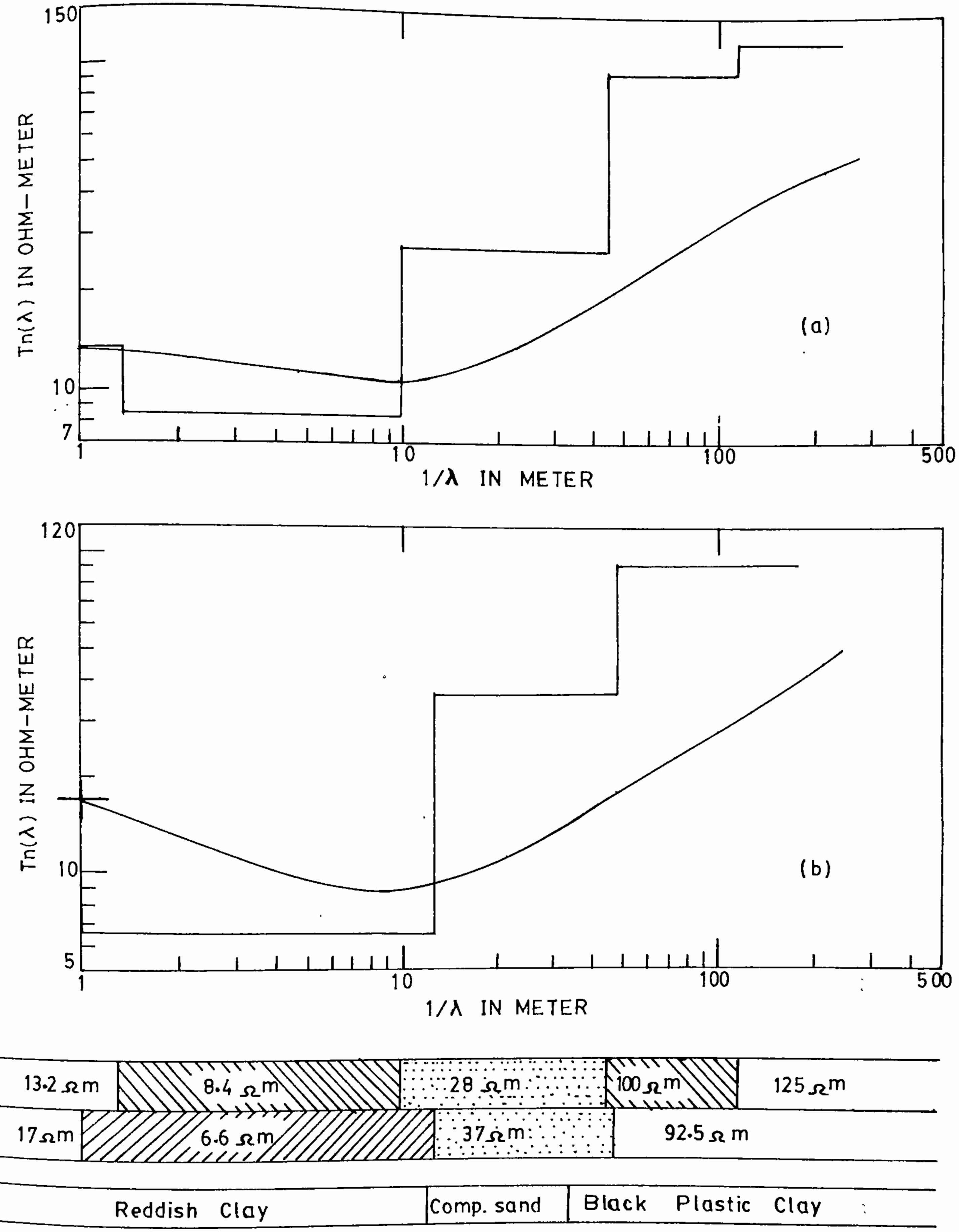

Fig.4.4 Interpreted field curves of VES-4; (a)March 1991, (b)June 1992.

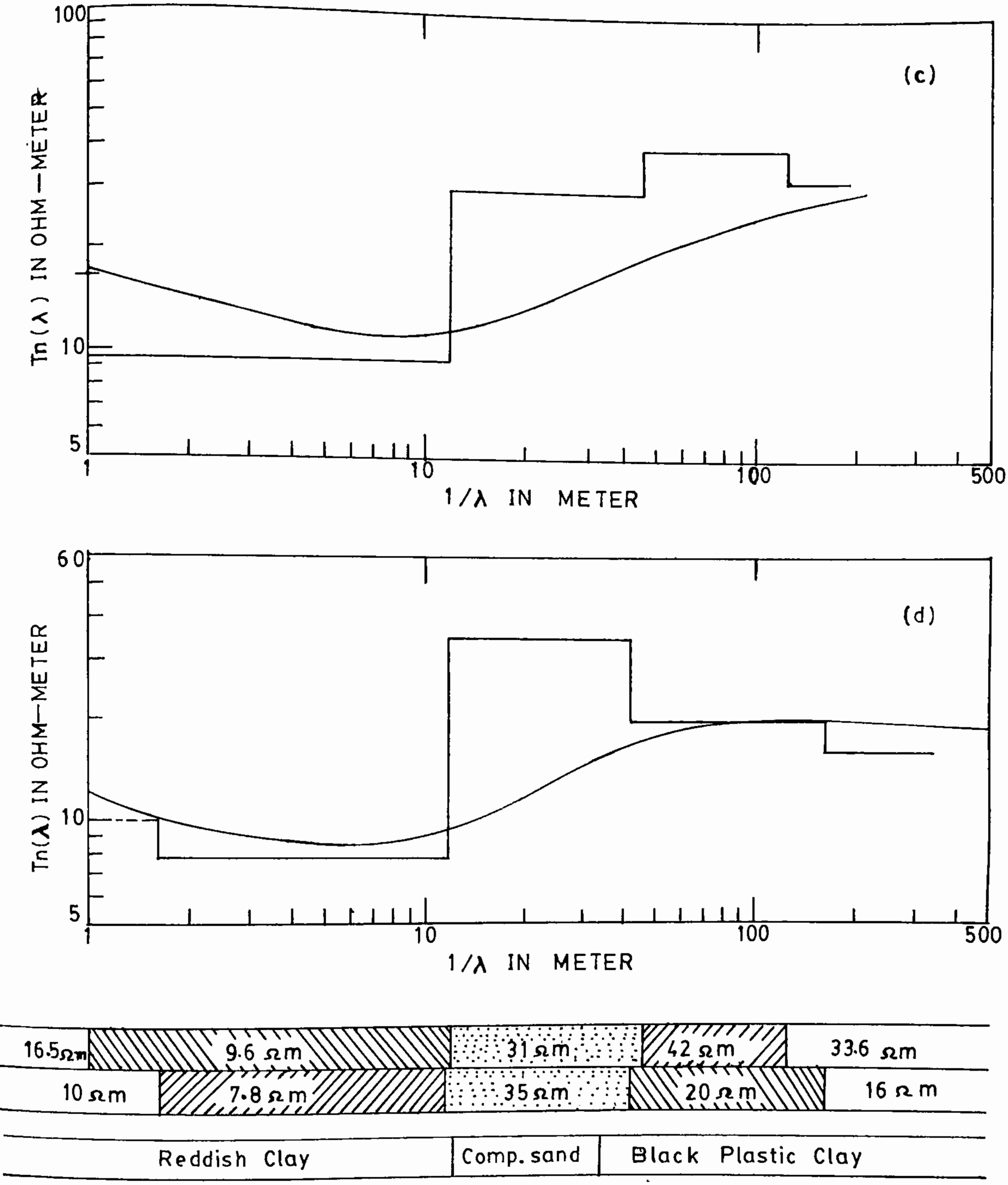

Fig.4.4 Interpreted field curves of VES-4; (c)January 1993, (d)May 1993.

The interpreted results of third and fourth sounding show more than four layers (Figure 4.5). The variation of resistivity of the top three layers are due to seasonal effect. The fifth layer of low resistivity is the impermeable clayey zone holding the aquifer.

Paschim Mirzapur(VES-6): The sounding point VES-6, Paschim Mirzapur is situated in Fatepur union, western part of the study area. Out of the four only two field work have been made successful. The second and third field programme were failed; because, that time this study area was covered by rain water and crops respectively. It should be also mentioned that the fourth sounding point has been shifted about 1.5 Km towards east due to unfavourable circumstances. The first sounding indicating only four layers but with the larger spacing of current electrodes six layers have been detected in the fourth sounding. The resistivity value of the top clay formation of 17 meter thickness lies within 9 to 46 ohm-m. The impermeable formation has been found below the depth of 40 meter. The interpreted curves are shown in the Figure 4.6.

Barenda(VES-8): The location Barenda is situated in the central part of the Nazampur union. The area almost a level Barind and was favourable for the field works. All the four field curves are almost H-type. The interpreted field curves are shown in Figure 4.7. The low resistive zones comprises more than two layer indicating the top clay formation. The thickness of the underlain layer is approximately 50 meter and the resistivity

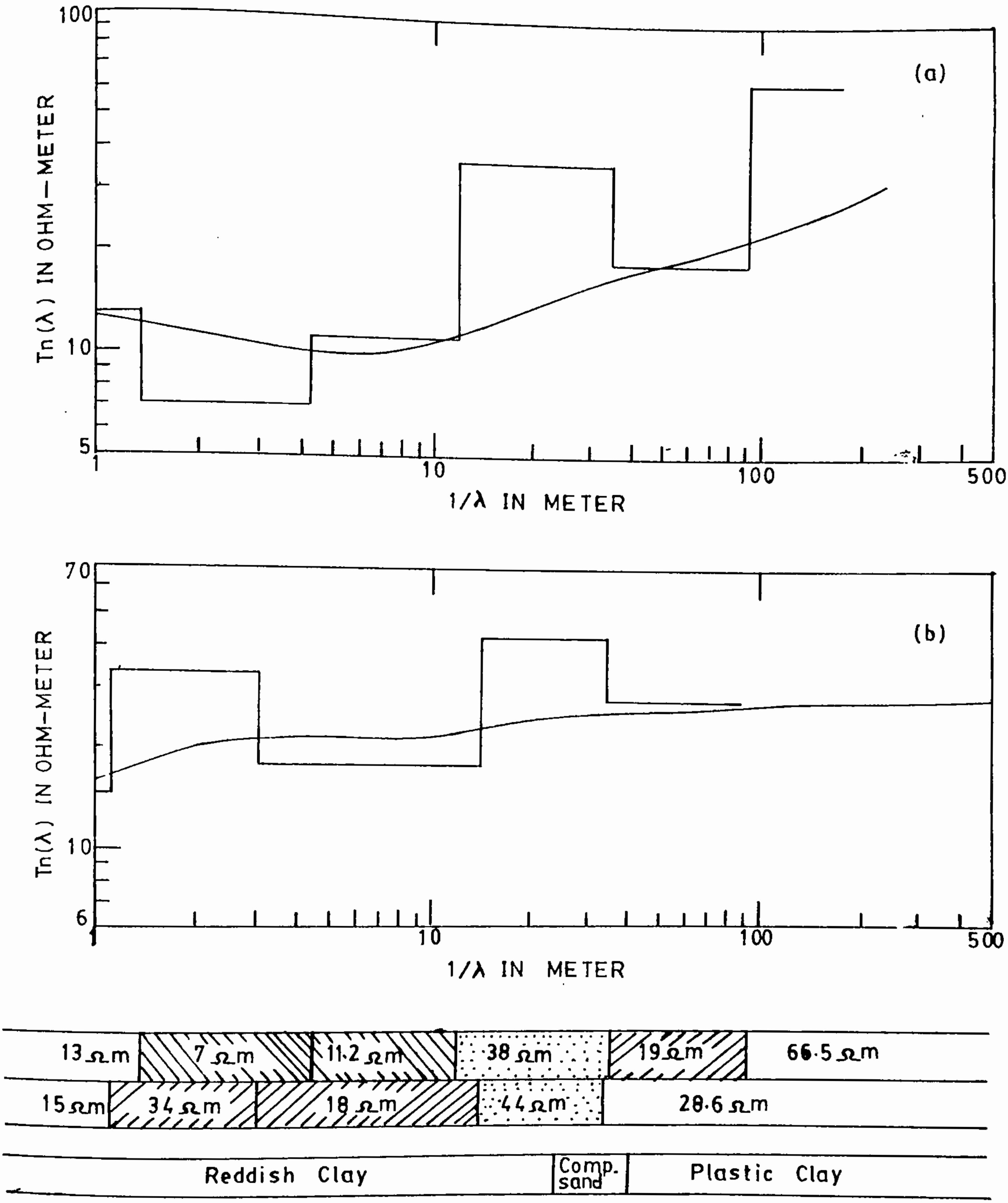

Fig.4.5 Interpreted field curves of VES-5; (a)January 1993, (b)May 1993.

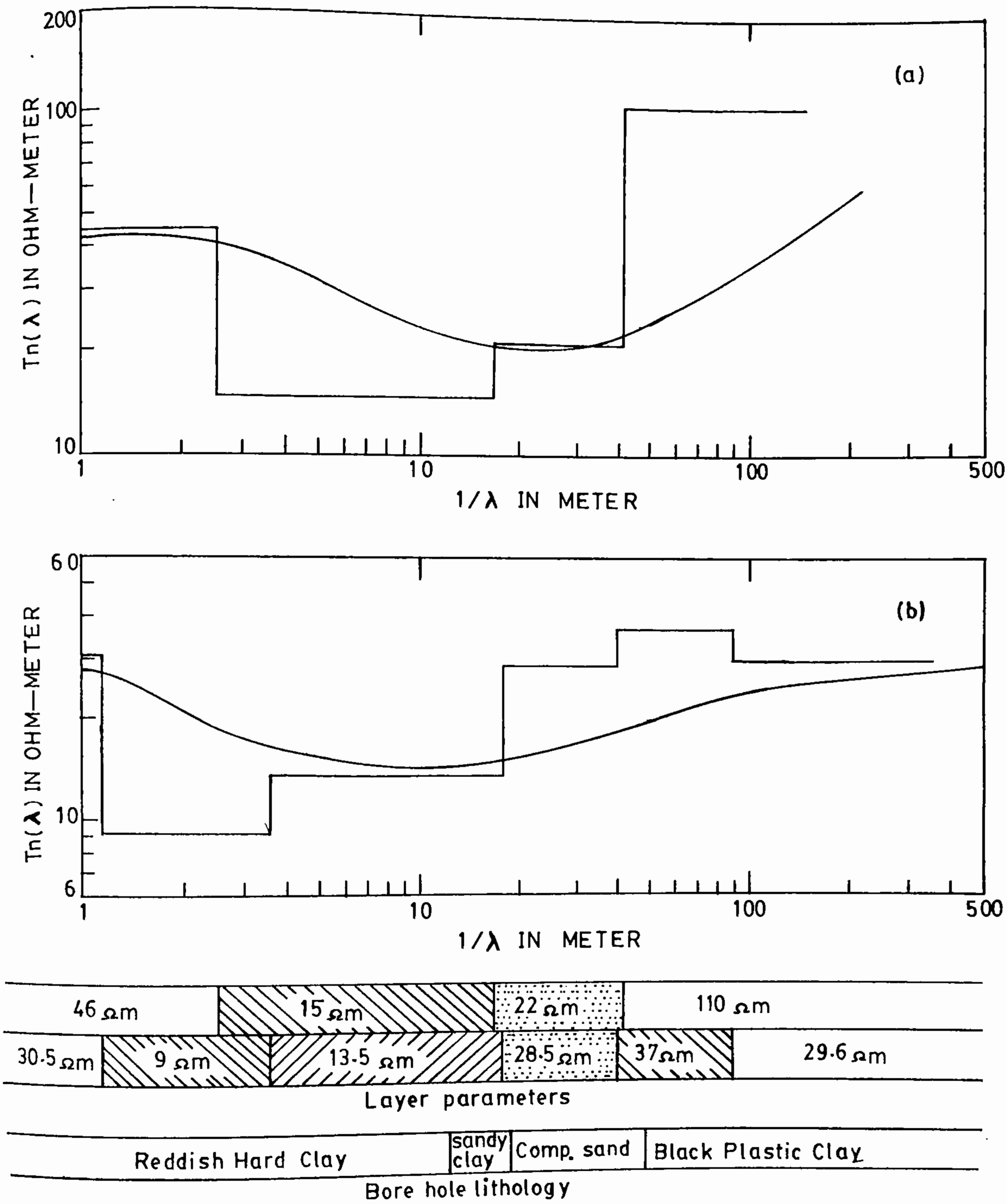

Fig.4.6 Interpreted field curves of VES-6;(a)March 1991, (b)May 1993.

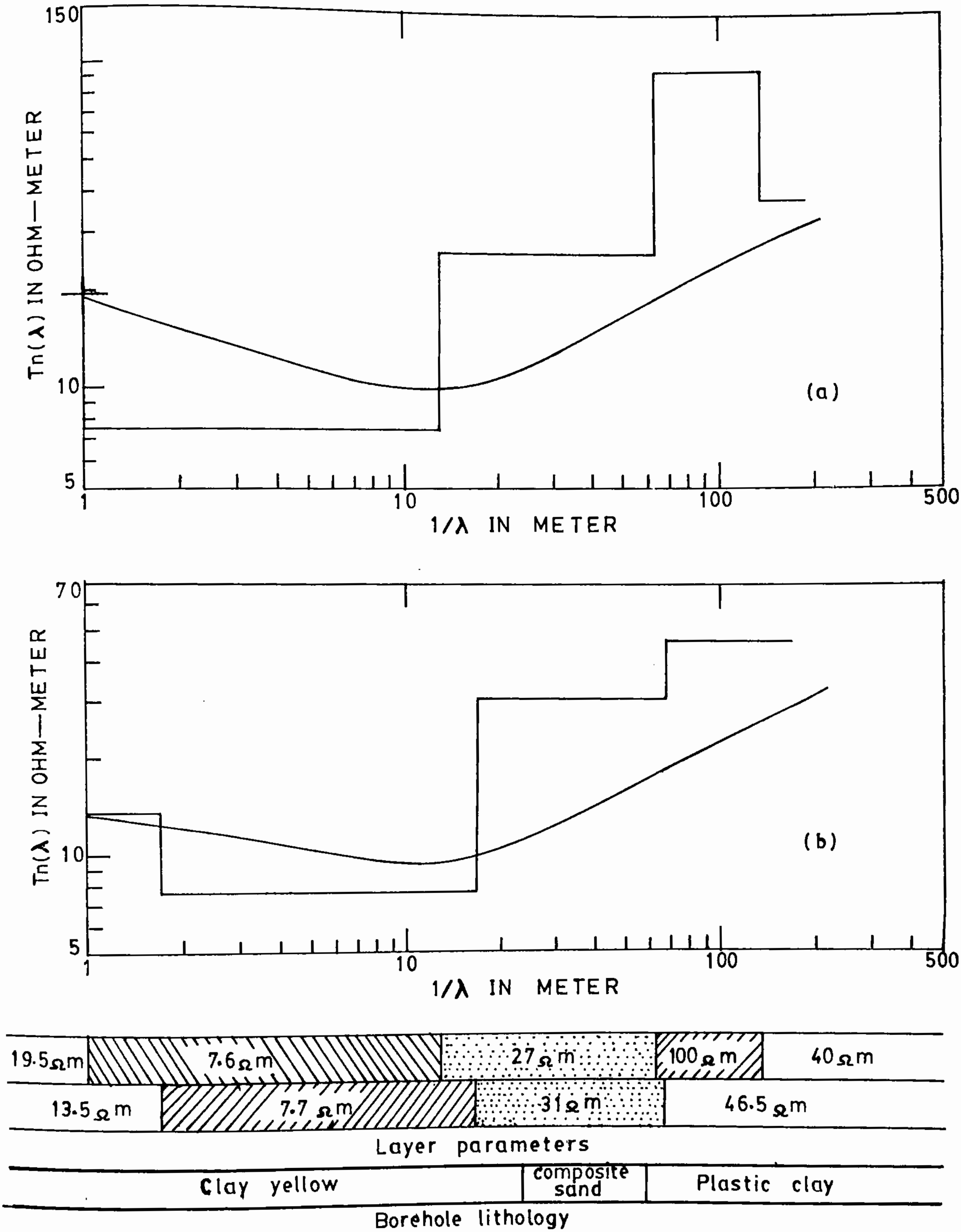

Fig.4.7 Interpreted field curves of VES-8; (a)March 1991, (b)Jan 1992

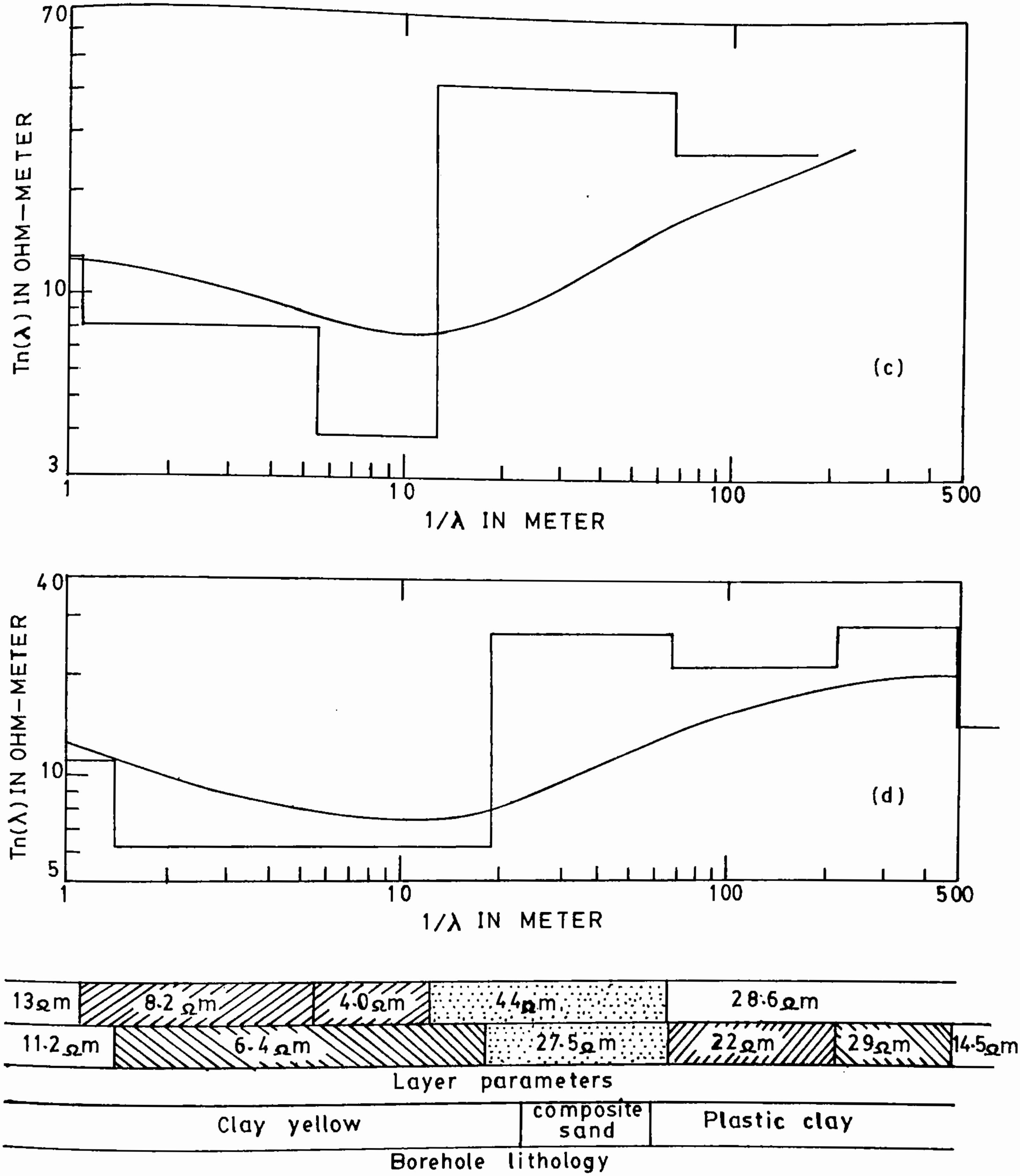

Fig.4.7 Interpreted field curves of VES-8;(c)January 1993, (d)May 1993.

ranges from 27 to 44 ohm-m. The existence of another two layers of greater thickness have been found in the fourth sounding whereas a layer of only 72 meter thickness having resistivity 100 ohm-m is observed in the first field curve. But the interpreted results of second and third sounding provides only the information of 66 meter depth to ground surface.

The result of the entire field programme(1991-93) of the above five sounding points (VES-1, VES-4, VES-5, VES-6 and VES-8) are presented in Table 4.2.

Table 4.2 Interpreted results of five different locations (Chatipur, Vujoil, Nachole, Paschim Mirzapur and Barenda).

VES No.	Period of work	Resistivity in ohm-m						Thickness in meter					
		ρ_1	ρ_2	ρ_3	ρ_4	ρ_5	ρ_6	h_1	h_2	h_3	h_4	h_5	h_6
1	March '91	30	14	9	16	80		1.2	2.7	20	30	**	
	January'92	16	7.2	18	38	24.7		1.0	20	31	50	**	
	May 1993	19	7.8	17.5	43	21.5		1.9	23.5	28.5	82	**	
4	March 1991	13.2	8.4	28	100	125		1.35	8.60	35.5	70	**	
	June 1992	17	6.6	37	92.5			1.0	11.5	35	**		
	January'93	16.5	9.6	31	42	33.6		1.0	10.8	34	77	**	
	May 1993	10	7.8	35	20	16		1.6	10	30	122	**	
5	January'93	13	7	11.2	38	19	66.5	1.33	3.00	7.6	23.3	58	**
	May 1993	15	34	18	44	28.6		1.1	1.95	11	20	**	
6	March 1991	46	15	22	110			2.5	14	25	**		
	May 1993	30.5	9.00	13.5	28.5	37	29.6	1.05	2.5	14	22	50	**
8	March 1991	19.5	7.6	27	100	40		1.0	12	50	72	**	
	June 1992	13.5	7.7	31	46.5			1.7	15	50	**		
	January'93	13	8.2	4.0	44	28.6		1.1	4.4	6.8	54	**	
	May 1993	11.2	6.4	27.5	22	29	16.5	1.4	17	49	150	280	**

** Undetermined Thickness

4.3 RELATIONS BETWEEN SEDIMENT AND GROUNDWATER SPECIFIC RESISTIVITIES.

In the study area only Quaternary sediments were found to occur upto the depths of 300 m, this being the maximum depth of penetration for the geoelectrical measurements. These sediments are clays and silts as well as sands of various grain size. The electrical conductivity of these sediments is dependent on the quantity and salt concentration of the water contained in them.

Clays and silts, being rich in water soluble minerals, have a low resistivity even if the water content is low. The clayey-silty sediment in the area above, as well as below the groundwater level, were found to have specific resistivities between 5 and 45 ohm-m. A high salt content may be expected in the case of sediments which show resistivities below 10 ohm-m.

There exist a simple relationship between the specific resistivities ρ_w of the water filling the pore spaces and the specific resistivity of saturated sand-gravel sediments, are as follows:

$$\rho = F.\rho_w \qquad (4.1)$$

Here F is the formation factor, a function of the pore volume, the degree of consolidation of the sediments and other quantities; it is not however affected by the particle size. The above equation is particularly important as regards interpretation of the geoelectrical measurements, since it is very difficult to establish the specific resistivity of saturated sand sediments directly from the interpreted layer parameters. Once some idea has been obtained of the magnitude of the F-value, however the specific resistivity of the sand sediments can be found from the water resistivities.

For the present investigation the formation factor F was determined by direct measurements of specific resistivity of the sand sample being saturated with the groundwater sample of the respective location. The experiment was done in the field with the standard equipment for higher accuracy. The formation factor thus obtained was found to lie between 2.0 to 3.0. However the measured value of electrical conductivity of groundwater sample of different locations are shown in section 5.4 in the next chapter.

In the whole area of operation aquifer of low specific resistivity were encountered. The aquifer of minimum specific resistivity was found in the extreme north of the study area such as in Chatipur. Water sample of these area shows a specific resistivity of only 9.5 to 10 ohm-m. In all the remaining parts of the area under investigation the specific resistivities of the aquifer as well as the groundwater were moderately high.

4.4 STUDY OF AQUIFER

An aquifer is a geologic formation or stratum containing significant quantum of water in its pores or voids or interstices that can be removed economically for use as a source of water supply. Water in an aquifer cannot be seen and its amount cannot be measured directly. In the present contribution aquifer have been studied through geophysical investigation and interpret its existence in terms of physical parameters, particularly the electrical conductivity or conversely the electrical resistivity of both the formation and water contained in the formation.

An aquifer or groundwater level, whether it be the water table of an umconfined aquifer or the piezometric surface of a confined aquifer indicates the elevation of atmospheric pressure of the aquifer. Any phenomenon which produces a change in pressure on the groundwater will cause the groundwater level to change (Todd, 1980). Hydrologically the groundwater level is the topmost surface of a water saturated zone (aquifer), and it acts as a separating media between the zone of aeration and the zone of saturation and hence the detection of groundwater level implied the detection of groundwater saturated zone. There are different methods for the investigation of groundwater in geo-sciences as mentioned in the first chapter. Among those, one of the widely used geophysical method, the electrical resistivity is employed here for the time variation study of the groundwater level and its thickness. For the study of groundwater level, several electrical sounding have been made during the period 1991-93. The geoelectrical parameters of the subsurface formation have been estimated and described earlier in section 4.2. These geoelectrical parameters have been interpreted in terms of subsurface geology and correlated with the available borehole lithology.

From the knowledge of formation factor and the resistivity of groundwater, the depth of aquifer and its thickness have been studied. It is found that the resistivity of water saturated zone lies within the range of 16 ohm-m to 44 ohm-m. This wide variation of resistivity of the saturated sediment is happened due to the variation of electrical conductivity of groundwater of the study area which ranges from 450 μs/cm to 1005 μs/cm.

In Chatipur(VES-1) the extreme north location of the study area, the resistivity of the saturated sediment is comparatively low(16 ohm-m to 18 ohm-m) and it is supposed the aquifer. The thickness of this water saturated formation is around 30 meter. In the first field it is found at a depth of 23.9 meter and in May 1993, during the the fourth field it is observed at a depth of 25.4 meter from the ground surface. Another sounding (VES-2) has been made in Kasba union in March, 1991. In this location, the aquifer of resistivity 40 ohm-m has been detected at a depth of 15.65 meter whose thickness is 30 meter.

Three sounding points(VES-3, VES-4 and VES-5) are situated in Nachole union. In Amjoan(VES-3) the only field is made in

1991. In this location the aquifer of resistivity 23 ohm-m and thickness 27 meter is detected at a depth of 9.5 meter. In Vujoil (VES-4) four electrical sounding were conducted. The aquifer parameters are easily estimated and it is found that the groundwater condition is well. The thickness of the aquifer varies within 30 to 35 meter and it occurs at a depth of 10 to 12 meter. The third sounding point in this union is Nachole (VES-5). In this location two field data is available for groundwater study. The groundwater resistivity of this area is the highest so that the resistivity of water saturated sediment is also high, e.g. 44 ohm-m. The thickness of the aquifer varies from 20 to 23 meter as observed in the interpreted results. The depth to groundwater level is 12 meter and 14 meter during January and May 1993 respectively.

The western part of Nachole thana is Fatepur union. The river Mahananda touches a few portion of this union. From the overall observation it is found that the groundwater potential of this area is good. VES-6, the only sounding point is taken in the eastern part of this uinon. The aquifer geometry of this location is almost simillar to that of VES-5 of Nachole union. But the resistivity of the water saturated zone differs only due to the low resistivity of groundwater.

The Barenda(VES-8) is one of the location of sounding points where field works were successfully carried out during the period (1991-93) of survey. The subsurface layer parameters indicate that the aquifer thickness of this area is the highest, 54 meter. The results of four sounding in different periods distinctly show the variation of groundwater level. In March, 1991 the position of water level was 13 meter and after two years, in May 1993 falls to 18.4 meter from ground surface. The resistivity of the water saturated formation ranges from 27 ohm-m to 44 ohm-m. VES-7, Diara the another location in Nazampur union is made during March 1991. The top clayey formation is composed of three layer varying the resistivity within 9.6 ohm-m to 22 ohm-m. The resistivity of fourth layer indicating the water bearing formation occurs at a depth of 19.4 meter from ground surface. During the first field work an attempt had been made to study the aquifer response of neighbouring Tanore thana and an additional sounding (VES-9) was made in Mundumala located in the south-east of the study area. Results of interpretation of VES-9 shows that the aquifer lies comparatively at a greater depth (25.6 meter) than in Nachole thana. However the sounding profile was to some extent on high land.

CHAPTER FIVE

HYDROLOGY AND HYDROGEOLOGY

Chapter 5

5.0 HYDROLOGY & HYDROGEOLOGY

Hydrology means the science of water that deals with the occurrence, circulation and distribution of water of the earth and earth's atmosphere. However Groundwater hydrology involves with the occurrence, distribution and movement of water below the surface of the earth. Geohydrology has an identical connotation but hydrogeology differs only by its greater emphasis on geology. In the study of a particular groundwater source, surface collection areas and underground conduits and reservoirs must be identified and hydrologic behavior of the system must be discovered to evaluate the equation of hydrologic equilibrium.

5.1 HYDROGEOLOGIC CONDITION OF THE AREA.

A complete work on hydrogeology of the area had been made by the FAO (Food and Agricultural Organisation) in conjunction with the then EPWAPDA (East Pakistan Water And Power Development Authority) during the year 1962 to 1966. The survey team investigated a vast area of northern part of the then East Pakistan(Bangladesh) which includes Rajshahi and Bogra district, and northern part of Rangpur and Dinajpur district. The present study area (Barind Tract) falls in Rajshahi district. From the hydrogeological point of view they divided the Rajshahi Barind Tract into two great units (Eastern and Western) by a N-S line. According to their statement, hydrogeologically Eastern and

South-eastern part is more favourable than Western part. The report concluded for the result of measurements on shallow wells that the superficial clay layer is permeable and about 13% of the mean annual precipitation (1400 mm/year) of the area infiltrating into the ground (Deppermann and Thiele, 1969). But yet it remains questionable whether in view of the relatively thick clayey-silty top stratum, a share of 13% of the precipitation can be assumed to infiltrate the soil, especially in the southern and western regions of Barind Tract of Rajshahi district.

A uniform continuous groundwater table is to be expected with some reliability in the eastern and southern part of the Barind Tract. In the north-western part of the region no continuous groundwater level is evident. The present study area is a part of the western unit. In this part the groundwater level is narrows and the subsoil is likely to consist predominantly of silt/clay sediment.

The aquifer system in the Barind Tract may be schematised into an aquifer of variable thickness overlain by a semi-confining layer of variable thickness. The aquifers have been encountered just below the overlying clayey sediments which acts as the upper confining bed. However the considerable thickness and low permeability of this layer is very significant in determining the recharge to the aquifer beneath this. Because of very great thickness of the upper confining bed and for the unfavourable grain size distribution, well-drilling is of high cost and is not always successful. According to a technical report of UNDP under the caption,"Groundwater survey-the hydrologic conditions of Bangladesh" in 1982 and from the drilling logs of many (about 100) deep tube wells of the study area, it is plain and clear that main aquifer does not occur in the upper 300 meter (980 feet) and the only exploitable aquifer which lies within the depth of 100 meter is a composite one. It is continuous but consists of composite sand (very fine to medium and to some extent coarse sand) formation. It has been tried to classify a part of this composite formation into main aquifer although it has no physical significance. For convenient lithologic logs of deep tube wells drilled in five different locations covering the total study area (Figure 2.2) are shown in the Table 5.1. The aquifer and non-aquifer facies and the hydrostratigraphic features can be obtained from the above lithology.

Table 5.1. Lithological logs of boreholes drilled in the study area.(After BIADP)

Tubewell Location	Lithology	Depth range (meters)	Thickness (meters)
Nachole H.Q.	Clay	0 - 24.38	24.38
nearer to (VES-5)	Fine sand,Brown	24.38 - 27.43	3.05
	Medium sand, brown	27.43 - 42.67	15.24
	Clay with fine sand	42.67 - 45.72	3.05
	Clay	45.72 - 54.86	9.14
	Plastic clay, black	54.86 - 57.91	3.05
	Plastic clay	57.91	
Vujoil (Nachole UP)	Reddish clay	0 - 12.91	12.19
nearer to (VES-4)	Medium sand	12.91 - 18.29	6.10
	Medium to coarse sand	18.29 - 33.53	15.24
	Coarse sand	33.53 - 42.67	9.14
	Plastic clay, black	42.67 - 48.76	6.09
	Plastic clay	48.76	
Pytali(Fatepur UP)	Hard clay, reddish	0 - 12.19	12.19
nearer to (VES-6)	Fine sand with clay	12.19 - 18.29	06.10
	Fine sand, reddish	18.29 - 24.38	06.09
	Fine to medium sand	24.38 - 33.53	09.15
	Medium sand, reddish	33.53 - 45.72	12.19
	Fine sand with clay	45.72 - 48.77	03.05
	Plastic clay black	48.77 -	

Contd........

Table 5.1 (contd.)

Tubewell location	Lithology	Depth range (meters)	Thickness (meters)
Barenda (Nazampur UP)	Clay, yellow	0 - 24.38	24.38
nearer to (VES-8)	Sandy clay, yellow	24.38 - 27.43	3.05
	Very fine sand, yellow	27.43 - 33.53	6.10
	Fine sand, yellow	33.53 - 39.62	6.09
	Medium sand, gray	39.62 - 48.76	9.14
	Coarse sand, gray	48.76 - 51.81	3.05
	Medium to coarse sand	51.81 - 54.86	3.05
	Coarse sand with gravel	54.86 - 57.91	3.05
	Plastic clay, black	57.91 - 61.87	3.96
	Plastic clay	61.87	
Uttar Chandipur(Kasba UP)	Hard clay, brown	0 - 24.38	24.38
nearer to (VES-1)	Hard clay with sand,	24.38 - 30.48	6.10
	Silty clay, brown	30.48 - 34.13	3.65
	Medium sand with clay	34.13 - 36.57	2.44
	Medium sand, brown	36.57 - 40.54	3.97
	Plastic clay	40.54 - 42.67	2.13
	Medium sand, red	42.67 - 43.89	1.22
	Clay, brown	43.89 - 45.72	1.83
	Plastic clay, black	45.72 - 152.40	106.68
	Plastic clay	152.40	

5.2 PIEZOMETRY, PIEZOMETRIC AND WATER TABLE FLUCTUATIONS

Bangladesh Water Development Board(BWDB), the national water management body, maintains a good network of observation wells in the Barind Tract like all other parts of the country. Most of the wells are dug wells with a number of piezometers installed under the BIADP during the recent years. The observation in these wells are recorded by BWDB. Besides this, BADC also maintains some monitoring wells in the area. Detail description of the water table occurence, movements and fluctuations are available from different previous works (Klinski, 1979; BWDB, 1990).

In Barind the depth to groundwater table from ground surface is bigger than the surrounding areas both in dry and wet season. The maximum depth to the groundwater table from land surface occurred during May/June of the year and it varied from 5 meter to 21.7 meter (BWDB,1990). It is also evident from the contour map (Figure 5.1) of static water level in dry season. In general the depth is greater in the Barind region than the flood plains. The minimum depth to the water table varies from a meter to as high as 13 meter as observed in September/October, 1988 (BWDB,1990).

The annual fluctuation of groundwater table is directly related to recharge and discharge conditions. Most of the groundwater abstractions take place in the dry months starting from January and continues up to May (also June in some dry years). During this period the recharge is almost nill, the rate of evaporation and evapotranspiration is high and most of the river

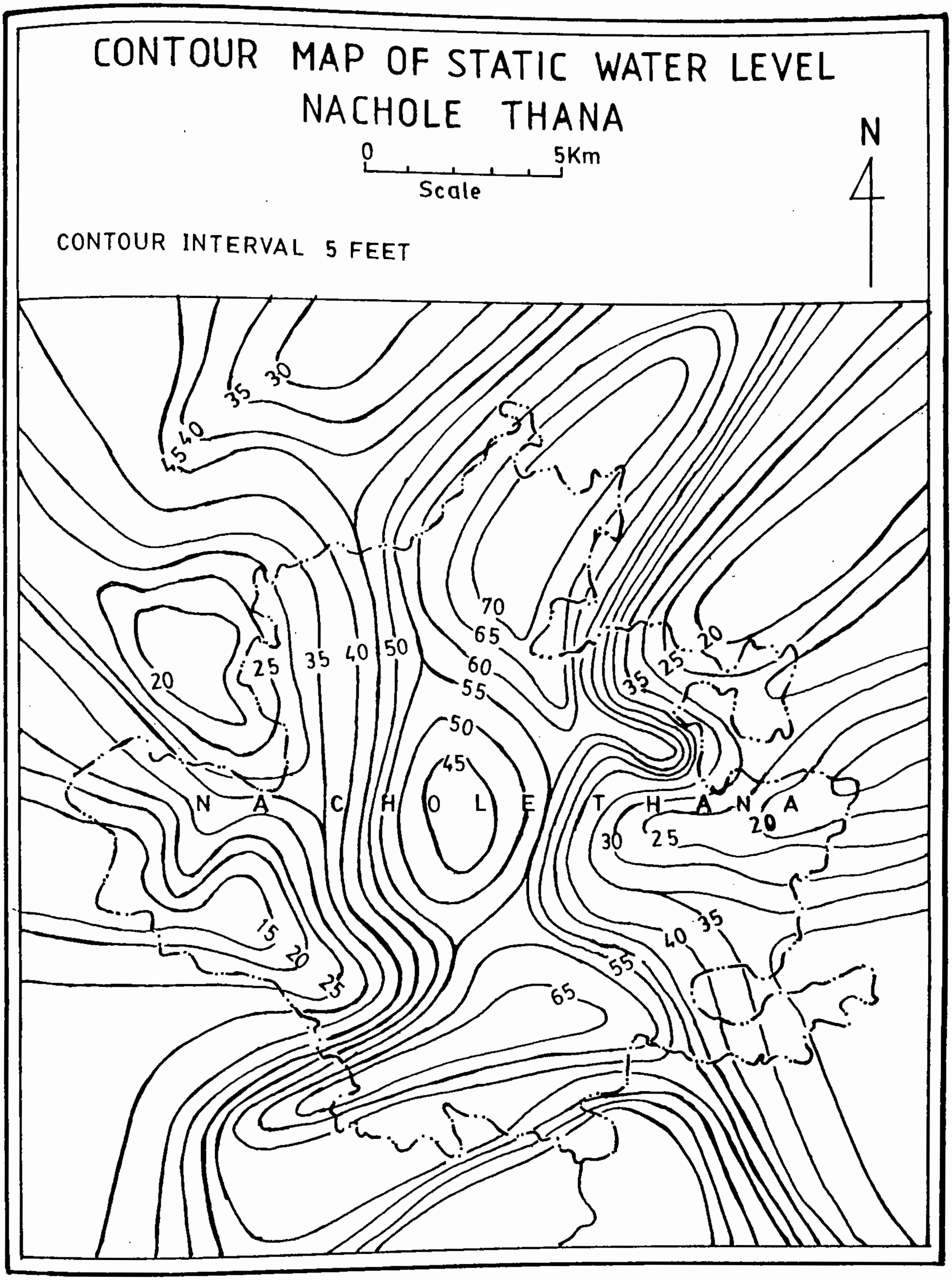

Fig. 5·1. Contour map of static water level of the study area in dry season.

flows is derived from groundwater reservoir as base flow. As a result of all these natural and artificial withdrawal, the water table declines sharply and reaches to maximum depth in May and/or June. Rain starts in the pre-monsoon period and at the same time begins the recharge to the under ground storage. The major artificial abstraction of groundwater is also stopped by this time and high relative humidity in the atmosphere reduces the rate of evaporation and evapotranspiration. All these causes a gradual increase in the groundwater reservoir which is reflected by the change in the water table. The water table starts moving upward and reaches to minimum depth from the land surface in September/October. The annual fluctuation in water table in the area varies from 10.00 meter to as high as 21.27 meter as observed in 1988-89 (BWDB,1990). The minimum fluctuation is observed in the flood plains whereas the maximum is found in the high Barind region. Hydrograph analysis shows that in most of the areas the dry season decline is getting higher and higher every year and it is not fully recovered during the wet season. As a result a gradual and permanent decline in the water table is observed.

A well-hydrograph is prepared with one of the observative well´s information (Well No.R-44) of the study area showing the annual fluctuation of water level for a period of 21 years (1973 to 1993) as shown in the Figure 5.2. From the hydrograph it is evident that, before 1984 the fluctuation is almost lie within 5 meter to 13 meter from ground surface but thereafter fluctuation

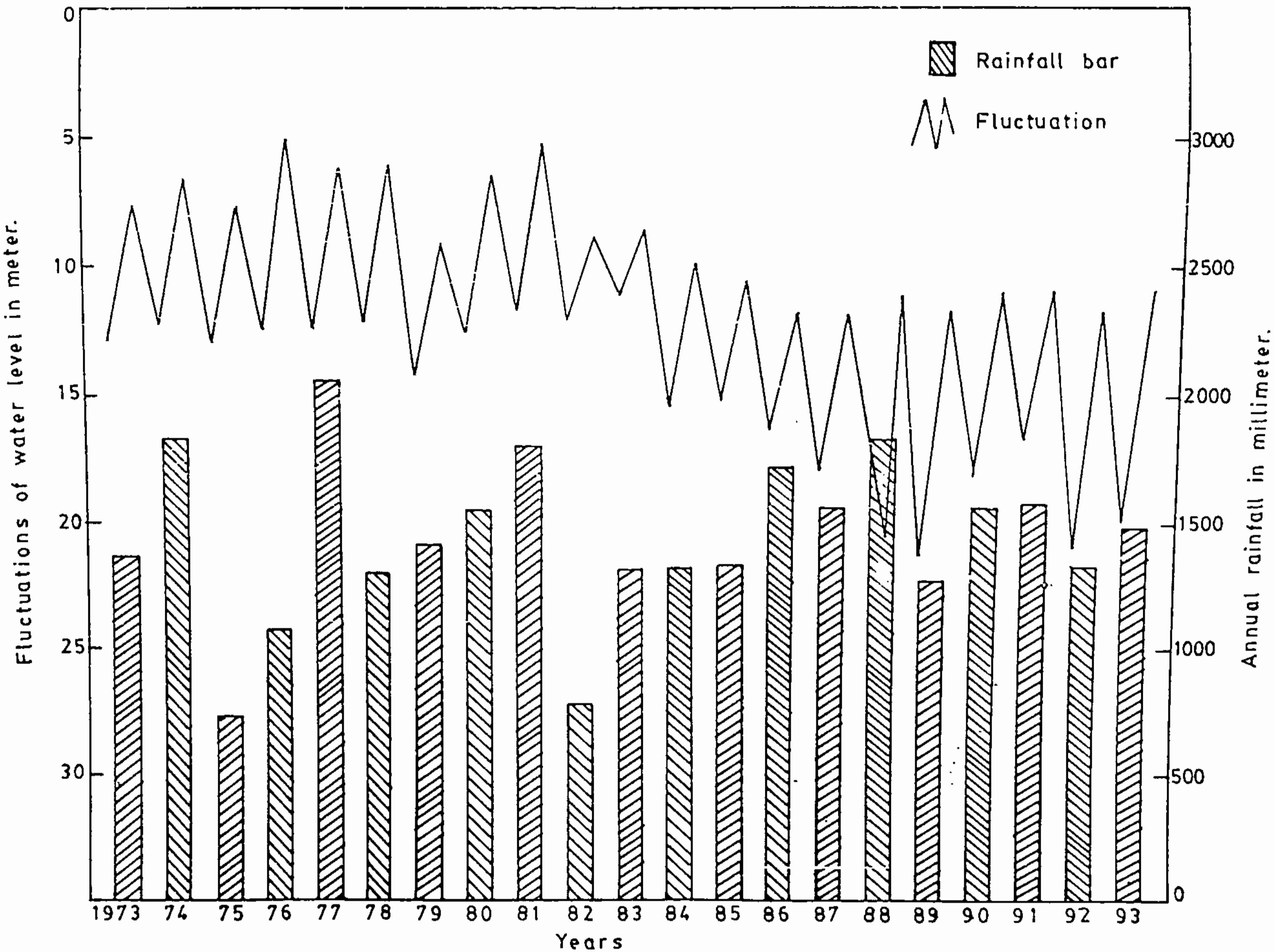

Fig. 5.2. Well hydrograph(Well No.R-44, Location-Nachole) showing the annual fluctuation of ground water level during the period (1973-1993) of 21 years.

zone is shifted below 10 meter from ground surface and at present the water level is fluctuating between 10 meter to 20 meter. It is also found that the maximum (21.27 meter) fall of groundwater level occurs during the year 1989.

It is needless to say that this declination of water level is chiefly, due to excessive withdrawal of groundwater. Since 1984, `BIADP´ has undertaken a programme of installating few thousands of deep tube wells for irrigation in the area. Soon after functioning their scheme several adverse effect was found to occur during the dry period, such as, abrupt fall of groundwater level, discharge of hand tube wells ceases to minimum and in some cases it is totally failed to yield any water and almost all the dug wells become dry. This declination of water level bringing some major ecological changes also in the region, particularly in the high Barind area.

5.3 HYDROLOGIC PROPERTIES OF THE AQUIFER

The principal hydrologic properties of aquifers are porosity, effective porosity or specific yield, specific retention, permeability and direction of maximum ease of percolation. These properties control the entrance of water into water-bearing formation or rocks; their capacity to hold, transmit and deliver water; and confinement and concentration of percolation to the direction of maximum ease of movement. Hydrologic properties depend chiefly on porosity, size of openings or interstices and their shape, arrangement, interconnection, and continuity (Tolman, 1937). Some of the hydrologic properties of the area have been estimated for the present investigation through different studies and experiments.

5.3.1 Porosity

Those portion of a rock or soil not occupied by solid mineral matter are known as voids, interstices, pores, or pore space. Because interstices serve as water conduits, they are of fundamental importance to the study of groundwater. The porosity of soil is a measure of the contained interstices or voids expressed as the ratio of the volume of interstices to the total volume (Todd, 1980). If ϕ is the porosity, then

$$\phi = v_i/V \tag{5.1}$$

Where v_i is the volume of interstices and

V is the total volume.

A rock is said to be saturated when all its interstices are filled with water. In a saturated rock the porosity is practically the percentage of the total volume of the rock that is occupied by water.

On the basis of the above principle, porosity of the aquifer materials (medium to fine sand) of the study area have been estimated in the laboratory. For this purposes a variety of sand sample of different locations of the study area have been collected from the BIADP authority. Groundwater sample of the respective locations are also collected for carring out the test. The sand samples are then processed and prepared for the test. The results of the test are shown in Table 5.2.

Table.-5.2 Volumetric measurement of porosity

Location of sample	Vol.of sand sample in dry state V_1 c.c.	Vol.of sand sample after saturated with water V_2 c.c.	Vol.of water occupied by the sample $V_3 = (V_2 - V_1)$ c.c.	Porosity of the sample $\phi = V_3 / V_2$ in percentage
Nachole HQ.	4.50	7.60	3.10	40.78%
Varendi	5.50	9.20	3.70	40.22%
Vujoil	5.70	9.20	3.50	38.04%
Barenda	5.50	9.10	3.60	39.56%

5.3.2 Permeability

Permeability is measured by the quantity of water passing through a unit cross section in a unit time under 100 percent hydraulic gradient. It is supposed to vary approximately as the square of the diameter of grain of water-bearing material. It also varies with percentage of fine material and arrangement of grains of coarse and fine material.

Permeability of the study area estimated into two phases; (i) permeability of the top stratum (clayey formation) which overlie on the aquifer and (ii) permeability of the aquifer material (composite sand formation). The first one is computed purely on theoritical basis from the total amount of annual recharged groundwater and the value is found as 4×10^{-4} m/day.

The second one is available from the pumping test result of Bangladesh Water Development Board (BWDB). They conducted 24 long duration pumping test in the total Barind area during 1988-89. The analysis shows an wide range of values for the hydraulic properties of the aquifer. Most of the test were carried out for 4320 minutes with more than three observation wells. The pumping test results of BWDB for the present study area along with its surrounding 6 (six) thanas is presented in Table-5.3.

From the table it is evident that both the permeability and transmissivity of the study area is low as compared to its surrounding areas which indicates that the area is not suitable for large scale groundwater abstraction.

Table 5.3 BWDB Aquifer Test Analysis of seven thana of Barind Tract including the present study area.

BWDB TEST NO. WITH LOCATION	TEST DURATION (minutes)	DISCHARGE (l/s)	SWL FROM GROUND SURFACE (m)	PERMEABILITY K(m/day)	TRANSMISSIVITY $T(m^2/day)$	STORAGE COEFFICIENT
TEST-18 TANORE	4320	30	9.35	40	700	0.05
TEST-22 GODAGARI	4320	34	6.88	15-18	600	0.10
TEST-21 NAWABGANJ	4320	31.15	4.67	57	1200	0.15
TEST-9 GOMASTA-PUR	4320	30	6.23	17	300	0.04
TEST-17 SHIBGANJ	4320	40	7.24	25	700	0.115
TEST-14 NIAMATPUR	4320	36	9.40	14	400	0.05
TEST-13 NACHOLE	4320	34	11.60	12	224	0.06

5.3.3 Specific Yield

Groundwater in the saturated zone can be divided into two parts: the portion which is free to drain out under the influence of gravity, and the portion which will remain with the solid material, primarily because of capillary forces. The portion free to drain out is measured by specific yield (S_y) and the portion remaining by specific retention (S_r). If porosity is represented by p, $p = S_y + S_r$. Specific yield is the storage capacity of a unit volume of material. The storage capacity includes only the water (or space for water) that can be yielded by gravity, which is identical with the water that can be pumped out by wells.

Under simple water table conditions only, the storage coefficient S obtained by standard aquifer tests is equal to specific yield but under confined condition S does not equal to specific yield.

Considerable research (Dos Santos and Youngs, 1969; Johnson, 1967; Jones and Schneider,1969) has been done to determine the specific yield of unconsolidated sedimentary materials. More recent research on the specific yield of unconsolidated materials has been undertaken by the hydrologic laboratory of the U.S. Geological survey. Preliminary results of this work are available and shown in Table.5.4. These unit values of specific yield are taken as the standard value for the computation of storage capacity in a sequence of sediments containing a number of beds or lenses of sand or gravel, silt, and clay such as is common in alluvial fill.

The storage capacity of any volume of geologic material can be obtained by summing up the specific yield of all the unit volumes it contains. Since nearly all such zones include various types of material with different specific yield, it is necessary to weigh each material according to its proportion of the entire volume.

Table-5.4 Provisional values of Specific yield after U.S.G.S. Hydrologic Laboratory.

Material	Specific Yield (per cent)
Clay	1
Silty clay	2
Sandy clay	3
Clay-silt	5
Silt	7
Clay-Sand	7
Sandy silt	14
Silty sand	20
Fine sand	26
Medium sand	35
Coarse sand	33
Sand Undifferentiated	32
Values from Eckis (1934)	
Fine gravel	25
Medium gravel	20
Coarse gravel	14

For computing the specific yield of the study area available information of bore-logs have been collected from the BIADP (Barind Integrated Area Development Project) authority. The simplified method of calculating the storage capacity/specific yield is shown in Table 5.5. Here the specific yield or the storage capacity is computed from a plane 5 meter below the surface to a plane 50 meter below the surface.

Table-5.5 Method of computation of storage capacity(or Sp.Yield), Location - Nachole Proper.

Depth intervals (meters)	Materials	Unit thickness (meters)	S_y (percent)	Weighted S_y (m^3 X 100)
0 - 5	(above zone)			
5 - 24	Clay	19	1	19
24 - 27	Fine sand	3	26	78
27 - 43	Medium sand	16	35	560
43 - 46	Sandy Clay	3	3	9
46 - 58	Clay (remainder below zone)	4	1	4
			Total-	670

The storage capacity of a column of materials one meter square and 45 meters high is obtained by dividing the total by 100 . Thus the storage capacity of materials at well in Nachole proper is 6.70 cubic meter while the specific yield is 6.70 percent. The study area Nachole thana is consists of 4 (four) union; Nachole, Nazampur, Kasba, and Fatepur. The storage capacity or the specific yield of each union is computed separetely from the respective available bore-logs. The average values of specific yield in percent of each union are, Nachole - 6.62, Nazampur - 7.5, Fatepur - 6.92 and Kasba - 4.38.

5.4 QUALITY OF GROUNDWATER

Quality of groundwater is just as important as its quantity. All groundwater contains salts in solution that are derived from the location and past movement of the water. The quality required of a groundwater supply depends on its purpose; thus, needs for drinking water, industrial water, and irrigation water vary widely.

The quality of water of Barind Tract have been studied for both drinking and irrigation purposes by some organisations like, Bangladesh Water Development Board (Klinski, 1979), Bangladesh Atomic Energy Commission (BAEC, 1989), and Public Health Enginnering Department.

In general the water quality of the area is good for drinking, irrigation and industrial uses only except some localised concentration of iron and chloride.

As relates to present geoelectrical investigation, mainly Electrical Conductivity (EC), T.D.S.(Total Dissolved Solid), Chloride, and pH of groundwater of the study area were determined. In course of the survey water sample were collected from tube wells all over the prospection area, particularly in the direct proximity of geoelectrical measuring points. Chloride and pH test were performed in the laboratory.

Electrical conductivity and T.D.S.(Total Dissolved Solids), the most useful test for the present study had been carried out absolutely in the field. Results of these test are shown in Table 5.6.

Excluding the above qualities, some other qualities (both anions & cations) of water as available from Water Development Board are also included in Table 5.6.

Table.5.6 Results of chemical analysis of groundwater samples from the study area.

Sample Location	Parameters							
	Tested in Lab. & in the field				Derived from BWDB(Bangladesh Water Development Board)			
	EC µS/cm	TDS mg/l	Cl- mg/l	pH	Nacl mg/l	Cacos mg/l	Fe mg/l	Boron mg/l
Nachole	450	325	12.8	6.8	21.12	266.00	2.40	0.237
Vujoil	570	398	10.4	7.6	17.16	243.20	2.24	0.252
Barenda	785	534	14.2	6.8	23.43	360.00	3.08	0.260
Chatipur	1005	735	48.6	7.9	NA	NA	NA	NA
Paschim Mirzapur	765	540	19	6.9	31.35	570.00	3.33	0.256
Kasba	720	506	8.0	6.7	13.20	316.00	2.46	0.270
Nazampur	470	335	11.4	7.2	18.81	421.00	3.36	0.253
Amjoan	810	575	16	6.9	NA	NA	NA	NA

NA = Not Available

CHAPTER SIX

MANAGEMENT OF GROUNDWATER

Chapter 6

6.0 MANAGEMENT OF GROUNDWATER

Management of groundwater means controlled use in accord with some plan. Maximum development of groundwater resources for beneficial use involves planning in terms of an entire groundwater basin. Management objectives must be selected in order to develop and operate the basin.

6.1 NEED FOR GROUNDWATER MANAGEMENT

Groundwater which is a renewable resources has certain inherent advantages such as:

(i) negligible evaporation or seepage losses during transmission or storage,

(ii) negligible expenditure on storage space in contrast to huge expenditure involved in surface water reservoirs,

(iii) low risk of pollution,

(iv) low cost of development and easy availability whenever required by individuals.

(v) no ecological hazards as are generally associated with surface water projects, and

(vi) phase-log in water level depletion after reduced recharge during draught years.

Notwithstanding the above advantages there are certain limitations also on the utilizable potential of groundwater regime. These arise due to wide variation in the quantity and quality of the available groundwater. Spatial variations are attributable to factors like geology, climate, topography and ecology etc. More important from management point of view, are predictable and unpredictable time domain variations of groundwater supply in relations to demands. Some of the hazards which may occur due to over-exploitation of groundwater are:

(i) Water levels may go down below economic levels of pumping (through progressive depletion of groundwater reservoir).

(ii) Water quality may deteriorate (due to increase in salinity) beyond permissible limits.

(iii) Long term dewatering of water-bearing formations may cause permanent deleterious effects on their hydraulic properties.

(iv) Substantial reduction of hydrostatic pressure may give rise to land subsidence.

(v) Stream-flow may decrease in some cases due to reduction of effluence from depleted aquifers.

It is, therefore, essestial that these hazards should be obviated through:

(i) planning the number and pumping rates of wells for optimal exploitation,

(ii) appropriate remedial measures such as artificial recharge to groundwater stroage during surplus period and conjunctive use of surface and subsurface water resources, and

(iii) exploration and exploitation of deeper aquifers.

The above precautions reveals that a proper management of groundwater is required to development and utilization of subsurface water.

6.2 GENERAL GROUNDWATER CONDITIONS.

Essentially all the groundwater that occurs in the study area originates from rainfall. A part of the rain which falls in the region returns to the atmosphere by direct evaporation from the land surface, a part flows directly to the streams and is carried away as runoff and the other part seeps into the soils. Of this last part some is also returned to the atmosphere by evaporation from the soil and by transpiration of plants. The rest percolates downward until it reaches to the water saturated zone.

According to the subsurface geology, based both on present geophysical study and hundreds of borelogs drilled by BWDB & BIADP, it was found that there exist a only one aquifer composed of very fine to medium sand (to some extent coarse sand) of variable thickness overlie on a great thickness of silty-clayey sediments. The thickness of this clayey zone is yet to determine.

The aquifers have been encountered just below the overlying clayey sediments which acts as the upper confining bed. The thickness of this upper confining layer is varied from 6 meter to 50 meter. The considerable thickness and very low permeability of this layer is very significant in determining the recharge to the aquifer.

Groundwater occurs under unconfined, semi-confined and also confined conditions at some places. The less permeable clayey sediments making up the top part of the aquifer may act temporarily as a cofining layer owing to its lower capacity to transmit water. During long periods of pumping, however, the upper material would be drained, the confining effect thus being dissipated and the aquifer would function under water table conditions. Such hydrologic conditions may be classified as `semi-artesian´ since they refelect characteristics which are common to both artesian and water table aquifer. The thickness of the saturated zone in the study area is varies from 20 meter to 50 meter. The depth of the water table from ground surface within the Barind Tract is bigger than the surrounding areas both in dry season and wet season. The water table generally reaches its minimum depth in September or October i.e. at the end of the rainy season and it varies from 3 meter to 13 meter. The maximum depths occur at the end of the dry season, in May or June and varies from 10 meter to 21.27 meter. It was found that the annual fluctuation of groundwater level is directly related to the recharge and discharge conditions.

6.3 ESTIMATION OF RECHARGE

Groundwater is recharged chiefly from pricipitation falling in the area. Part of the rainfall directly percolates underground, while a part percolates after entering the streams as runoff. In addition, a large number of tanks along with some natural canals (locally known as Khari) form the additional, but local sources of groundwater recharge. Besides this, an artificial recharge is considered because of shallow and deep tubewells irrigation in the area since 1984.

A quantitative assessment of groundwater recharge has been made for the study area. A variety of technique is used for groundwater recharge. For the present study an empirical method is used for the primary assessment of recharge and finally the total input to groundwater is cross-checked by the actual fall and rise of groundwater level (Well-Hydrograph Method).

The empirical method is employed here for the following criteria for recharge assessment.

(i) Recharge due to rainfall,

(ii) Natural recharge due to surface water bodies like tanks, canals etc.

(iii) Artificial recharge due to irrigation return.

(i) Recharge due to Rainfall (Re1)

Only a small fraction of the annual pricipitation percolates downward, a major portion runs-off on the surface because of some high undulating and terrace like topography, and the remaining portion is lost by evapotranspiration. As regards to present geology there is no established formula for the estimation of recharge due to rainfall, the Chaturvedi formula (Chaturvedi,

1947) developed for the Uttarpradesh in India is employed here. This formula is used because of, a lot of similarities exist in the field of climatic records, topography, soil characteristic etc. between them. The formula employed is as follows:

$$R_p = 1.26\ (R - 38)^{0.5} \qquad (6.1)$$

where R_p = net recharge to groundwater in cm.

R = rainfall in cm.

Besides the above formula, a completely different approach is used for the pricipitation recharge and this new technique is the Chloride Mass Balance method (Hydrotechnica, 1985; Houston, 1982). This technique relies on the fact that except in areas of evaporite deposits, chloride is a conservative and generally non-reactive anion in natural water. Therefore chloride in rainfall (derived from ocean water evaporation) usually passes through the soil zone to the water table without change. The ratio of chloride concentration in rainfall to that in groundwater is then a measure of recharge, thus;

$$\text{Recharge(mm)} = \text{rainfall(mm)} \times \frac{\text{mg cl}^{-1}\ \text{rainfall}}{\text{mg cl}^{-1}\ \text{groundwater}} \qquad (6.2)$$

For the above two techniques the rainfall data for the last 22 years (Table 2.1) have been collected from Bangladesh Water Development Board (BWDB). For the Chloride Mass Balance method, rain water was collected in three phases during 1991-92 monsoon period and the sample was tested in the University's Chemical labratory for chloride. The average value of three sample was taken into consideration for recharge calculation and it was found as 1.05 ppm. In the same way a number of groundwater samples were collected from different location of the study area and then tested in the labratory. The concentration of chloride in groundwater sample is varied from 8 ppm to 66 ppm but generally it ranges around 12 ppm and this value is considered for the present recharge computation. Thus Re1 is calculated individually by both the Chaturvedi formula and chloride mass balance method with the involved area (282.9 sq.Km) of aquifer and to avoid the uncertainty the average value of the two technique is considered as the recharge due to rainfall (Table 6.1).

(ii) Natural recharge (Re2):

Investigated area has about 900 tanks (very small to big) along with some natural canals with total water spread area (At) about 5.5 sq Km. Although there is a river Mahananda flowing outside the investigated area but it touches a minimum portion of the western side of the area as shown in the location map. Hence the influence of recharge from the river bed is considered as negligible. The seepage from the tanks and canals occurred in a identical type of soil and the seepage factor (Rt) for both the surface reservoirs is used as 0.55 m/yr (Nabard, 1984). In the normal rainfall periods (Dn), during August to December (about 5 months) tanks and canals are full. Natural recharge is thus calculated using the following formula:

$$Re2 = At \times Dn \times Rt \qquad (6.3)$$

Where

Re2 is recharge due to tanks and canals

At is the total water spread area

Dn is the total number of days

Rt is the seepage factor

and the calculated value is shown in the Table 6.1.

(iii) Artificial recharge (Re3):

Artificial recharge is estimated from return flow from agricultural fields due to irrigation. The water table in the study area is very deep in compared to other parts of the country and during wet season it lies in the upper clayey formation. The thickness of this clay formation is very large and its permeability has estimated in the order of 4.4×10^{-4} m/day. The specific yield of this clay composition is also very low. Because of low yield of the underlying aquifer material discharge of the irrigation equipment is not enough. Considering these different types of limitations, the artificial recharge (Table 6.1) is considered as 20 percent of the total draft for irrigation as shown in Table 6.1.

Besides the above recharge assessment technique, another assessment has been also made for cross-checke with the actual change in water level in the observation wells during the period. The national water management body maintains a good network of observation wells in the Barind Tract like other parts of the country. Bangladesh Water Development Board monitored different hydrogeological parameters. For the present investigation related data like weekly water level records, temperature and annual rainfall for the last 22 years are collected. Thus the total input was also estimated by using the following relation (Raghunath, 1985).

Table 6.1 Estimated value of annual recharge by empirical method during the period 1984-85 to 1992-93

Session	Annual Rainfall in mm.	Recharge due to rainfall (Re1) in mcm			Natural recharg -e(Re2) in mcm	Artific -ial recharg -e(Re3) in mcm	Total input to ground water I= Re1+Re2 +Re3 in mcm
		By *Ch. formula	By Cl-mass balanc -e method	Average			
1984-85	1329.69	34.73	32.91	33.82	1.24	5.06	40.12
1985-86	1343.66	34.99	33.26	34.12	1.24	5.69	41.05
1986-87	1729.99	41.42	42.82	42.12	1.24	6.80	50.16
1987-88	1558.79	38.70	38.58	38.64	1.24	10.13	50.01
1988-89	1848.80	43.19	45.76	44.48	1.24	12.12	57.84
1989-90	1279.30	33.80	31.66	32.73	1.24	12.35	46.32
1990-91	1564.20	38.78	38.72	38.75	1.24	12.24	52.23
1991-92	1572.20	38.89	38.92	38.90	1.24	12.96	53.10
1992-93	1342.30	34.96	33.22	34.09	1.24	13.44	48.77

*Ch.= Chaturvedi

$$\Delta GWS = A_{aq} \times \Delta GWL \times S_y \quad (6.4)$$

where ΔGWS = change in groundwater storage due to monsoon recharge

A_{aq} = Involved area of the aquifer

ΔGWL = change in groundwater level

S_y = Average specifio yield of the material in the zone of water level fluctuation

According to the available information, it is found that the fluctuation of groundwater level occurs within the upper clayey zone. The average specific yield of this clayey formation is computed as 0.03 with the technique as mentioned in the earlier chapter. Thus the annual change in groundwater storage due to monsoon recharge of the study area of 282.9 sq.Km is calculated individually for a period of 9 years (1984-85 to 1992-93) as shown in the Table 6.2. With a view to groundwater balance study, respective annual discharge is also computed simultaneously.

6.4 COMPUTATION OF DISCHARGE

In general the main components of groundwater discharge are (a) evaporation, particularly in low lying areas where the water table is close to the ground surface; (b) natural discharge by means of spring flow and effluent seepage into surface water bodies; (c) groundwater leakage and outflow through aquitards into adjacent aquifers; and (d) artificial abstraction.

Table 6.2 Total annual input to groundwater by hydrograph method and empirical method .

Session	Annual rainfall in mm	Average fluctuation of GWL in m	Annual recharge(ΔGWS) by hydrograph method in mcm.	Annual recharge by empirical method.in mcm
1984-85	1329.69	4.56	38.70	40.12
1985-86	1343.66	4.85	41.16	41.05
1986-87	1729.99	5.78	49.05	50.16
1987-88	1558.79	5.69	48.29	50.01
1988-89	1848.80	6.85	58.13	57.84
1989-90	1279.30	5.48	46.50	46.32
1990-91	1564.20	6.12	51.94	52.23
1991-92	1572.20	6.38	54.15	53.10
1992-93	1342.30	5.65	47.95	48.77

In the present study area, evaporation loss is considered as negligible, because evaporation loss occurs where the water table rests within a depth whereform the groundwater can ascend to the land surface by capillary action. According to White (1932) evaporation is high where water table lies within a depth of 0.3 m below surface. It however, decreases to an almost negligible rate where the water table lies one meter deep. Inasmuch as the water table lies below 10 m depth in the study area, there does not seem to be any possibility of loss by evaporation. For the same reason the effluent seepage to surface water bodies (like tanks, canals etc.) is not possible. Transpiration loss through plants is also minimum because of very thin vegitation and it is not considered in the present discharge computation.

However the significant amount of discharge occurs chiefly due to artificial abstraction. With the increase of population, domestic demand of water supply have been also increased. It is remarkable to note that before 1960 there was no Hand Tube Wells (HTW) in the study area and the people met up thier domestic demand by the dug wells, ponds, river etc. and still many of the villagers are used dug wells. During the field work, it is observed that about 400 hundred dug wells being used in the study area. These dug wells are used about 2000 hour in a year. Considering the discharge rate of the dug wells as one-third of the hand tubewells the average annual discharge is computed as 10 million cubic feet(mcf) (Table 6.4). After 1960, Public Health

Engineering Department with the help of different foreign international organisation (like FAO, UNICEF, etc.) have been sinking different types of hand tube wells in the study area. The number of tube wells has since considerably increased.

Accordingly, during the earlier part of the 80's, Barind Integrated Area Development Project (BIADP) has been initiated a irrigation programme in the Barind Tract. Under this programme a large number of Deep Tube Wells (DTW) have been installed since 1984 and still the installation programme is continued. Besides this, a large number of Shallow Tube Wells (STW) have been functioning in the study area. There is also a number of Low Lift Pump (LLP) is used in irrigation from surface water bodies.

Available information regarding the number of tube wells installed in each year is collected from the respective organisations. For convenient, a table is given here (Table 6.3) mentioning all types of discharging equipments with their respective Discharge Rate (DR) & Discharging Hour (DH) during the year 1984 to 1993.

With a view to groundwater management, the discharge of groundwater accomplished by the different discharging equipment is computed for a period of 9 (nine) years. The discharge is calculated individually according to the discharge rate and discharging hour of the respective discharge element that are used in the study area for both the domestic and irrigation purposes (Table 6.4).

Table 6.3 Total number of discharging wells running through out the year during the period 1984-85 to 1992-93

Discharging equipments with discharge rate & hour	Total no.of active discharging equipments during the the period 1984-85 to 1992-93								
	84-85	85-86	86-87	87-88	88-89	89-90	90-91	91-92	92-93
1. Hand Tubewell sunk by Public Health Eng.Deptt.(a) Abyssinia wells DR = 0.011 cft/sec DH = 3000 hr/yr	304	304	337	353	350	345	348	355	355
1. (b)Tara pump/DSP DR = 0.026 cft/sec DH = 3000 hr/yr	318	320	331	325	355	410	488	610	622
2. Prvt. Hand Tubewell DR = 0.01 cft/sec DH = 2000 hr/yr	30	35	42	45	46	48	52	55	55
3. Low lift pump(LLP) DR = 1.0 cft/sec DH = 900 hr/yr	55	57	59	62	64	60	65	68	71
4. Shallow tubewell (STW) DR = 0.5 cft/sec DH = 1500 hr/yr	185	200	210	220	232	240	242	250	254
5. Deep tube well(DTW) DR = 2.0 cft/sec DH = 1500 hr/yr	20	26	41	92	121	124	120	129	135

DR = Discharge Rate, DH = Discharge Hour, DSP= Deep set Pump

6.5 GROUNDWATER BALANCE STUDY

Groundwater is extracted from the ground just as are other minerals such as oil, gas, or gold. Water typically carries a special constraint: it is regarded as a renewable natural resource. Thus when a water well is drilled, people presume that production of water will continue indefinitely with time. In effect, this can only occur if there exist a balance between water recharged to the basin from surface sources and water pumped from within the basin by wells. But if groundwater is withdrawn at a rate exceeding the recharge, mining yield exists (Domenico, P.A.,et al., 1968) and if mining continues, different types of hazards may occur such as (i) declination of water level (ii) deterioration of water quality, (iii) destruction of hydraulic properties, etc.

Since 1984 the present study area suffers from some of the above problems, for large scale abstraction of groundwater due to irrigation purposes. So with a view to management and further development of groundwater, an assessment of groundwater resources of the study area has been made on the basis of input-output stresses.

INPUT:

During a hydrologic year all incoming water from both the natural and artificial sources reached the aquifer basin is considered as the input to groundwater. In the present investigation inputs to groundwater has been estimated from measured annual recharge due to rainfall, estimated return flow from agricultural fields, seepage from tanks and canals. The total input to groundwater has been estimated (Table 6.1) through different studies and available information collected from different concerned authority as mentioned in details in sectin 6.3.

OUTPUT:

Total outflow is calculated on the basis of actual quantity of groundwater drawn by the different discharging elements being used in the study area for both the domestic and irrigation purposes. The annual discharge for each discharging equipment is computed individually and presented in a tabular form (Table 6.4).

Groundwater Balance

Groundwater balance for the study area is worked out using the following relation, assuming the natural groundwater inflow to be equal to the groundwater outflow,

$$\Delta S = I - O \qquad (6.5)$$

Where ΔS = Change in storage.

I = Annual input to groundwater system

O = Annual output from groundwater system

Where $I = Re1 + Re2 + Re3$

$O = W1 + W2$

Where Re1 is recharge from precipitation

Re2 is return flow from irrigation

Re3 is seepage from tanks and canals

W1 is quantum of groundwater withdrawal for domestic uses

W2 is quantum of groundwater withdrawal for irrigation purposes

Adopting the above methodology, the groundwater balance is worked out with the observed data for the period 1984 to 1992(Table 6.5)

Table 6.4 Amount of annual discharge for both domestic and irrigation purposes due to different discharging equipments during the period 1984-85 to 1992-93.

period	Discharge for domestic purposes (W1) in mcf (million cubic feet)					Discharge for irrigation by surface water (W2') and groundwater (w2) in mcf				Total groundwater discharge Q = (W1+W2) in	
	HTW by (PHE)	Tara/DSP (PHE)	Private HTW	Dug wells	Total (W1)	W2' by LLP	W2 by		Total W3=(W2'+ W2)	mcf	mcm
							STW	DTW			
1984-85	36.11	89.29	2.16	10.0	137.56	178.20	499.50	216.00	893.70	853.06	24.16
1985-86	36.11	89.85	2.52	10.0	138.48	184.68	540.00	280.80	1005.48	959.28	27.17
1986-87	40.03	92.94	3.02	10.0	145.99	191.16	567.00	442.80	1200.96	1155.79	32.73
1987-88	41.94	91.26	3.24	10.0	146.44	200.88	594.00	993.60	1788.48	1734.04	49.11
1988-89	41.58	99.68	3.31	10.0	154.57	207.36	626.40	1306.80	2140.56	2087.77	59.13
1989-90	40.98	115.13	3.45	10.0	169.56	194.40	648.00	1339.20	2181.60	2156.76	61.08
1990-91	41.34	137.03	3.74	10.0	192.15	210.60	653.40	1296.00	2160.50	2141.55	60.65
1991-92	42.17	171.29	3.96	10.0	227.42	220.32	675.00	1393.20	2288.52	2295.62	65.02
1992-93	42.17	174.65	3.96	10.0	230.78	230.04	685.80	1458.00	2373.84	2374.58	67.25

Thus, overall study in the area of 282.9 sq.km indicates that there exist a balance between annual recharge and withdrawal upto the period 1987-88. But henceforth a cumulative annual deficit is found to exist because of progressive annual discharge. It is also found that during the period 1989-90 the deficit is maximum because of minimum rainfall.

Table 6.5 Groundwater balance for different years

Period	Rainfall in mm	Input in mcm	output in mcm	Change in storage in mcm	
				Calculated	Observed
1984-85	1329.69	40.12	24.16	+15.96	+14.54
1985-86	1343.66	41.05	27.17	+13.88	+13.99
1986-87	1729.99	50.16	32.73	+17.43	+16.32
1987-88	1558.79	50.01	49.11	+00.90	-00.82
1988-89	1848.80	57.84	59.13	-01.29	-01.00
1989-90	1279.30	46.32	61.08	-14.75	-14.58
1990-91	1564.20	52.23	60.65	-08.42	-08.71
1991-92	1572.20	53.10	65.02	-11.92	-10.87
1992-93	1342.30	48.77	67.25	-18.48	-19.30

CHAPTER SEVEN

DISCUSSIONS AND CONCLUSIONS

Chapter 7

7.0 DISCUSSIONS AND CONCLUSIONS

The groundwater studies in Bangladesh, particularly in Barind Tract have been handicapped in several ways and so the present study which has been the first ever carried out complete work in parts of Barind Tract simulating various realistic features of an aquifer. The most important lacuna of this type of research is the sparse and inadequate data base. The data for the present study was partly obtained from different organisations who did not collect it in a coherent manner with a view to carry out a quantitative water balance study. This conspicuous deficiency greatly restrict the validity of prediction of groundwater resources. The data gaps necessitated several simplifying assumption for the conceptualization of an aquifer system and the gaps had to be filled through a guess work based on some general knowledge of the system. Besides the above intrinsic difficulties, another fact is noticeable that the study area is one of the most remote places of Barind Tract and possesses an uncommon geology and geography (highly undulating and terrace like topography) and hence the number of sounding points and locations are restricted.

However an attempt has been made for an optimal use of the available data and field investigation to study the groundwater resources of the investigated area.

7.1 DISCUSSIONS

While the historical response of the aquifer could be inferred from the available records, there is no way of computing the future behavior of a system unless it is actually subject to the stresses. It is vital to know for the purpose of groundwater management, the quantitative response of the aquifer system under study to different output/input stresses. The behavior of the aquifer system is based on the simulation of all the relevant physical parameters (such as i) space dimension, ii) time dimension, iii) Hydrogeologic parameters defining the system and iv) flow rates) which describes the significant characteristic of the system. The electrical resistivity method is a potential tool to study the aquifer response for the effective groundwater management.

To study the time variation of the depth of aquifer and its thickness Geophysical investigation has been carried out during the period 1991-93. The first field work was carried out in the early part of the dry season (March). However to observe the maximum fall of groundwater level, in the second year the field programme had been made in June but it was not completed due to early monsoon. So in the third year the time of the field work has been selected in May. The result of the investigation shows a gradual fall of groundwater level which is supported by the well-hydrograph prepared for 21 year. Taking into consideration the several input and output stresses for the groundwater system of the study area, the change in storage has been estimated for the period of 9 years (1984-85 to 1992-93) which shows a gradual annual deficit since 1987-88 causing net declination of groundwater level. From the results of electrical sounding of five different locations, the time variation of the depth and thickness of aquifer is also evident. It is observed that the groundwater level have been gradually declined and as a result the thickness of aquifer is also reduced.

In Chatipur(VES-1), the extreme north location of the study area, the water level was found comparatively at a greater depth from ground surface. During the period of study, it was found from the interpreted result that the water level is declined about 1.5 meter in 1993 from the level of first observation(23.9 meter) in 1991. The aquifer thickness is also varried; in 1991 it was 30 meter while in 1993 it is reduced to 28.5 meter. In January 1993, the depth of aquifer and its thickness was found 21 meter and 31 meter respectively.

On the contrary, the lowest depth of aquifer is observed at Vujoil(VES-4). All the field work was made possible in this location. A distinct variation of aquifer level and its thickness is observed throughout the study period but in May 1993 the variation is to some extent different because of shifting the sounding point towards east due to the larger spacing of current electrode and also for the time variation of field work. In the first observation during March 1991, the water level was found at

9.95 meter below the ground surface. This level is gradually decreased and in the second field observation during June 1992, it was found at a depth of 12.5 meter. In January 1993 i.e. in the middle of the winter season the third field work has been made and the water level was found at a depth of 11.8 meter and thereafter in May 1993 the water level has to be declined but because of shifting the sounding point and also for shifting the period of field work in May instead of June, the water level found at a depth of 11.6 meter. However it is declined to 1.65 meter from the result of first sounding. The aquifer thickness is gradually decreased from 35.5 meter to 30 meter during the investigation period.

In Nachole(VES-5), only the two (third and fourth) soundings are successful in all respect, although the first field work had carried out but its interpretation could not be possible due to inconsistency of data. The second field work was interrupted by rain. The third field work has been made in January 1993. The aquifer was detected at 11.93 meter from ground surface and thereafter it has been gradually decreased and attains a maximum value 14.03 meter in May which was identified by the fourth sounding. The aquifer thickness was 23.3 meter in January while in May it was reduced to 20.00 meter in the year 1993.

Like Nachole two field work were made possible in Paschim Mirzapur (VES-6). In this location second and third field was not possible due to interruption of rain water and crops cultivation in the land respectively. Interpreted result of the first field work shows that the aquifer level lies at a depth of 16.5 meter from ground surface and during that time the aquifer thickness was 25 meter. After two year, that is, in the year 1993 the aquifer level has declined to 17.55 meter and accordingly the aquifer thickness is also reduced from 25 meter to 22 meter.

The most favourable field work had been made in the location Barenda(VES-8). All the four field was made properly and the field curves were also favourable for interpretation. Interpreted results show a clear variation of aquifer level and its thickness throughout the study period (1991-93). In March 1991 during first field observation an aquifer of 50 meter thickness was identified at a depth of 13 meter from ground surface. This water level has been gradually decreased and in the second field work it was found at 16.7 meter. In the third year(1993) two field work had been made, one in January and the other in May. In January the water level found at 12.3 meter and in May it is abruptly fall and found at a depth of 18.4 meter. Thickness of the aquifer is also varied from 54 meter to 49 meter in January and May respectively. A large number of deep tubewells were in operation in the vicinity of the location and the discharge is gradually increased in each year and this excess artificial discharge is one of the prime factor of abrupt fall of groundwater level.

From the overall locationwise description, the declination of aquifer level from 1.05 meter to 5.4 meter is found during the period(1991-93). It is also observed that the fall of water level is maximum in the area where the artificial abstraction of groundwater is high e.g.in Barenda; conversely the declination is minimum where the artificial abstraction is comparatively low, as is observed in Chatipur(VES-1). The aquifer level and its thickness as derived from the interpreted result is correlated with the available information of observation wells and borehole lithology of the area.

The above interpretation of electrical sounding is strongly supported by the different well-hydrograph prepared by the available and reliable information of national water management body (such as BWDB, BIADP, BADC etc.). For example one well-hydrograph (Figure 5.1) is studied here. From the hydrograph, it is observed that the water level is gradually declining and this declination have been started since 1984. It has been already mentioned that a large number of deep tubewells have been installed in the area since 1984 under a irrigation programme. Now it is evident that this abrupt fall of groundwater level from 1984 is mainly due to the large abstraction of groundwater by the deep tubewells.

Fluctuation of water level as shown in the hydrograph (Figure 5.1) can be classified into two phases; fluctuation before 1984 and after 1984. It is observed that the fluctuation before 1984 was occurred within 5.0 meter to 13 meter while after 1984 it happened between the depth of 10.5 meter to 21 meter below ground surface.

From the hydrograph it is also observed that the maximum annual fall of groundwater level(during dry season) maintains a constancy of 12 meter before the installation of deep tubewells, but after the installation of deep tubewells (since 1984), this maximum fall of water level has been gradually declined; e.g. in 1984 it was 15.39 meter while in 1989 it was declined to 21.27 meter and this is the highest fall of water level of the well No.R-44 located at Muradpur under Nachole union. Simillar happenings is also observed in the other observatory wells located in different places of the study area.

As mentioned above that, the result of electrical sounding shows a net declination of aquifer level from 1.05 meter to 5.4 meter throughout the study area during the period of 1991-93. From the hydrograph (Figure 5.1) it is observed that, during the above period(1991-93) the net declination of water level was 3.26 meter i.e. in 1991 the maximum water level was found at 16.64 meter and in 1993 it was at a depth of 19.90 meter from ground surface.

The declination of water level is as correlated with the well hydrograph also correlated with the water balance study of the investigated area. With a view to groundwater management an attempt has been made for groundwater balance study of 9 (from 1984-85 to 1992-93) years with the input/output stresses of the present aquifer system of the area. The result of this balance study (section 6.5, Table 6.5) shows that there is an annual deficit of groundwater storage from the period of 1987-88 and the deficit is continuing and cumulative. An annual deficit of 8.42 mcm (million cubic meter) volume of water is observed during the period of 1990-91 which implies a net 0.992 meter declination of water level and in the same way the net 2.18 meter declination of water level is observed during the period 1992-93 in consequence of an annual deficit of 18.48 mcm of groundwater.

7.2 CONCLUSIONS

In this work an attempt has been made to evaluate the availability of groundwater resources, its occurrence and characteristics of groundwater aquifers; particularly its variation of depth and thickness in different periods during the course of the survey. A total area of about 282.9 sq. km was investigated and over 19 measurements were carried out within a period of 3 years. The results of geoclectrical investigation indicated an aquifer of composite formation at a depth between 10 meter to 70 meter and this is the only aquifer which have been utilized for both the domestic and irrigation purposes. The variation of the depth of aquifer level and its thickness is distinctly observed and it was found that the water level is gradually declining. This declination is also estabilished by the available hydrographic information of the study area. Moreover, it is also confirmed from a 9 years groundwater balance study.

Different factors are involved for the present groundwater situation of the area. From the overall observation it is found that over exploitation of groundwater for the irrigation purposes is the main reason for the on going permanent declination of water level. The average annual rainfall which is the chief source of groundwater recharge of the study area is almost same and from the well-hydrograph it is observed that the recharge of groundwater is also same and during the last few years it is somewhat increased. But in comparison to increasing of discharge since 1984, the rate of recharge is insignificant. According to groundwater balance study (Table 6.5), it is found that an annual deficit is observed during the period 1987-88, although the recharge is almost same as the previous year. It is mentionable that the number of discharging equipments are gradually increased (Table 6.3) and particularly during 1987-88 the number of deep tubewells is increased more than doubled than the previous year and hence the discharge exceeded the recharge. Thereafter, with the increase of discharging equipments an appreciable change of annual deficit of groundwater storage is observed. Thus the aquifer is being depleted to the extent and no longer yields enough water to meet the demand.

The declination of groundwater level is bringing some major geohydrological and ecological changes in the area. For the progressive depletion of groundwater reservoir, water level go down below the economic level of pumping and so that the domestic demand of water supply is severely handicapped. The river Mahananda flowing across the western portion of the area are now a days becomes dry during the dry periods and the river stages go down compared to the groundwater level and results into loss of water from groundwater storage as base flow at higher rate.

The situation is also aggravated by the regional climate and vegetation. The area possess very thin vegitation and normally the temperature recorded is very high in comparison to other parts of the country. In these circumstances, the area is characterised as a high evaporation zone. All the above adversities are affected the ecological balance of the area and some parts of the area are showing evidences of desertification.

From the above studies, it is clear that the prospect of further groundwater development for irrigation is highly restricted. The present situation of groundwater and the ecological hazards may be obviated only through a proper management of groundwater. The following precautionary measurements should be taken for the immediate remedies.

1. Installation of deep tubewells should be stopped immediately and the rate of discharge of the existing deep tubewells would be checked accordingly and if necessary the number of deep tube wells may be reduced.

2. The numerous tanks and canals situated in the study area have to be utilized as the reservoir of surface water and also as the source of artificial recharge.

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