EXPLORATION OF GROUND WATER POTENTIAL IN COASTAL AQUIFER OF ORISSA - A CASE STUDY

By

Sudhanshu Kar

A THESIS SUBMITTED TO
THE ORISSA UNIVERSITY OF AGRICULTURE AND TECHNOLOGY, BHUBANESWAR
IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF

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(AGRICULTURAL ENGINEERING)

IN

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College of Agricultural Engineering & Technology
Orissa University of Agriculture and Technology
BHUBANESWAR, ORISSA

September 1995

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DEDICATED TO MY
BELOVED PARENTS

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Dated : 28th Sept.'95

CERTIFICATE

This is to certify that the thesis entitled "EXPLORATION OF GROUNDWATER POTENTIAL IN COASTAL AQUIFER OF ORISSA - A CASE STUDY" submitted in partial fulfilment of degree of Master of Technology (Agricultural Engineering) in Soil and Water Conservation Engineering of the Orissa University of Agriculture and Technology, Bhubaneswar is a faithful record of bonafide research work carried out by Sri Sudhanshu Kar under my guidance and direct supervision. No part of the thesis has been submitted for any other degree or diploma.

The help and information as have been availed of in course of this investigation have been duly acknowledged by him.

28.9.95

(S. C. Nayak .)

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Sudhanshu Kar

Place : Bhubaneswar.

Sudhanshu Kar.

Dated 26th September, 1995.

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List of Symbols and Abbreviations

Symbol/Abbreviation	Description
^oC	Degree centigrade
%	Percentage
p	Resistivity
ΔV	Change in voltage
Avg.	Average
B.D.O.	Block Development Officer
Ca^{++}	Calcium ion
CAET	College of Agricultural Engineering and Technology
CCA	Culturable command area
Cd	Cadmium
CGWB	Central Groundwater Board
cm	Centimeter
DANIDA	Danish International Development Agency
Dept.	Department
Dr.	Doctor
Er.	Engineer
etc	et cetra
et-al	and other fellows
F	Figures of merit
FAO	Food and Agriculture Organisation

Fig.	Figure
Govt.	Government
ha	hectare
ha.m.	hectare meter
hr	hour
Hz	Hertz
I	Current
i.e.	that is
K	Kernel function
K^{++}	Potassium ion
km	kilometer
l	litre
m	meter
mA	milli ampere
mg	milligram
M.ha	Million hectare
M ha-m	Million hectare meter
mm	millimeter
ms	milli siemens
Na^{+}	Sodium ion
Ni	Nickel
No.	Number
ohm.m	Ohm meter
OUAT	Orissa University of Agriculture and Technology

Ph.D	Doctorate of Philosophy
R	Resistance
RWSS	Rural Water Supply and Sanitation
SAS	Signal Averaging System
sec	second
SWCE	Soil and Water Conservation Engineering
Tab	Table
V	Volt
VES	Vertical Electrical Sounding
v.good	very good
viz.	videlicet

CHAPTER-I
INTRODUCTION

CHAPTER - 1

INTRODUCTION.

Water being a replenishable dynamic resource is the most precious and versatile of all the natural resources. It is vital for the very existence of man-kind and all other living beings and thus occupies an unique position in the resources endowment map of any country. The prominent role of the water resources in moulding and promoting the economic development and advancement of a nation in the key sectors of agriculture, industries, energy and public health is well known. Especially, the contribution of the water resources in the field of agriculture and irrigation is of great relevance and importance in the context of the agrarian economy of the country as a whole in general, and Orissa State in particular. Of late there has been a growing demand for water resources from the agricultural sector due to accepted concept of irrigated agriculture for ensuring higher productivity. The increasing demand for the water on the one hand and the limited availability of surface water resources due to various reasons including vagaries of monsoon on the other hand has brought about a critical situation for seeking alternative sources like the groundwater, which cannot only supplement but also at times supplement the surface water resources for achieving the desired results.

The earth's total water resources are estimated at 1.37×10^{s} million ha.m. Out of these, global water resources about 97.2% is salt-water and only 2.8% fresh water is available in this planet. Again of the fresh water 2.2% is found on the surface and 0.6% lies underground. Only 0.3% or about 41.1 x 10^4 Mha.m. of these fresh groundwater can economically be extracted. The remaining quantities of groundwater is available at a very deep depth of above 800 m. Groundwater is the largest source of fresh water on this planet excluding the polar ice-caps and glaciers. The amount of groundwater within 800 m. from the ground surface is over 30 times the amount in all fresh water lakes and reservoirs and about 3,000 times the amount in stream channels at any times (Raghunath, 1987). Keeping in view of the rapid urbanization, industrialisation, above all higher crop production, the use of groundwater is of significance. Because of its importance as a significant source of water supply, various aspects of groundwater dealing with the exploration, development and utilisation have been extensively studied by workers from different disciplines, such as geology, geophysics, geochemistry, agricultural engineering and civil engineering etc.

Groundwater can very well and efficiently be utilised in irrigation purposes. It has many advantages over the surface or canal irrigation system.

(i) Tubewells can irrigate isolated lands which cannot be covered under canal irrigation system.

(ii) Cultivators can possess their own tube-wells and thus have not depend on government owned canal water.

(iii) Tube-wells can be constructed with less funds and small time while considerable time and huge funds are required for construction of canal irrigation projects.

(iv) Whenever required the water can be supplied from a tube-well and can be stopped at any time, taking the advantage of momentary rainfall.

(v) Tube-well water is generally be supplied on a volumetric basis resulting optimum utilisation of water at the correct time.

(vi) Pumping of groundwater lowers the groundwater-table, thus reduces the water-logging problems and associated soil salinity hazards. This is an important aspect in the canal command areas.

(vii) Tube-well irrigation helps raise more than one crop in a year.

(viii) Groundwater which is colder in hot weather and warmer in cold weather is much suitable to crops.

(ix) Land aquisition is less for tube-well irrigation.

(x) Unless drought continues for many years, well irrigation does not fail in drought.

(xi) Groundwater lends itself beautifully to modern technologies like drip and sprinkler irrigation.

Coastal areas of the country have the maximum concentration of population, centres of urbanization. It is industrial growth and intensive agricultural activities due to the area is enriched with abundance of water resources and fertile land, One of the environmentalist of the World Bank Mr. Ismail Sheragildin has predicted war among the develpping countries in the next century for fresh water to fulfil the requirement of fresh water the extraction of groundwater is obvious. It is also concluded that groundwater is the best option for drinking, domestic, industry and irrigational use. Better land and water management can be achieved by using groundwater through tube-well irrigation. Hence, the importance of groundwater exploration in coastal areas is obvious.

1.1 Groundwater Development :

The quantum of groundwater available in a basin is dependant on the inflows and discharge at various points. The recharge of the basin depends on precipitation, infiltration from lakes, streams and canals and artificial recharge if any. The discharge of the basin depends on pumping, surface outflows, seepage into lakes and rivers and evapotranspiration. The rain fall has contributed a lot to groundwater and the contribution has influenced by topography of the area, the depth of soil and its permeability and nature of vegetal cover. In an average India receives 400 Mha.m. of annual rain fall. About 215 Mha.m. of rain fall infiltrate into the soil. A major part of it about 165 Mha.m. is retained as soil moisture. About 20% of the annual rain fall is responsible for recharging the ground water (Adyalkar, Rao, 1982).

Well and tube-well irrigation has increased from 4.0 Mha. in 1911 to 6.5 Mha. in 1951. It has increased to 35.00 Mha. in 1990 (Anonymous, 1992).

1.2 Groundwater Development in Coastal Tract of Orissa :

The State of Orissa can be divided into four different tracts by hydrogeological set-up for contri-

Table 1.1 progress of irrigation development from groundwater

Sl. No.	Period	Irrigation potential (M.ha)
1	1911-1915	4.00
2	1916-1920	4.70
3	1921-1925	4.70
4	1926-1930	4.80
5	1931-1935	4.80
6	1936-1940	5.20
7	1941-1945	5.40
8	1946-1950	6.30
9	1950-1951	6.50
10	End of 1st plan (1955-56)	7.63
11	End of 2nd plan (1960-61)	8.30
12	End of 3rd plan (1965-66)	10.50
13	End of tri-annual plan (1968-69)	12.50
14	End of 4th plan (1973-74)	16.50
15	End of 5th plan (1978-79)	19.80
16	End of annual plan (1979-80)	22.00
17	Target for sixth plan (1980-85)	7.00
18	Achievement during sixth plan	5.97
19	Total potential created at the end of sixth plan	27.97
20	Target for 7th plan (1985-90)	7.10
21	Ultimate feasible	40.00

Source :

1) Principles of Agricultural Engineering-II (A.M.Michael and T.P.Ojha, 1987)
2) CGWB Report, (1986)
3) Irrigation Theory and Practice (A.M.Michael, 1991).

buting groundwater development. They are ;

(1) Rainfed erosional plain

(2) Rainfed alluvial plain

(3) Coastal saline tract

(4) Command area of flow irrigation projects.

The State consists of 30 Districts. Of these only 6 districts with of about 40 numbers of blocks comes directly in contact with the sea coast and are termed the saline belt of Orissa. This coastal saline tract is a narrow strip of alluvium bordening the Bay of Bengal on eastern side of the State. It extends for 480 Km. starting from the mouth of river Subaranrekha in north and continuing to the south into the Ganjam District bordening Andhra Pradesh.

1.3 Groundwater Resources of Cuttack District :

The Cuttack (undivided) District occupies an area of 11,211 sq.kms. As per one estimate done by CGWB, Govt. of India, the district gets a mean monsoon recharge of 3022.50 MCM. The annual dynamic reserve of groundwater has been estimated at 3487 MCM. The per cent of utilisation being estimated at around 12% of the total recharge, a groundwater balance of about 2461 MCM has been estimated for future development.

1.4 Coastal Ecology :

Though water is aparently bountiful in the coastal saline belt of Orissa, availability of fresh water of the right quality and desired quantity is difficult to get. The surface water being saline due to the tidal activities of the rivers and seas, the groundwater regime is a system containing the saline and fresh aquifers in an equilibrium condition. The later aspect is important in the context of large scale groundwater development in this area. Therefore, it is very important to understand the aquifer geometry. Also it is equally or more important to utilise the reserves judiciously. There are number of swamps, sand dunes, tidal rivers and natural barriers intercepting the tracts at regular interval causing the salinity of the surface water and groundwater. Generally, the following type of situations are encountered in coastal aquifers.

i) A shallow fresh aquifer at the top and immediately below it saline aquifer prevails, causing difficult in extraction of groundwater.

ii) Fresh aquifer at a greater depth and top aquifer is either brackish or saline.

iii) Top layer is a saline aquifer, below which a fresh aquifer is encountered at a greater depth which is in turn is overlying a saline aquifer.

iv) Possibility of existence of fresh aquifer below 600 m. is yet to be investigated.

1.4 Objectives :

The National Water policy, 1987 stipulates (Raghunath; H).

(a) Exploitation of the groundwater resources should be so regulated as not to exceed the recharging possibilities, as also to ensure social equity. Groundwater recharge projects should be developed and implemented for augmenting the available supplies.

(b) There should be periodical reassessment on a scientific basis of the groundwater resources taking into consideration the quality of the water available.

Keeping in mind the above points, a case study has been carried out in Kujang Block of Jagatsinghpur district with the following objectives.

i) Investigation of the groundwater regime ;

ii) to delineate the dimensions of the fresh groundwater resources of both shallow as well as deep aquifer ;

iii) to investigate the quality of the aquifer ;

iv) to estimate the potentiality and sustainability of the aquifer ;

v) to study the possible application of results in other saline belt of the state.

CHAPTER-II
REVIEW OF LITERATURE

CHAPTER - 2

REVIEW OF LITERATURE

Groundwater is commonly understood to mean water occupying all the voids within the geologic stratum. It constitutes one portion of the earth's water circulating system known as the hydrologic cycle. Groundwater survey by drilling test hole is very expensive. Hence, geophysical approach has been adopted judiciously in location and exploration procedures. History of groundwater assessment in India, in Orissa and in study area Kujanga block has been highlighted in the following paragraphs.

2.1 History of Assessment of Groundwater Resources :

In 1901 under the guidance of S.R. Robertson the first Irrigation Commissioner of India, the Water Resources of India was assessed, followed by a similar assessment by Khosla in 1949, (Michael, 1987).

Two agencies namely the Geological Survey of India and Central Groundwater Board (CGWB) were engaged in the techniques of prospecting the groundwater resources. Under this programme the regional hydrological mapping, collection of hydrological inventory data, geophysical surveys for groundwater test drilling, geohydrological evaluation of the formation, characteristics of water bearing strata and groundwater assessment and management studies were undertaken. The water wing of geological survey of India has merged with the CGWB in 1972. State Groundwater

Directorates were established in 1963 for collection of hydrological information on day-to-day programme basis.

2.2 Geophysical Exploration :

Geophysical exploration is the scientific measurement of physical properties of the earth's crust. Investigation of mineral deposits, geologic structures etc. are determined by this method (Kelly, 1962 and Drobin, 1976). Sub-surface structure and lithology have been defined by this. The interpretation is indirect and the coastal area has been studied extensively by Chandra (1993). This brings out a comparative picture of the anomalies and interprete them contextually.

2.2.1 Georesistivity survey :

Georesistivity survey is the most efficient, widely accepted, less expensive and time saving technique in groundwater investigation (Ssantz, 1937; Bays, 1950; Spicer, 1952; Bhule, 1953; Mc Ginnis and Kempton, 1961; Mc Donald and Wantland, 1961; Kelley, 1962; Bierschenk, 1964; Dudley et al 1964; Zohdy, 1969, Smith, 1974; Verma et al 1980; Rogers and Kean, 1980; Kosinki and Kelly, 1981; Sri Niwas and Singhal, 1981; 1985, Kwader, 1985). This study is more useful when combined with other studies like areal photography, test-well drilling etc. (Foster and Bhule, 1951; Mc Ginnis and Kemton, 1961; Imam et al, 1973).

2.2.2 Groundwater assessment in coastal areas :

The groundwater investigations in the State date back to several decades. In the initial period, all such investigations related to specific purposes like water supply to a village, Railway Station or a Military Camp.

The activities of the Central Groundwater Board, being the apex body charged with the responsibility of groundwater surveys, exploration and assessment programme are classified into ;

a) Systematic Hydrogeological survey ;

b) Groundwater Exploration and First Approximation Resource Evaluation ;

c) Regional Groundwater Studies.

The first phase of exploration was taken-up in the coastal tracts of undivided Balasore and undivided Cuttack Districts between November, 1958 and June, 1959. Maximum depth of 302 m. was drilled. The exploration brought to light the occurrence of potential aquifers between 30 and 150 m.bgl and between 200 m. and 300 m. bgl with feasibility for development of the aquifers through medium to deep tube-wells. In all 14 bore-holes were drilled.

The second phase of exploration was carried out between the period 1974 and 1976. In all a total of 69 exploratory bore-holes, including 8 observation wells were drilled and tested to have a first hand knowledge about the configuration of the aquifers.

Apart from the Central Agency, the Orissa State Lift Irrigation Corporation is the State's principal agency responsible for groundwater development and management for Minor Irrigation Programmes. Rural Water Supply and Sanitation and Public Health Engineering Department are responsible for tapping the groundwater for drinking and domestic use purposes.

A Committee was constituted by the Government of Orissa with the following Organisations to estimate the groundwater potential of the State (Anonymous, 1993).

(1) C.G.W.B. ; (2) OLIC Ltd.; (3) R.W.S.S.;
(4) P.H.E.D. ; (5) Industries Department ;
(6) W.R. Department (7) Agriculture Department;
(8) O.U.A.T. ; & (9) NABARD.

The Chairman of the Committee was the Commissioner-cum-Secretary to Government, R.D. Department.

The Committee after scrutinising the data from various sources and several deliberations has worked out the potential of grundwater in Orissa as on 1.4.1992.

The salient findings were as follows :-

	As on 3/85	As on 3/92
Total Groundwater Resources	23279.22 MCM	20004.71 MCM
Utilisable resources for irrigation	19787.34 MCM	17004.00 MCM
Utilisable resources for drinking and other uses	3491.88 MCM	3000.71 MCM
Stage of Development	4.80%	8.46%
Ultimate irrigation potentials.	5402715 ha	4635087 ha

2.2.3 Resistivity surveys in undivided Cuttack District :

The first systematic attempt towards the groundwater resource evaluation in selected tracts of coastal Orissa including the study area was made in mid-seventies when a total of 55 bore deep tube-wells were constructed in parts of undivided Balasore, Cuttack and Puri District (Radhakrishna and Dutta, 1976).

The Oil and Natural Gas Commission (ONGC) carried out gravity and magnetic surveys in this region during 1965-68 (Sahid 1967-68). The ONGC has also carried out seismic studies during 1969-1974 in parts of the Mahanadi Delta area. Oil India Limited has also carried out Oil exploration programme. Based on their datas, it was revealed that the basin is composite and comprises several basement depressions and ridges (Murty et al, 1973).

National Geophysical Research Institute has carried out electrical resistivity survey in some parts of Mahanadi Delta for delineation of fresh and saline aquifers (Satapathy et al, 1976). They found out fresh aquifer supposed to be under unconfined to semi-confined conditions.

Deep drilling dawn to 600 M was carried out by CGWB in the study area (Chakladar, 1981). It was revealed that fresh water and saline water relationship does not follow a fixed trend in the area. Two reversal in hydrochemical profile have been noticed here. First reversal takes place between Manijanga, Ersama tract and Arilo Machagaon tract of Jagatsinghpur District, where occurrence of saline water at the top charges to occurrence of fresh water at the top.

An exhaustive groundwater exploration-cum-tube-well implementation programme was carried out by the Davish International Development Agency (DANIDA) in colaboration with the State Government in the coastal blocks of the State from 1985. It was also included the study area. DANIDA has explored 35 different blocks of the State (Anonymous,१९८९).

2.2.4 Electrical logging :

Electrical logging was done in deep tubewells in particular when resistivity value is very low of the

National Geophysical Research Institute has carried out electrical resistivity survey in some parts of Mahanadi Delta for delineation of fresh and saline aquifers (Satapathy et al, 1976). They found out fresh aquifer supposed to be under unconfined to semi-confined conditions.

Deep drilling dawn to 600 M was carried out by CGWB in the study area (Chakladar, 1981). It was revealed that fresh water and saline water relationship does not follow a fixed trend in the area. Two reversal in hydrochemical profile have been noticed here. First reversal takes place between Manijanga, Ersama tract and Arilo Machagaon tract of Jagatsinghpur District, where occurrence of saline water at the top charges to occurrence of fresh water at the top.

An exhaustive groundwater exploration-cum-tubewell implementation programme was carried out by the Davish International Development Agency (DANIDA) in colaboration with the State Government in the coastal blocks of the State from 1985. It was also included the study area. DANIDA has explored 35 different blocks of the State (Anonymous,1989).

2.2.4 Electrical logging :

Electrical logging was done in deep tubewells in particular when resistivity value is very low of the order of 1.5 to 2 ohm-m. shows deterioration in quality of water. Once the resistivity values are caliberated with clay content, water quality and formation temperature, the salinity stratification or iso-conductivity depth section could also be prepared (Lusczynski and Ssarzenski, 1966).

According to Swain and Kanungo (1987) in coastal Orissa and in the study area revealed occurrence of saline water both above and below the fresh water.

2.3 Quality of groundwater :

On the basis of total salt concentration and soluable sodium percentage Scofield (1936) and Wilcox (1948) classified the groundwater. Kelly et al (1940) suggested that the ratio of sodium to other cations (Ca^{++} and Mg^{++}) should not exceed one for good water. Cossidy (1949) proposed index 'F' (figures of merit) calculated by the ratio $(Ca^{++} + Mg^{++})/(Na^{+} + K^{+})$ in groundwater. A value of 0.5 or less was suggested for water of good quality.

U.S. Salinity Laboratory (USSL) staff (1954) proposed a two-way diagram for determining the suitability of water for irrigation purpose on the basis of electrical conductivity and sodium adsorption ratio (SAR), which is widely used as it covers both salinity and alkalinity hazards.

Duran (1955) in Algeria, Wileox (1958) in USA, Kanwar (1961) and Ramamoorthy (1964) in India modified the classification as given by USSL, keeping in mind the more salt concentration in well water and its tolerance by crops.

Water possess no inherent quality except for some extremal condition. It is independent of the condition under which is to be used, suggested by Bernstech (1967). Therefore, water quality can be evaluated only in the context of a specified set of conditions including soil properties, irrigation management, climate and crops.

Irrigation suitability be evaluated on the basis of its potential of creating soil conditions hazardous to crop growth suggested by Rhoodes (1972). He, further, concluded that water of a specific quality may be suitable under one set of condition but unsuitable for another.

2.3.1 Groundwater quality in coastal aquifer :

Existence of salinity hazards in coastal aquifer is not uniformity distributed in the groundwater systems, (Radhakrishna and Dutta, 1976).

The major features of coastal aquifers may be briefly catagorised as in the following manner (Karamtha, 1987; Handa, 1989).

i) Fresh water laterally grades into saline water either under water table or under semi-confined to combined condition.

ii) Saline water underlies trash water in a homogeneous and isotropic medium under water table conditions.

iii) Saline water underlies fresh water, the two aquifers being separated by a semi-pervious or impervious layer.

iv) Saline water overlies fresh water, the two zones being separated by a semipervious or impervious layer.

v) Saline water percolates from the intermediate zone into the fresh water aquifer.

2.4 Salinity map :

Sub-surface information and borehold geophysical profiles have provided certain degree of information which has permitted construction of an apparent picture of the occurrence and disposition of the saline ground water bodies in the coastal tracts, (Radhakrishna and Dutta, 1976). It revealed from the study that in the outfall regions of the Baitarani, Brahmani and Mahanadi river system, the uper saline groundwater body seems to have transversed for inland from the sea coast.

2.5 Closure of Review :

Relevant geophysical investigations carried out in different parts of coastal tracts of Orissa for assessment of good quality groundwater have been reviewed in the foregoing pages. From the above reviews, it is seen that geophysical approach is the best method for assessment of good quality groundwater in coastal areas. Thus, keeping in view, the chance of occurrence of quality groundwater in coastal areas, this study can find a good scope to demarcate the area abundance in fresh aquifer in Kujanga Block.

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CHAPTER-III
THEORETICAL CONSIDERATIONS

CHAPTER - 3

THEORETICAL CONSIDERATIONS.

Theoretical consideration is needed for exploration of the groundwater. There are several methods for identification of groundwater aquifers.Geophysical method is the most suitable and dependable method for identification of an aquifer. Geophysical methods are classified into two groups i.e., surface methods and sub-surface methods. Surface methods can be gravity and magnetic methods, seismic methods or electrical and electromagnetic methods. Sub_surface method is by well logging method. Electrical resistivity method is the most suitable method for identification of groundwater aquifer. Guidelines for getting different results and the interpretation of electrical survey data for assessment of quality groundwater are discussed in this Chapter.

3.1 Groundwater Exploration :

Groundwater exploration can be made through different stages like ;

1. Reconnaissance stage
2. Prospecting stage
3. Development stage

3.1.1 Reconnaissance stage :

At this stage a geological map of the concerned area is prepared through geological investigation.

If possible mapping of watertable and aquifers are made. Suitable geophysical method is adopted for the area knowing its hydrological situations, existing rock type and mode of occurrence of the aquifer.

3.1.2 Prospecting stage :

In this sense geophysical data collecting and interpretation are carried out. Correlation between the prevailing data and lithology and geological section is developed at this stage.

3.1.3 Development stage :

On completion of the surface geological and geophysical studies a lithological section is prepared after correlation.

3.2 Methods of Investigation :

A third dimension to geological map is to be provided by meaningful interpretation of geophysical anomalies measured through scientific instruments. These anomalies are caused due to changes in the physical properties of rocks below the surface of the earth either in lateral or vertical directions. Characteristics of various physical fields are governed by properties of the medium they permeate as well as the properties of source they generate.

The most highly variable of all the physical properties of minerals and rocks is electrical conductivity (Electrical resistivity^{-1}). Near the surface and for deep seated rocks give large spectrum of resistivity values (10^{-2} to 10^{16} ohm-m). Geoelectrical methods should be used to exploit this large range of resistivity variation for mapping subsurface geological structure. Geoelectrical methods can be broadly divided into two groups on the basis of source of current excitation viz. resistivity method (d.c. source) and electro-magnetic method (A.C. source).

3.2.1 Resistivity method (Surface investigation method) :

Of all the electrical methods, the direct current resistivity method is probably the simplest to manipulate and certainly simplest to understand. This method is largely used in hydrogeology. The surface geoelectrical measurements are used for the exploration of groundwater as well as in estimating the aquifer parameters.

The resistivity of a water bearing rock decreases with increasing water content. Mathematically, resistivity can be defined as the resistance of the unit cube of the material and expressed is in ohm-m. 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. The texture of rock also has some effect on the resistivity.

Porespace must be interconnected and filled with water in order that a rock may conduct electricity. It has been observed that resistivity varies approximately as the inverse square of the porosity when the rock is fully saturated with water.

This observation leads to an emperical function relating resistivity and porosity which is known as Archie's law. (

$$\rho = a \rho_w \phi^{-M} \qquad 3.1$$

Where, ρ - Bulk resistivity of the rock

ρ_w - Resistivity of the saturating water

ϕ - Porosity expressed as a fraction per unit volume of rock

a & m - Parameters whose values are assigned arbitrarily to make the equation fit for a particular group of measurements.

The value for the parameter a varies from slightly less than 1 for rocks with intergranular porosity to slightly more than 1 for rocks with joints porosity.

The exponent M is somewhat larger than 2 for cemented and well sorted granular rocks and somewhat less than 2 for poorly sorted and poorly cemented granular rocks.

For ordinary practical purposes the value of a. and m.are taken as 1 and 2 respectively.

Extreme ranges in temperature may affect the resistivity, of a waterbearing rock markedly, particularly if the temperature is high enough to drive water from the rock as steam or low enough to freeze the water in pores of a rock. At moderate temperatures, a change in temperature changes the conductivity of a rock only in so far the conductivity of the electrolytes increases with increasing temperature since the viscosity of the water is decreased in turn increasing the mobility of the irons. The dependence of resistivity on temperature for eitheran electrolyte or as rock saturated with an electrolyte is given by equation.

$$\rho_t = \frac{\rho_{18^\circ}}{1 + \alpha_t (t - 18^\circ)} \qquad 3.2$$

where ρ_{18° is the resistivity measured at a reference ambient temperature of $18^\circ C$ (any other reference ambient temperature may be used).

α is the temperature co-efficient of resistivity which has a value of about $0.025^\circ C$ for most electrolytes. Temperature within the first few miles of the earth's crust rise gradually with depth at a rate of about $0.5^\circ C/30$ m. in sedimentary rocks and about $0.2^\circ C/30$ m. in igneous rocks. Temperature at a depth of 2,400 m. in sedimentary rocks will be about 40^{o} higher than the temperature at the surface and this difference in temperatures means the rock at a depth of 2,400 m. has a resistivity only half as large as that which the same rock would have at the surface. At depth of 4,500 m. to 6,000 m. in sedimentary rocks the temperature may be 100 to 150^{o}C with rock resistivity being quarter or less of the value at the surface temperature.

3.2.1.1 Measurement :

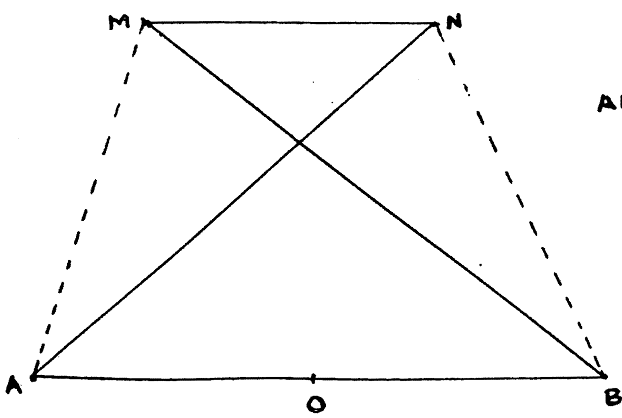
The D.C. resistivity method consists, in the use of two pieces of apparatus ; One, a source of electric current and the other, a device for measuring potential differences. Each is connected to a pair of electrodes. When the current electrode is inserted into the ground a stationary current field is established, and because of the potential drop, an electrical potential field is created also. This field can be distorted by sub-surface zones of anomalous conductivity and the object is to search for such anomalies in the electrical field with the pair of potential probes. It is always assumed that the current flow in the potential measuring circuit is negligible in comparison with the current flow in the ground, so that the potential electrodes themselves will have no disturbing effect upon the electric field.

The deployment of the current and potential electrodes will depend entirely upon the type of problem confronted. Broadly speaking there are two major categories, which one distinguishes as "Vertical Drilling" and horizontal (profiling) exploration problems. The first applied to situations in which the rocks tend to lie in flat and fairly uniform beds, such as are found in relatively undisturbed sedimentary basins. Here, the object is to be sound the depth of strata by expanding the electrode configuration about a fixed location and observing the changes in the potentials.

Figure No.   is an arbitrary four electrode arrangement with A and B as current electrodes and M and N as measuring electrodes. Since potential is a scalar quantity, it can be added or substracted algebrically.

Thus, the potential difference between point M and N can be written as

$$\Delta U = \frac{I\rho}{2\pi}\left[\frac{1}{AM} - \frac{1}{BM} - \frac{1}{AN} - \frac{1}{BN}\right].$$



$AM = r_1$; $BM = r_2$; $AN = r_3$; $BN = r_4$

Fig-3.1. General Four Electrode array. A, B Point Source And Sink. M, N measuring points on the earth surface

A predetermined arrangement of electrode positions are popular as a particular electrode configuration. The more commonly used configuration for resistivity sounding are (i) symmetrical arrangement and (ii) dipole arrangement. In symmetrical arrangement the four electrodes are placed in a straight line and effective current and measuring electrodes are symmetrically placed with reference to the sounding point. More commonly used symmetrical arrays are Wenner (AM = MN = NB = a) and Schlumberger array (AB = 2S, MN = 2b, b $\leqslant$ S/5). The apparent resistivity can be calculated using the formula

$$\rho_a = K_g \frac{\Delta U}{I}$$

Where; $\frac{\Delta U}{I}$ is the measured resistance

Kg. is the geometrical factor for a particular electrode configuration.

The value of Kg is given as follows.

Wenner = $Kg_w = 2\pi a$

Schlumberger = Kgs = $\frac{\pi}{2b}$ (S + b) (S - b)

3.2.1.2 Interpretation of resistivity data :

The whole operation of adducing a picture of geology at depth from surface resistivity measurements forms the domain of interpretation. This is achieved in two distinct steps. The first step which is closely controlled by well established physical and mathematical laws is to identify the resistivity anomaly curve in terms of geoelectrical model parameters. This step is known as quantitative interpretation or geophysical interpretation. The second step consists of translation of geophysics into geology is known as geological interpretation or qualitative interpretation and is perfected through direct contact with rêal situations.

3.2.1.3 Quantitative interpretation :

The objective of quantitative interpretation of resistivity sounding data is to determine the true resistivities and thickness of subsurface layers purely on theoretical considerations. The interpretation is done from field curve. The field curve is compared with the theoretical curve or graphical curves having suitable chosen parameters. When the field curves perfectly coincide with theoretical curves, the values of the field parameters are the same as those of the geoelectrical section for which the theoretical or graphs have been constructed. But, it is next to impossible to have an album of theoretical curves representing all geological conditions met in the field. So different type of field curves have been interpretated by available match curves by following methods.

(a) **Interpretation of two layer curves :**

The layer VES field curves may be of two types ; $\rho_2 > \rho_1$

and $\rho_2 < \rho_1$

The following procedure may be adopted for interpretation. (i) The field curve is plotted on a bi-logarithmic transparent graph sheet with a modulus of 62.5 mm with apparent resistivity (ρ) on the orinate and AB/2 along the abscissa.

The field curve is superposed on the sets of two layer master curves and the curve is shifted keeping the axes parallel to the coordinate system until a good match is obtained.

The coordinates of the origin of the master curves read on the field curve gives the value of ρ_1 and h_1. The value of $\mu_2 = \rho_2/\rho_1$ is read from the theoretical curve and ρ_2 is calculated. It should be remembered that for a finely layered sedimentary section. ρ_1 and ρ_2 represent the mean resistivities of the top and the bottom layers. If no match is obtained, interpolation on logarithm scale is necessary.

(b) **Interpretation of three-layer curves :**

Interpretation of three-layer VES field curves can be achieved with the help of available two and three-layer master curves and the auxiliary point charts.

(i) After completion of the curves, matching of the left hand part of the curve is done by superposing the field curve on the set of two layer master curves, keeping the axes parallel to the coordinates. The coordinates of the origin of the mastercurve, as read on the field curve give ρ_1 and h_1 . From the curve on which the match is obtained, and by interpolation, if necessary, $\mu_2 = \frac{\rho_2}{\rho_1}$ can be read. Since ρ_1 is known, ρ_2 can be calculated.

(ii) Matching of the curves with three-layer master curves is done as per the detailed procedure.

a) Choosing of the right set of three-layer master curves from the knowledge of $\rho_1 \mu_2 = \rho_2/\rho_1$ and the most probable value of ρ_3 (Guessed at).

b) The three-layer field curve is superposed with the point (h_1, ρ_1) on the origin of the three-layer master curve set chosen and the value of $\nu_2 = h_2/h_1$ is read from the curve with which the field curve matches. To obtain ν_2, interpolation on a logorithm scale may be done, if necessary.

c) If, there is an exact match with a three-layer curve the value of ρ_3 may also be read from the asymptotic value. Thus, so far these values ρ_1, h_2, μ_2 (hence ρ_2), ρ_3 and ν_2 are obtained, and it is solved, since; $h_2 = \nu_2 \times h_1$

(iii) If, the value of ρ_3 cannot be obtained accuratelu, the following procedure using the auxiliary point charts and two layer master curves is recommended.

a) The field curve is superposed in the proper set of auxiliary point charts, with the point (h_1, ρ_1) on the origin of the chart.

b) The corresponding values of $\mu_2 = \rho_2/\rho_1$ and $\nu_2 = h_2/h_1$ with the axes parallel is read. This gives h_e and ρ_e.

c) Now, this point (h_e, ρ_e) is put on the origin of the matched with the suitable, two-layer curve, which gives ρ_3/ρ_1 since ρ_e is known, ρ_3 is calculated.

iv) If, for three-layer curve requisite parameters are not available the following principle of equivalence is applicable.

a) If, the three-layer curve for the proper value of μ_2 is not obtained, the value nearest to it, i.e. is taken.

b) The value ν_2' is obtained, after matching with three-layer curves.

c) The actual value ν_2' is obtained by the principles of equivalence, i.e. by keeping (for H - and A types) and T_2/T_1 (for K - and Q - types) constant

For H - and A type : $\nu_2/\mu_2 = \nu_2'/\mu_2'$ i.e. $\nu_2 = \nu_2'\mu_2/\mu_2'$

For K - and Q type : $\nu_2/\mu_2 = \nu_2'/\mu_2'$ i.e. $\nu_2 = \nu_2'\mu_2'/\mu_2$

These are valid, provided the corresponding values are within the limits of equivalence.

(v) When the three-layer master curves are not available and the principles of equivalence are not applicable, the following procedure-using two-layer master curves and a uniliary point charts - is recommended.

(a) The values of ρ_1, h_1 and ρ_2 are found from the two-layer master curves.

(b) The last part of the curve is matched with a two-layer master curve. Put a crossmark on the field curve. Corresponding to the origin of the set of master curves. This gives ρ_e and h_e .

(c) The point (h_1, ρ_1) is marked on the origin of the auxiliary point charts and the value $\gamma/2$ is read corresponding to the crossmark.

(d) From the knowledge of H_1, h_2 is obtained from γ_2 If, the bottom layer is a highly resistive basement, one can adopt the simplified procedure for interpretation.

(c) Interpretation of Four-layer curves :

Interpretation of four-layer field curves consists of the following procedures.

i) With the help of two-layer master curves, as in the case of three-layer interpretation, the value of ρ_1, h_1 and μ_2 are obtained.

ii) Then, with the values of ρ_1, h_1 and μ_2 noted in step and a suitable choice of ρ_3 , the value of γ_2 is obtained as in the case of the three-layer curves.

iii) From the knowledge of ρ_1, h_1, ρ_2 and h_2 , the resistivity and thickes of the reduced layer, i.e. ρ_e and h_{e_1} are obtained with the analytical formulae for the type curves or from the auxiliary point charts for corresponding type curves.

iv) **The whole curve now reduces to a three-layer curve, with parameters $\rho_{e1}, h_{e1}, \rho_3, h_3$ and ρ_4 . The interpretation now is limited to a three-layer case, with the ρ_{e1} and h_{e1} point superposed on the origin of the three-layer theoretical master curves.**

(d) **Interpretation of curves with five and more layers :**

Curves representing five or more layers can be interpreted by means of auxiliary point method together with three-types of curves. The interpretation becomes complicated when the layers are more.

2. Qualitative Interpretation :

It tells about the lithology quality of formation water and water bearing nature of the formations from test sounding data of existing bore holes, the resistivity datas are interpretated. For the purpose of correlation, the advantage is also taken to use the sub-surface information available from the electric logs in particular of those bore wells where the VES are conducted under the investigation. For interpretation of lithology, quality of formation water and water bearing nature of the formation, a list is given as a guide-line.

Table 3.1.

Resistivity in ohm-m.	Lithology
1-5	Clay/sand saturated with saline water.
4-15	Sand saturated with brackish water or clay saturated with fresh water
11-20	Sand with clay intercalations saturated.
21-50	Sand saturated with fresh water (moderate to granular aquifer).
80-150	Weathered Khondalite.
More than 300	Khondalite
More than 700	Dry sand.

N.B. : (The resistivity values are overlapping particularly between the range of 1-15 ohm-m. The resistivities in this range have some times well related with clays, next time with brackish water saturated sand and also at times with fresh water saturated clayey sands. In case of granular aquifers, resistivity increases with increasing granularity.)

CHAPTER-IV
MATERIALS AND METHODS

CHAPTER - IV

MATERIALS AND METHODS

Physiography of the Area

This chapter deals with the description of study area including its location, physiography, hydrometeorology, hydrology, geology, hydrogeology and hydrochemistry etc. This provides the fundamental guidelines for a scientific approach to the study.

4.1.1 Location and communication :

Kujanga block i.e. the study area falls in the 20°22' to 20°36' north latitude and 86°49' east longitude. The Bay of Bengal lies in the South-East side of the block. The blocks of Marsaghai, Tirtol, Marsaghai, Mahakalapada, Ersama and Tirtol are the adjacent blocks to the Kujanga Block in the North, South and East direction respectively. The State Highway connecting Cuttack to Paradeep Port passes through this block. The area is quite accessible except for some interior villages like Musadia, Boiterakuda etc. which is difficult to approach during rainy season.

4.1.2 Geomorphology :

Geomorphology deals with physiography, drainage, soil and land use of the study area, which is summarised below.

4.1.2.1 Physiography :

The study area has generally flat topography and falls in the east and the south-eastern coastal plain zone of the State. It forms part of the delta portion of the Mahanadi delta system. This is a coastal tract which is sub-divided into; (a) The narrow saline marshy tract running parallel to the coast with an average width range of 3-10 km. and dissected by creeks and sand bars; (b) The intermediary belt between the narrow marshy land and the undulating upland with a 30 km. width range.

4.1.2.2 Drainage :

Mahanadi is the major river to drain out in the rainy season of the study area. This is an effluent type of discharge. The river in the downstream portion is confluence with the sea becomes tidal rendering the water saline in some places and thereby making it unfit for domestic use and irrigation. Taladanda canal also helps in reducing inland water conjestion. Budhanai and Chandpur nala etc. also help in clearing the water.

4.1.2.3 Soil :

Two type of soils are found in the study area.

They are Aridsols and entisols.

Aridsols are saline and saline alkali soils found along the coast. These soils are rich in calcium magnesium and also contain organic matter. Entisols are found in Mahanadi delta. The soils are deficient in nitrogen and phosphorous and rich in potash and lime. The PH values shows alkalinity and the texture is sandy and loomy sand.

4.1.2.4 **Land use :**

The study area has table-land. It is mainly occupied by agricultural land. Along the sea coast a strip varying 1 to 2 km. width is full of forest trees like casaurine, eucalyptus, cashewnut etc.

4.1.2.5 **Cropping pattern :**

The major crop is cereal crop, rice during Kharif followed by pulses, oil seeds and vegetables in rabi. Blackgram and greengram are the main pulses. Most of the farmers are switching to groundnut crop under Oil Production Programme. Scheme.

4.1.3 **Hydrometeorology :**

Hydrometeorology includes the study of climate, rain fall, evaporation and evapotranspiration.

4.1.3.1 **Climate :**

It is a tropical monsoon climate with three marked seasons, i.e. Summer, Rainy and Winter. Rainy season begins with the arrival of south-west monsoon by mid of June and continues up to mid of October. Winter season starts from November to mid February and Summer season starts from March to mid June. The mean daily maximum temperature during heat season is $36^{oo}.0^{o}C$ and during cold season, it is $16^{o}C$. The relative humidity is 73% on an average.

4.1.3.2 **Rainfall :**

The mean annual rainfall for Kujanga is 1480 mm. with highest rainfall of 2269.5 mm. (1991) and lowest rainfall of 1052.0 mm. (1987) and about 74% of annual rainfall is received from South-West monsoon during June to September with maximum rainfall in July.

4.1.3.3 **Evaporation and evapotranspiration :**

The mean daily evaporation is assessed to range from 3.5 mm. (December) to 9.5 mm. (April). The mean annual evaporation is estimated to be of the order of 1885.00 mm., the major part of the study area is characterised by shallow groundwater level and moderately thick vegetation. So, there may be significant loss of groundwater by evapotranspiration which may vary from season to season.

4.1.4 **Hydrology :**

Hydrology is the science which deals with the occurrence, circulation and distribution of water of the earth and earth's atmosphere. A large number of different dimensions ponds are there, which is feeding through inundation and runoff from the area around. There are 1569 number of dugwells and 368 number of tubewells in the area.

4.1.5 **Geology :**

The study area forms a part of Mahanadi basin and is underlain by the coastal alluvium. Consisting of sand, gravel, clay etc. ranging in age from tertiary to recent. The sediments have been deposited under fulvial to marine environment. The thickness of the sediments are considerable. More than 3,000 meters of sediments are estimated to have been deposited in this area as revealed from the deep seismic studies for oil exploration. The general stratigraphic sequence for the area can be given as follows.

i) Recent and Sub-recent - Sanddune Alluvium
   - Sand (very fine to medium grained) brown; clay, gravels of various shades.

ii) Tertiary - Pliomiocene - Brown, yellowish brown and grey clamp, brown, gritty sandstones, gravel of ferrugenous nature.

- Miocene - Brownish yellow and grey arenacceous calcic sediments, clay, claystones, sand, sandstones.

4.1.6 **Hydrogeology :**

Groundwater occurs both under unconfined and confined conditions. The unconfined aquifer is saline in general. But fresh groundwater under unconfined condition occur over different parts of the study area. The sand dunes boardening the present sea coast contain fresh groundwater. The previous test results have revealed that the transmissivity values for the unconsolidated sand material vary from less than 10 $m^2/day^{(low)}$ to more than 150 $m^2/day^{(high)}$.

4.1.7 **Hydrochemistry and water quality :**

There is increasing degree of deterioration in water quality from inland to coast. The chemical quality of groundwater in any area depends upon the local lithology, climatic conditions including rainfall and topography and varies from place to place. pH values of shallow aquifers is 6.4 - 8.65 and of deep aquifers, it is 6.6-9 bicarborate from 5 to 468 ppm, chloride values from 14 to 307 ppm, iron content from 0.02 to

1.5 ppm, manganese content from 0.03 to 0.4 ppm calcium content from 1.5 to 7.8 ppm and sulphate content from 3 to 149 ppm. Sodium is found to vary from 22.5% to 88.7% and sodium adsorption ratio values (SAR) vary from 0.54 to 8.2.

4.2 Instrumentation :

The ABEM Terrameter SAS 300 was used for vertical electrical saunding and electrical profiling in the study area. Detailed descriptions of the instrument accessories and its use has been described in the following paragraphs.

4.2.1 Specifications of ABEM Terrameter SAS 300.

Transmitter	Selectable currents	0.2, 0.5, 1, 2, 5 10, 20 MA
	Voltage, max.	160V. (320V.P.P)
Receiver voltage measurement :	Input impedence	10 mohm, min.
	Input ranges	1, 10, 100, 500V.
	precission	+0.00001 V(IV range).
	Noise rejection	95 dB at 50-60 Hz 85 dB at 16-20 Hz
Receiver resistivity measurement	V/I ranges	10 hm 1000 hm 10 Kohm 1 Mohm
	V/I precision	0.0005 ohm (10 hm range, 20 MA, one reading).

Systemdata	Selectable cycletimes	3, 6, 7, 2, 14, 4
	Selectable total averaging period (1-64 readings)	Seconds. 3.62 - 920 sec.
	Accuracy	+2%+precision
Temperature range	Within specification operating	0. ....+60 c. - 10. ...+70 c.
Power supply		Rechargeable 12 V. battery.
Battery capacity		3,500 - 5,000 single cycle measurements per charge.
Weight		5 - 6 kg. incl. battery
Dimensions		WxLxH (105x325x300 mm.)

4.2.2 Details of Terrameter SAS 300

SAS means signal averaging system - a method in which consecutive readings are taken automatically and the results are averaged continuously.

The terrameter SAS 300 contains three main units, all housed in a single casing.

The transmitter, the receiver and the microprocessor.

Electrically isolated transmitter sends out well defined and regulated signal currents.

Receiver discriminates noise and measures voltages correlated with transmitted signal current.

Microprocessor monitors and controls operations and calculates results.

Controls :- The instrument has five controls.

1. **Signal averaging system selector ::**

This is a four position selector, which is used to choose either the signal reading mode or 4, 16 or 64 automatically averaged readings.

2. **Voltage/Resistivity range Selector :**

This is a 9 position selector consists of 4 resistance selector, 4 of voltage selector and 1 is battery check position. Resistivity ranges are 1 ohm, 100 ohms, 10 kilo ohms and 1 mega ohm and voltage ranges are 1 V., 10 V., 100 V. and 500 V. When this selector is turned to the battery check position the battery voltage is measured.

There is one ON/OFF switch.

There is a 11 position current selector, which select current for the built in transmitter (0.2 MA to 20 MA in seven steps.).

i) **Measure Push Button :**

When the measure push button is depressed, the microprocessor runs through its automatically diagnostic programme and if everything is satisfactory, the terrameter SAS 300 measurement procedure starts automatically. When measurement is complete, the SAS 300 is returned to the stand-by mode with the result on the digital display.

ii) **Terminals :**

The current electrode terminals are at right on the control pannel and the potential electrode terminals are at left. Both terminal circuits are protected by semi-conductors.

iii) **Desiccator cartridge :**

The desiccator cartridge is screwed into the lower right hand corner of the control panel to keep the circuit dry.

iv) **Display and beeper :**

A liquid crystal display presents data warning and instructions for the operator. A beeper signal is also provided which helps the operator interprete the displayed information.

4.2.3 Accessories :

Different accessories are there along with the instrument.

i) **Ni-cd battery pack :**

The instrument was provided with a rechargeable nickel-cadmium (Ni-cd) battery pack that clipped conveniently onto the bottom of the instrument.

ii) **Steel electrodes :**

Both current and potential electrodes were made of stainless steel.

iii) **Sounding cable set :**

It consists of the followings.

a) **Current cables :**

750 m. lengths of 1 mm^2 copper-wire wounded in two separate plastic reel.

b) **Potential cables :**

Two separate 50 m lengths of 1 mm^2 wire wound in parallel on a single reel which is provided with a short reel-to-instrument hook up cable.

iv) Two porous pots, copper sulphate salt packet etc. were other necessary things needed for conducting survey.

4.2.4 Operation of the instrument :

The schlumberger arrangement of electrodes were arranged in the site. For potential electrodes, porous cups filled with a saturated solution of copper sulphate were employed to inhibit electric fields from forming around them.

The SAS 300 was positioned half way between the potential electrodes (Mand N) and terminal P_1 and P_2 were connected to M and N respectively. Sounding cable set with the conductors separated at the electrode end.

The current electrodes (A & B) were connected to terminals G and C_2 respectively. The cables were run in parallel, adjacent to the SAS 300, and were arranged symmetrically with respect to the potential electrodes.

The range selector was turned to 1 ohm position and cycle selector to position 4. The current selector was turned to position 20. The power switch was made on and the measurement button was pressed.

If, everything was perfect, the measurement procedures were started automatically and when measurement was complete the result was displayed on the display screen. If, any error code appeared on display, then corresponding corrections and checkings were made by operating the instrument manually.

4.3 Electrical Resistivity :

Generally for shallow aquifer identification vertical electrical sounding (VES) was conducted employing schlumbenger configuration of electrodes. Electrodes are separated to a maximum length of 300 M.

Five numbers of VES were taken all over the Kujanga Block starting from Village Pankapala, Sandapur, Siju, Bagadia to Musadia. All the other VES datas were collected from the RWSS department covering the entire Block.

The VES were conducted deploying the Terrameter SAS 300. Steel stakes were used for current and potential electrodes and wires with markings of specified current electrode, separations wrapped on spools were used for connection of the electrodes with the Terrameter. For the potential electrodes, porous cups filled with a saturated solution of copper sulphate were sometimes employed to inhibit electric fields from forming around them.

In VES calculation of apparent resistivity and plotting was done on a bi-logarithmic graph paper on the spot. When the calculated value confirmed with the trend of the sounding curve, it was accepted as satisfactory and the electrodes were moved out.

4.4 Collection of Electrical Resistivity Field Data :

The VES data which are incorporated in this thesis work was collected from RWSS Department, Govt. of Orissa, Bhubaneswar.

The apparent resistivities (P) corresponding to different spread lengths were calculated by the formula :

$$= K.R.$$

Where ; K = Kernel function depends upon spread length

R = Resistance.

The graph taking spread lengths (AB/2) along abscissa and corresponding apparent resistivities along ordinate were plotted on the spot on transparent bi-logarthmic papers. These points were then joined by smooth curves. These curves were then used for interpretation.

The current electrode separation was 4 m., 6m., 8m. up to 100 m. potential electrode separation was 1 m. i.e. AB/2 = 4/2 m. = 2 m. and MN 1/2 = 0.5 m. interval. The corresponding apparent resistivities were obtained for each station. Then a graph was plotted taking apparent resistivities along ordinate and station number along abscissa. From this plotting, the demarcation between fresh and saline (brakish zone was determined).

4.5 Interpretation of vertical electrical sounding :

The vertical electrical sounding curves which were plotted in the field were interpreted to find out the layer parameteres including the thickness of different layers and thier corresponding resistivities.

4.6 Electrical Logging :

Electrical logging of the entire block was done in different places by DANIDA. Fourteen numbers of deep-well datas were collected for interpretation of lithology of aquifers and also quality of the aquifer.

4.7 Water quality :

Water quality of different hand pumps were obtained from RWSS Department, Govt. of Orissa. The pumps were generally used for drinking purposes. Hence, the quality data was based on only Chloride and Iron content.

4.8 Groundwater Assessment :

In recent times basin-wise evaluation of groundwater resources considered to be the most scientific of all methods has assumed lot of importance and is widely adopted for quantification of (basin-wise). Groundwater being an underground system, not amenable for direct observation, it becomes necessary to take into account certain inherent factors to compute the actual recharge.

Total groundwater recharge not only includes recharge from the rainfall that is the primary source but also contribution from surface water (surface water inflow), groundwater from adjoining basins (sub-surface inflow) recharge from canals, tanks and other surface water bodies and contribution from recycled water. It is normally assumed that similar to surface water and groundwater inflow, there will be an equal amount of surface and sub-surface outflow. Hence, in the longer run these values will not be of any practical value.

For computing the recharge from the precipitation two approaches are being adopted, which are given below.

(a) Water table fluctuation approach in which the average amount of fluctuation of water table in a particular formation is estimated. The amount of fluctuation multiplied by the areal extent or distribution of the formation and its specific yield factor will give the actual recharge.

(b) Rain fall infiltration approach in which estimation of the direct infiltration of rain fall through various litho and soil units depending upon the local geological, topographical and soil conditions is taken into account.

In both the cases there is certain amount of assumption regarding the "specific yield" and infiltration factors on the basis of data collected after studies and explorations in various parts of the country

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CHAPTER-V
RESULTS AND DISCUSSIONS

CHAPTER - V

RESULTS AND DISCUSSIONS

Vertical Electrical Sounding was done in a profile zone for assessment of good quality groundwater in Kujanga Block. Well logging data of some deep wells were also studied covering the entire block. The periodical water quality data were studied. The sustainability of the aquifers were calculated on the basis of draw down in different hand pumps, and on the basis of recharge by rain-fall. The potentiality of the aquifer was calculated on the basis of thickness and areal extent of the aquifers. The general salinity profile of the coastal aquifer of the State, of the area from Cuttack to Paradeep and so also the entire block were drawn on the basis of available datas of CGWB and RWSS Department. Existing Dug-wells data of the entire Block were collected and plotted in the block map and the relationship between fresh and saline dug-wells were studied.

5.1 Georesistivity Sounding :

Sounding means measurement of the depth. Different geological strata were measured from the ground surface by georesistive methods. It is an indirect means of measurement of different vertical layers inside the earth. Hence, it is known as vertical electrical sounding method or in short VES.

VES was carried out at 56 different stations covering the entire block. VES data were interpreted for two type of results.

i) Quantitative interpretation

ii) Qualitative interpretation

5.1.1 Results of VES (Quantitative interpretation) :

VES was conducted for identifying shallow aquifer up to a maximum depth of 50 M.

VES results interpreted quantitatively told about the layer parameters of the aquifers. The various layer parameters were resistivity of different layers and corresponding thickness. Results so obtained are presented in Table - 5.1.

The different columns of Table - 5.1 tells the following things of the underground.

Column (1) - VES number ; Column (2) - Location ; Column (3) to Column (6) - Layer parameters resistivity expressed in ohm. ; Column (7) to (9) - Thickness of the corresponding layers expressed in meter Column (10) - Remarks.

For understanding the table, one VES site namely - 1 - is explained in detail.

Column - 1 VES - 1

Column - 2 Location - Nischintokoili.

V.E.S. DATA SHEET

lage : Pankapal   Date : 15.05.95

. : Pankapal

2	MN/2 m	K	R ohm	pa ohm-m	AB/2 m	MN/2 m	K	R ohm	pa ohm-m
	0.5	5.88	2.14	12.5	30	5.0	137.37	172.5	23.69
	"	13.73	1.102	15.13	40	"	247.27	83.1	20.54
	"	38.85	524	20.35	50	"	388.5	44.3	14
	"	76.53	299	22.88	65	"	659.4	19 .3	12.72
	"	156.6	161.5	25.29	80	"	100.87	7.5	7.5
	"	264.93	107.2	28.40					
	"	508.28	56.2	28.56					
	"	830.13	33.8	28.05					
	"	1412.60	17.62	24.89					
	"	2511.60	7.88	19.79					
	"	3924.6							
	"	6632.85							
	"	10004	7.6						

V.E.S. DATA SHEET

Village : Pankapal Date : 15.05.95

G.P. : Pankapal

AB/2 m	MN/2 m	K	R ohm	pa ohm-m	AB/2 m	MN/2 m	K	R ohm	pa ohm-m
2	0.5	5.88	2.14	12.5	30	5.0	137.37	172.5	23.69
3	"	13.73	1.102	15.13	40	"	247.27	83.1	20.54
5	"	38.85	524	20.35	50	"	388.5	44.3	14
7	"	76.53	299	22.88	65	"	659.4	19 .3	12.72
10	"	15[illegible].6	161.5	25.29	80	"	100.87	7.5	7.5
13	"	264.93	107.2	28.40					
18	"	508.28	56.2	28.56					
23	"	830.13	33.8	28.05					
30	"	1412.60	17.62	24.89					
40	"	2511.60	7.88	19.79					
50	"	3924.6							
65	"	6632.85							
80	"	100047.6							

<u>V.E.S. DATA SHEET</u>

Village : Bandhapur　　　　　　　　Date : 07.06.95

G.P. : Kujanga

AB/2 m	MN/2 m	K	R ohm	pa ohm-m	AB/2 m	MN/2 m	K	R ohm	pa ohm-m
2	0.5	11.7[illegible]	[illegible]	36.05	40	50	494.8	221	109.35
3		27.49	1.39	38.21	50		777.5	2.65	2.06
4		49.48	564	27.906	60		1123.1	22.9	25.72
5		77.75	136.2	10.59	80		2002.3	1.36	2.77
6		112.3	283	31.78					
8		200.28	1.12	224.31					
10		313.37	359.	112.49					
12		451.6	278	125.54					
12	2.0	109.95	6.61	726.77					
10		75.36	7.14	538					
15		173.6	10.86	1885.29					
20		311.0	25.2	7.84					
25		488.7	9.88	4828.4					
30		703.7	53.7	8014.7					
40		1253.3	21.4	26820.6					
30	5.0	274.9	8.22	2259.6					

V.E.S. DATA SHEET

Village : Musadia   Date : 07.06.95

G.P. : Paradeepgarha

AB/2 m	MN/2 m	K	R ohm.	pa ohm-m	AB/2 m	MN/2 m	K	R ohm	pa ohm-m
2	0.5	11.78	563	6.63	25	2	488.7	4.4 3.9	2.15 1.90
3		27.49	192.9	5.30	30	"	703.7	2.5	1.75
4	"	49.48	95.5	4.72	"	5	274.9	7.9	2.17
5	"	77.75	60.1	4.67	40	2	1253.3	1.88	2.35
6	"	112.3	42.2	4.74	"	5	494.8	5.23	2.58
8	"	200.28	19.8	3.96	50	"	777.5	2.64 3.8	2.05 3.95
10	"	313.37	10.18	3.2	60	"	1123.1	1.45	1.62
12	"	451.6	5.63	2.54	80	"	2002.8	0.62	1.24
"	2	109.95	26.26	2.88	"	10	989.6		
10	"	75.36	39.6	2.98	100	"	155.51		
15	"	173.6	14.06	2.44	100	5	3133.7		
20	"	311.	8.4 8.62	2.61 2.68	120	10	2246		

V.E.S. DATA SHEET

Village : Siju　　　　　　　　　　Date : 08.06.95

G.P. : Bagadia

AB/2 m	MN/2 m	K	R ohm	pa ohm-m	AB/2 m	MN/2 m	K	R ohm	pa ohm-m
2	0.5	11.78	4.25	.05	25	2	488.7	6.17	3.015
3		27.49	.368	.01	30	"	703.7	2.28	1.604
4	"	49.48	1.85	.091	"	5	274.9	1.98	.544
5	"	77.75	3.01	.23	40	2	1253.3	2.11	2.64
6	"	112.3	1.48	.166	"	5	494.8	3.56	1.76
8	"	200.28	4.87 6.15	.975 1.23	50	"	777.5		
10	"	313.37	9.27	2.90	60	"	1123.1		
12	"	451.6			80	"	2002.8		
"	2	109.95	1.75	.192	"	10	989.6		
10	"	75.36	8.16 15.47	.614 1.165	100	"	155.51		
15	"	173.6	7.87	1.36	100	5	3133.7		
20	"	311	31.6	9.83	120	10	2246		

V.E.S. DATA SHEET

Village : Bagadia (Dalimbhpur) Date : 08.06.95

G.P. : Bagadia

AB/2 m	MN/2 m	K	R ohm	pa ohm-m	AB/2 m	MN/2 m	K	R ohm	pa ohm-m
2	0.5	11.78	253	2.98	25	2	488.7	2.23	1.09
3		27.49	106.5	2.93	30	"	703.7	1.75	1.23
4	"	49.48	57.5	2.84	"	5	274.9	4.75	1.3
5	"	77.75	33.8	2.63	40	2	1253.3	1.18	1.48
6	"	112.3	22.1	2.48	"	5	494.8	3.1	1.53
8	"	200.28	10.57	2.12	50	"	777.5	2.05	1.59
10	"	313.37	5.88	1.84	60	"	1123.1	1.41	1.58
12	"	451.6	3.5	1.58	80	"	2002.8	1.22	2.4
"	2	109.95	15.52	1.71	"	10	989.6		
10	"	75.36	25.5	1.92	100	"	155.51	1.45	.225
15	"	173.6	9.23 8.61	1.60 1.49	100	5	3133.7	.339	1.06
20	"	311	4.86	1.51	120	10	2246		

Results of V.E.S. in Kujanga Block of J.S.Pur District
(Shallow depth)

V.E.S. No.	Location	Layer Parameters Resistivity P_1	P_2	P_3	P_4	Thickness in mt h_1	h_2	h_3	Remarks
1	2	3	4	5	6	7	8	9	10
1.	Nischintakoili	12	4	24	Low	0.75	6.0	13	Fresh down to 20 mt.
2.	-do-	2.5	4.25	7.5	-	1.7	42.5	-	No fresh water
3.	Pankapal	4.6	46	4.6	-	0.75	12	-	Fresh down to 12.75 mt.
4.	-do-	15	90	3.75	-	1.6	6.4	-	Fresh down to 8.0 mt.
5.	-do-	5.8	34.8	5.8	-	2.7	21	-	Fresh down to 23 mt.
6.	-do-	4.4	6.6	88	-	0.8	4.8	-	Could not interpretated.
7.	Lathanga	-	-	-	-	-	-	-	No fresh zone
8.	-do-	5.4	3.6	4.8	-	1.8	7.2	-	Brackish to saline.
9.	Sailo	22	7.3	4.4	-	0.5	12.5	-	Brackish up to 12.0 mts.
10.	Totapada	-	-	-	-	-	-	-	Saline zone.
11.	Badapal	75	7.5	1.9	-	1.9	7.4	-	Brackish up to 9 mt.
12.	-do-	8	27	24	1.4	1.0	1.0	18	Fresh down to 18 mt.
13.	-do-	6	2	12	4	2.1	2.1	12.6	Fresh up to 17.0 mt.
14.	Naliapal	3.3	2.2	1.1	-	2.7	16.2	-	Saline
15.	Kothamula	-	-	-	-	-	-	-	No fresh zone.
16.	Gaurapada	17	8.5	51	2.13	0.4	3.6	9.6	Fresh down to 15 mt.
17.	Agpala	16	96	2.67	-	0.6	7.2	-	Fresh down to 8.0 mt.
18.	Mallasahi	3.8	3.8	38	3.8	2	1	16	Fresh down to 19 mts.
19.	Balarampur	-	-	-	-	-	-	-	Could not interpreted.
20.	-do-	4.8	72	1.2	-	1.5	9.0	-	Fresh down to 10.5 mt.
21.	-do-	2.3	57.5	2.3	-	0.65	10.4	-	Fresh down to 11 mt.
22.	Bagoi(Dandasahi)	2.2	2.2	5.5	-	1.8	7.2	-	Saline up to 9 m.

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
24.	Bagoi(Dandasahi)	-	-	-	-	-	-	-	Could not interpreted (may be fresh)
25.	Duadia	7	70	7	-	0.55	2.25	-	Interpretation incomplete.
26.	Balarampur (Bandhasahi)	4	40	2.0	-	0.95	9.25	-	Fresh down to 10 m.
27.	Banikunda Dhia Sahi	5	2	10	-	1.3	20.8	-	Saline
28.	Arakhia	20	30	10	-	1.9	16.1	-	Fresh down to 18 mt.
29.	Balia	6.8	40.8	6.8	-	2.1	25.2	-	Fresh down to 27 m.
30.	Tentaikuda	80	8	78	2.2	2.3	2.3	13.8	Fresh down to 18 mt.
31.	Santara	16	24	2.7	-	1.8	21.6	-	Fresh down to 23 mt.
32.	Bagoi (Baunsapara)	8	48	8	-	1.8	14.4	-	Fresh down to 16 mt.
33.	Borikhi (Telepatna)	10	150	Low	-	2.2	13.2	-	Fresh down to 15 mt.
34.	Ranipada	6.8	40.8	1.7	-	3	3.6	-	Fresh down to 39 mts.
35.	Pathuria	2.2	7.14	14.3	-	2	36	-	Brackish to saline.
36.	Paramanandapur	-	-	-	-	-	-	-	May be brackish.
37.	Borikhi (Upper pada)	18.5	1.85	18.5	-	3.4	3.4	-	30 mt. may be fresh
38.	Repur	4.4	2.2	4.4	-	0.2	9.6	-	Not promising.
39.	Pahana	-	-	-	-	-	-	-	Not interpreted.
40.	Repurpatna	-	-	-	-	-	-	-	-do-
41.	Raigaon	11	22	0.66	-	5.5	22	-	Saline below 5.5 m.
42.	Kothi	8	12	2	-	2	12	-	Fresh down to 14.0 mt.
43.	Patapur	11	110	5.5	-	2.1	12.6	-	Fresh down to 14.7 m.
44.	Kothi	5.6	56	.56	-	2	4	-	Fresh down to 6.0 mt.
45.	Paikasta	9.5	28.5	0.95	-	2.3	13.8	-	Fresh down to 16 mt.

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
46.	Balidia	13	2.6	0.9	-	3	24	-	Saline below 3.0 m.
47.	Balidia	21	6.9	1.4	-	5.5	33	-	Fresh down to 5.5 mt. to 39 mts.
48.	Pipala	4.4	8.8	1.1	-	2.2	13.2	-	Fresh down to 15 mts.
49.	Kothada (Thakurdia)	30	20	Low	-	1.2	14.4	-	Fresh down to 15 mts.
50.	Koladia	65	97.5	Low	-	1.25	7.5	-	Fresh down to 9.0 mts.
51.	Pitambarpur	2	4	0.5	-	2.3	18.4	-	Brackish to saline.
52.	Kothda	5.5	2.75	0.9	-	0.9	18	-	Saline below 1.0 mt.
53.	Sandhapur	3.5	1.75	9.0	25.0	1.3	32.5	130	Brackish to fresh for 60 to 135 m.
54.	Siji	-	-	-	-	-	-	-	Proper curve is not available.
55.	Lagadia (Dalimbapur)	12	2.4	1.2	-	1	3	-	Saline
56.	Musadia	7.25	2.4	0.51	-	1.8	36	-	Saline

Column - 3, 4, 5, 6 - Layer parameters i.e.

Column 3-P_1 - 1st layer - Resistivity - 12 ohm.m.

Column 4-P_2 - 2nd layer - " - 4 ohm.m

Column 5-P_3 - 3rd layer - " - 24 ohm.m

Column 6-P_4 - 4th layer - " - Low

Column 7 to 9 - Thickness in m.

Column 7 - Thickness of 1st layer i.e. 0.75 m.

Column 8 - Thickness of 2nd layer i.e. 0.60 m.

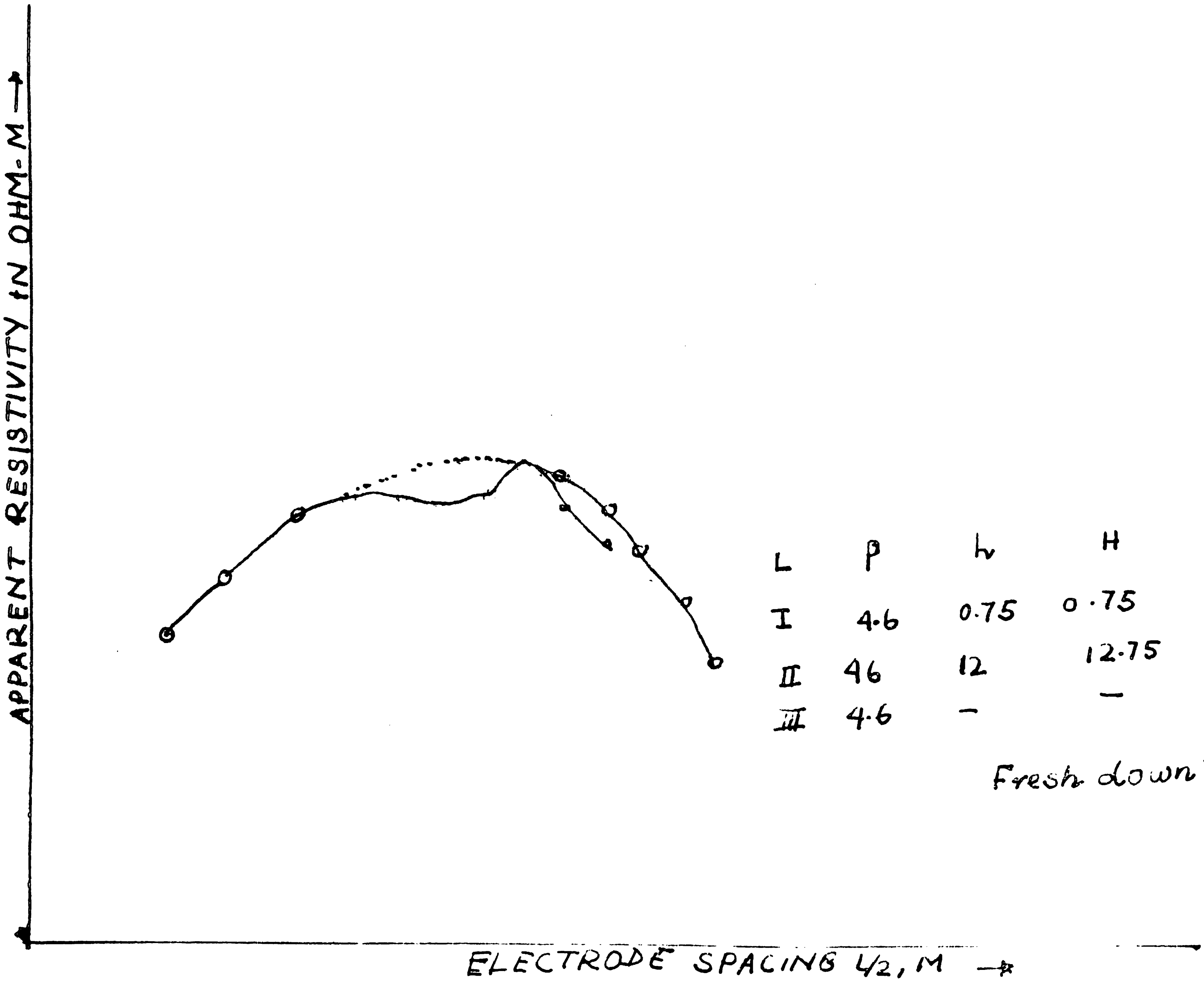
Column 9 - Thickness of 3rd layer i.e. 13 m.

These quantitative interpretation of shallow aquifer lead to qualitative results.

5.1.2 Qualitative interpretation :

VES results interpreted qualitatively tell about the nature of land surface, depth to fresh aquifer, thickness of fresh aquifer, protecting capacity etc. The resistivity of land surface (P_1) tells about the nature of surface layer. This interpretation was supported by visual observation of top soil at VES sites. When resistivity of a layer is more than 200 hm.m. the layer is assumed to be a sandy aquifer saturated with fresh water. Thus, the fresh aquifer is determined from resistivity value of different layers. The qualitative interpreted results of shallow VES including depth to fresh aquifer, thickness of fresh aquifer, nature of surface layer, protecting capacity and depth

VES MAP OF VILLAGE PANKAPAL
GP. PANKAPAL



L	ρ	h	H
I	4.6	0.75	0.75
II	46	12	12.75
III	4.6	—	—

Fresh down to 12.75m.

FIGNO 54

VES MAP OF VILLAGE SANDAPUR, G.P. MALASAHI

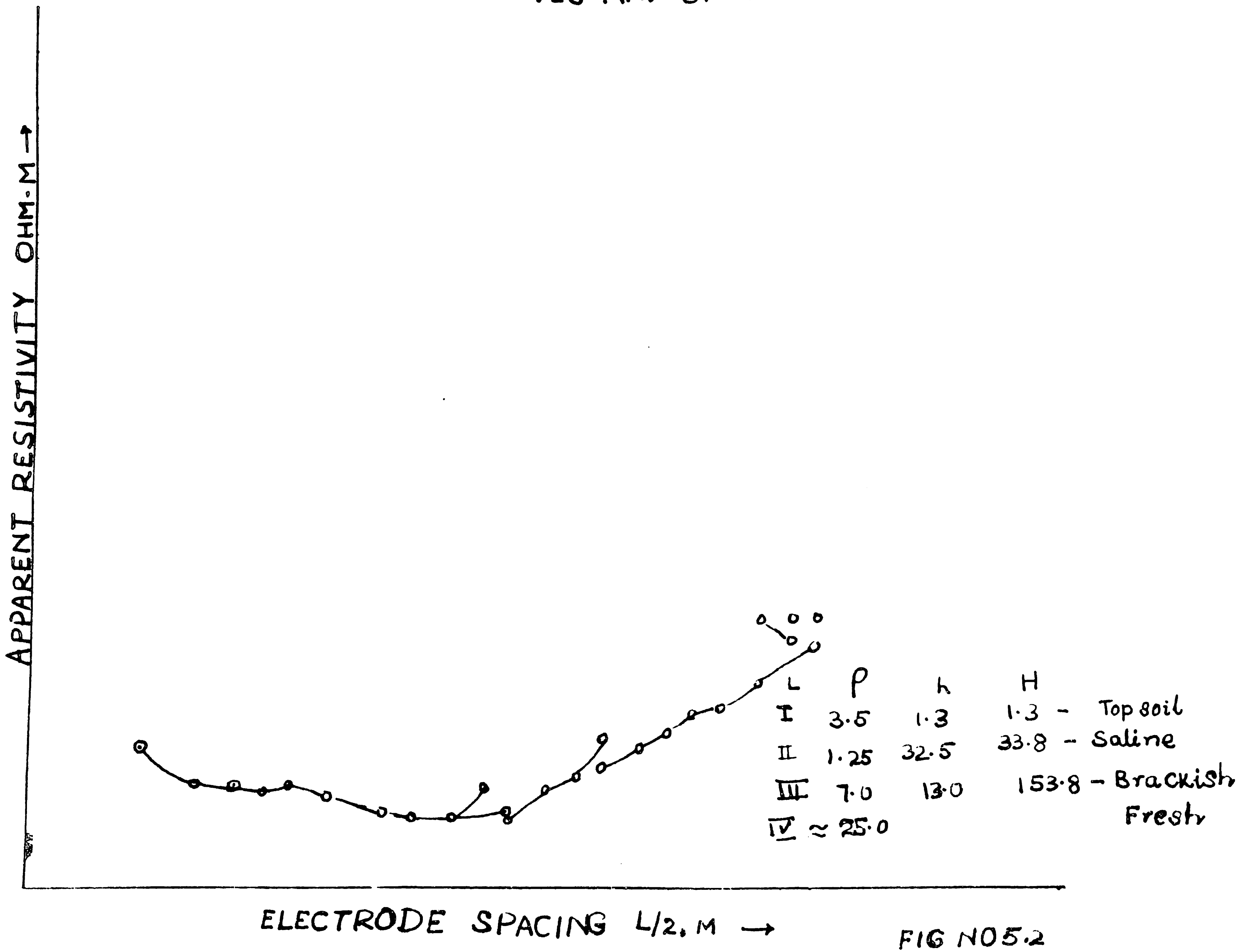


FIG NO 5.2

VES MAP OF VILLAGE MUSADIA
GP PARADEEPGARH

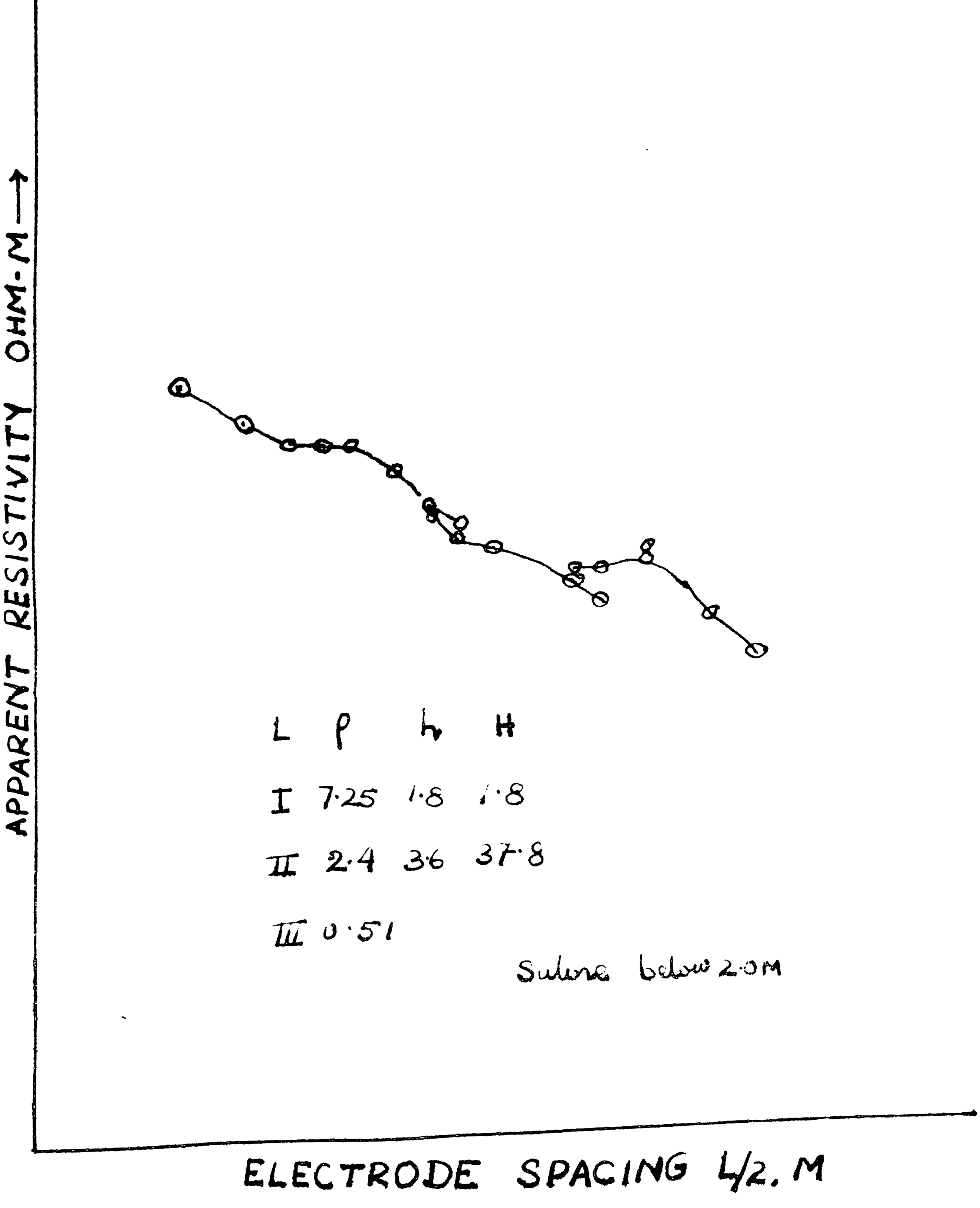


FIG No 5.3

VES MAP OF VILLAGE SIJU
G.P. BAGADIA

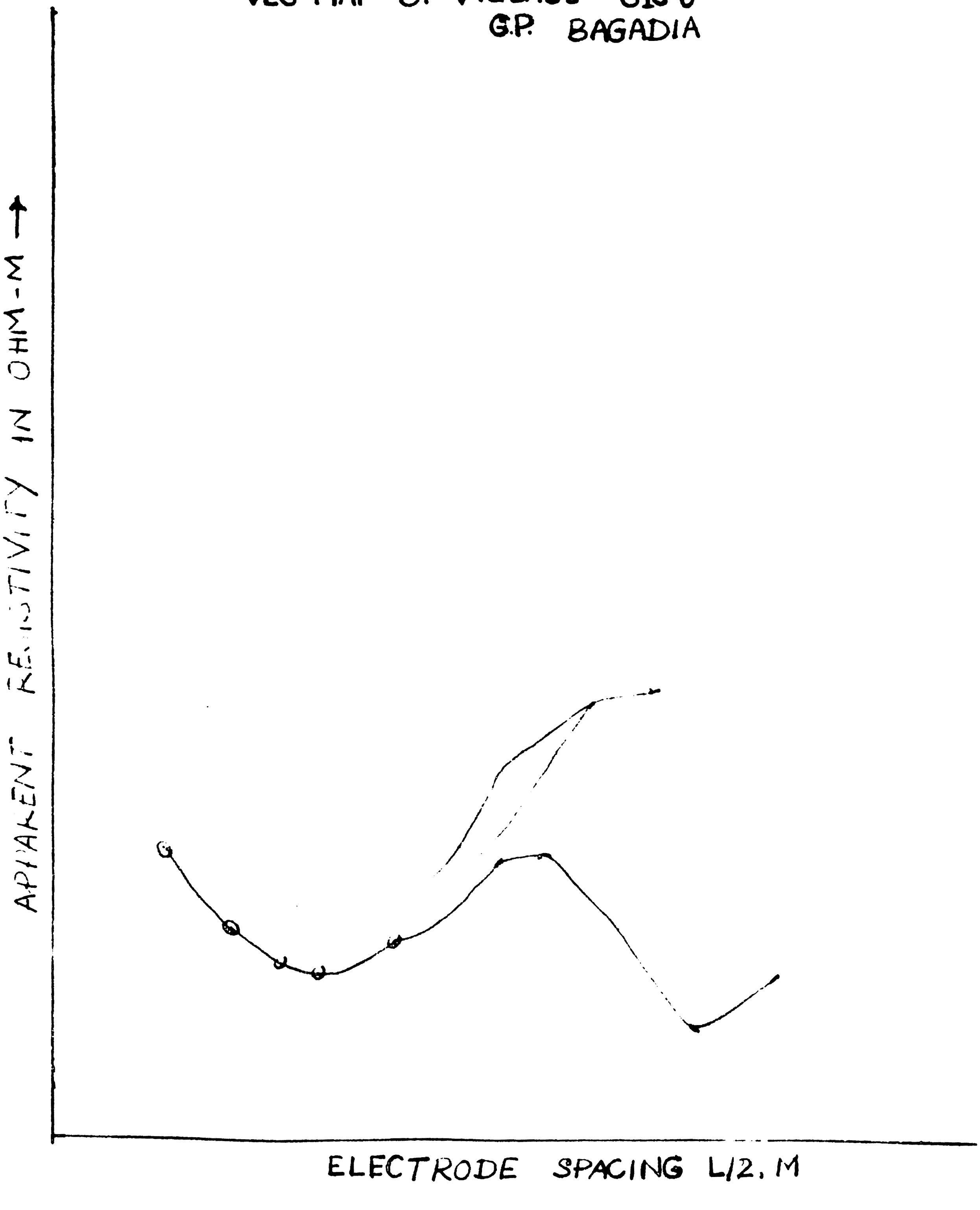


FIG NO 5.4

to watertable are given in Table - 6.2. For example, at Nischintokoili Village, the 1st layer the thickness is 0.75 m. having resistivity of 12 ohm.m. means the layer is clay saturated with fresh water. The 2nd layer i.e. (6 + 0.75) m. up to below ground level contains sand saturated with brakish water as per the resistivity of 4 ohm.m. The 3rd layer, i.e. (6 m. + 0.75 m. + 13 m.) + 9.75 m. or say 20 m., the aquifer is fresh, i.e. sand saturated with fresh water and the aquifer tends to be moderate to granular aquifer.

5.2 Electrical Logging Results :

Electrical logging was done in many test deep drilling holes in the study area to know the complete lithology of the underground. Fourteen numbers of electrical logging curves covering the entire study area are incorporated in this study.

In the curves, it has been indicated the name of Village, Gram Panchayat, diameter of the well, type of resistivity i.e. mud resistivity temperature reading has been indicated for interpretation, specially in Millivolt, 'N' resistivity in ohm.ft. and the lithology. In x-axis - 1 cm. = 20 mv. and in other - 1 cm. = 10 ohm.ft. and in y-axis 1 cm. - 10 m. scale has been adopted.

ELECTRIC LOG

VILLAGE PANKAPAL

GA - PANKAPAL

DIA- 4½"

MUD Resistivity 6.4 Ωm at 27°c

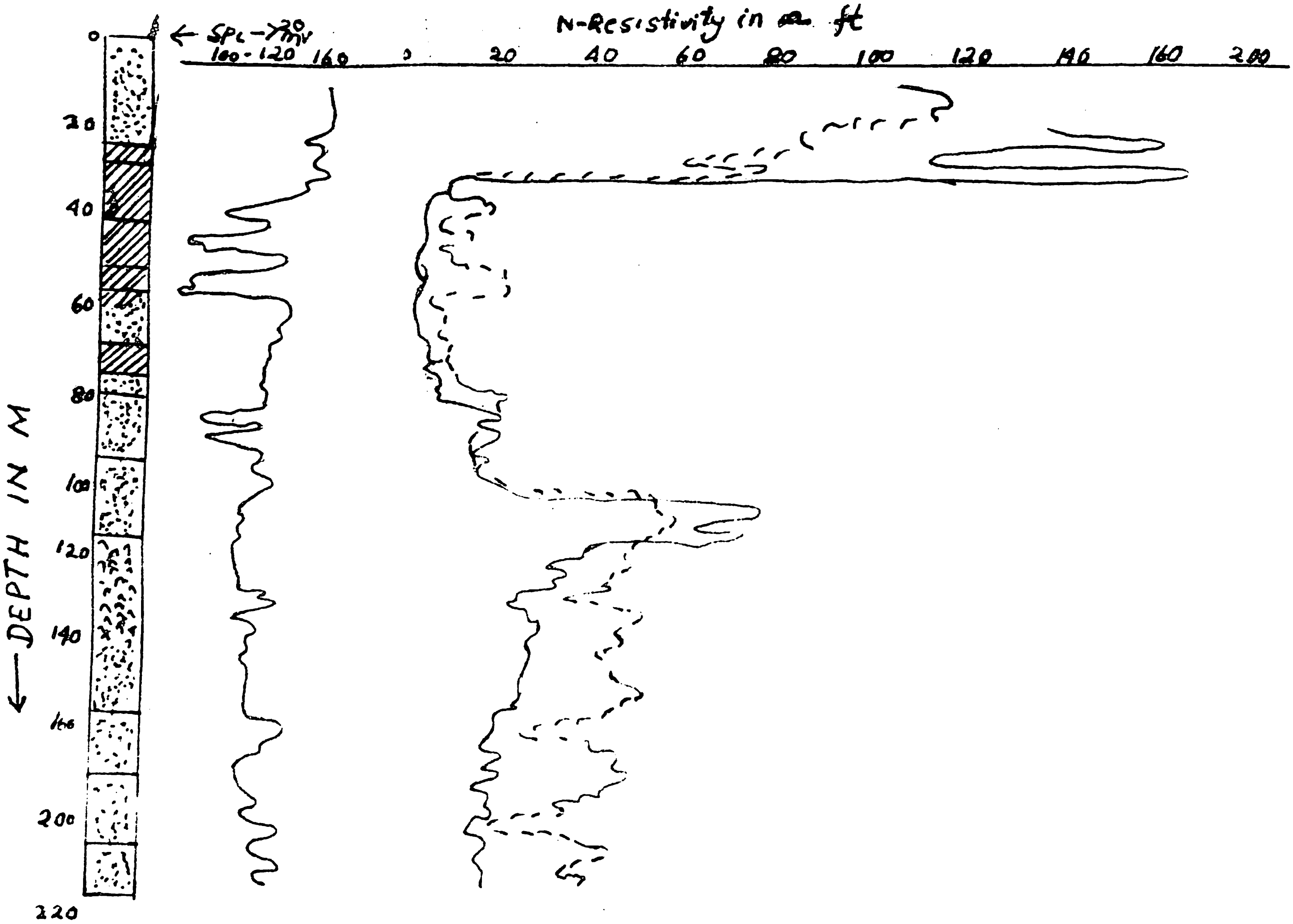
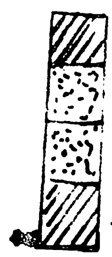


FIG NO - 5.6



ELECTRIC LOG

VILLAGE GOBARDHANPUR
GP TANSURA

DIA - 4½"
MUD RES - 8 ohm at 26°C

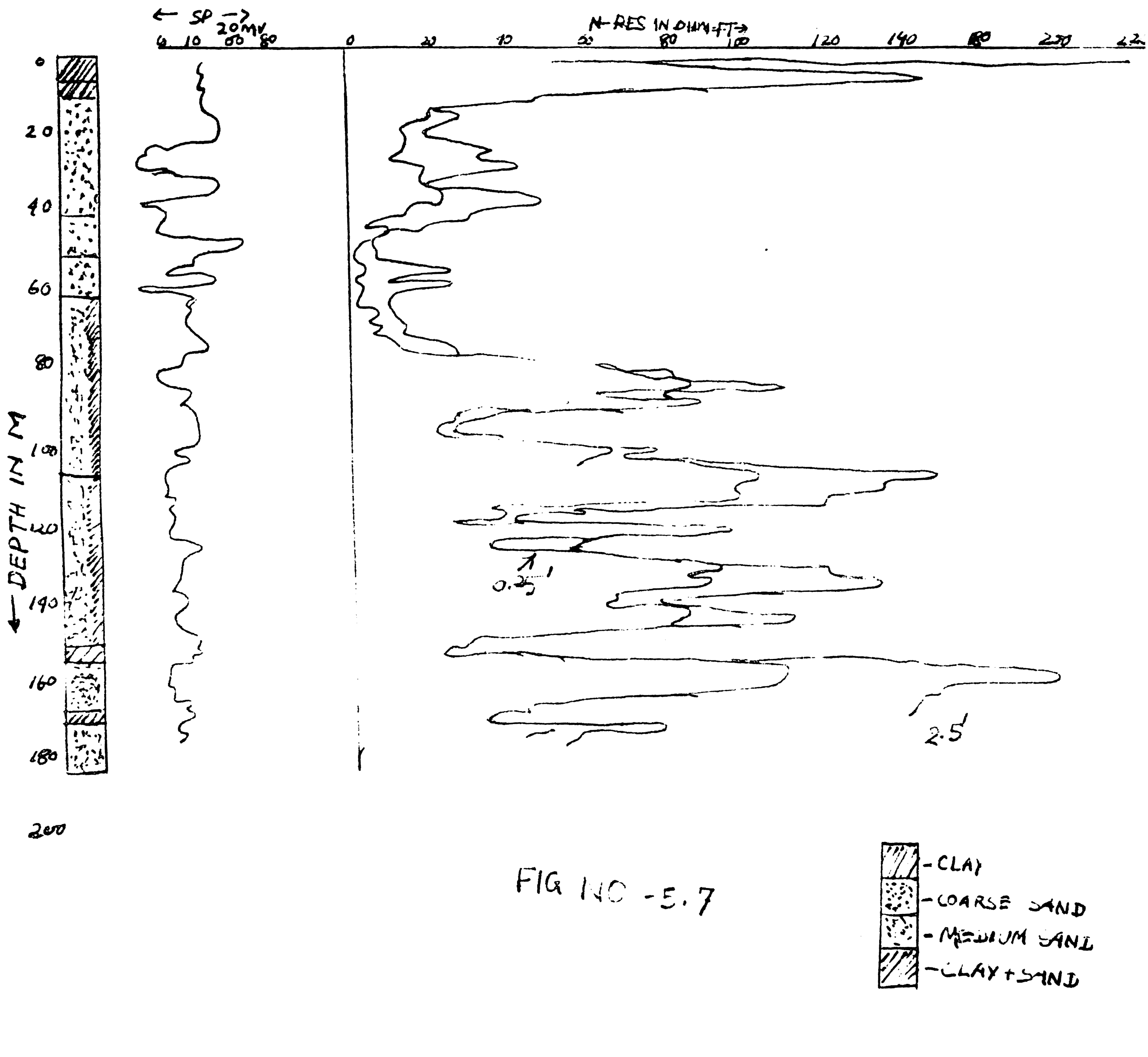


FIG NO - 5.7

VILLAGE GHODAMARA

ELECTRIC LOG

GP - GHODAMARA DIA - 4"

MUDRESISTIVITY 8 ohm at 98°F

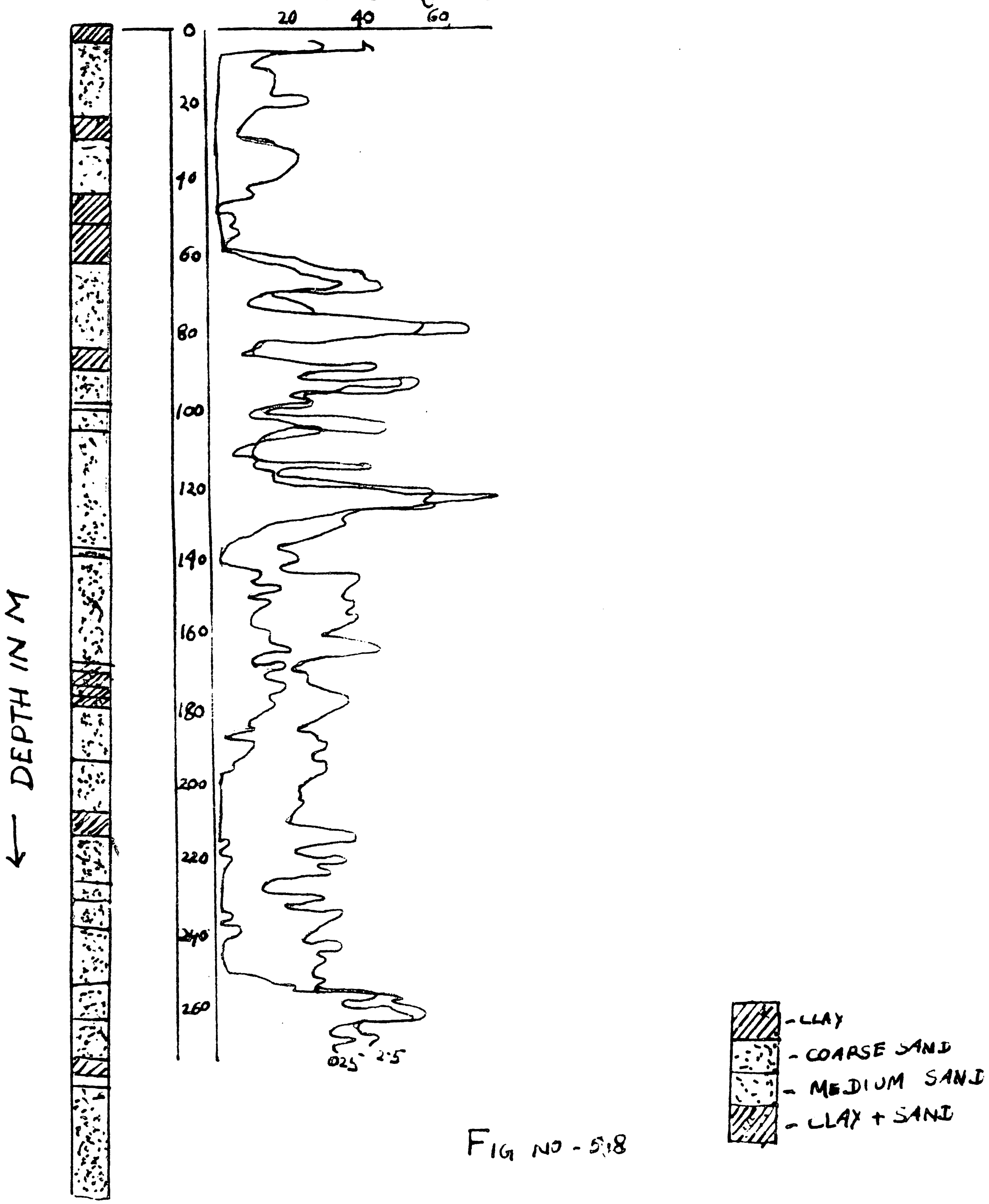


FIG NO - 5.8

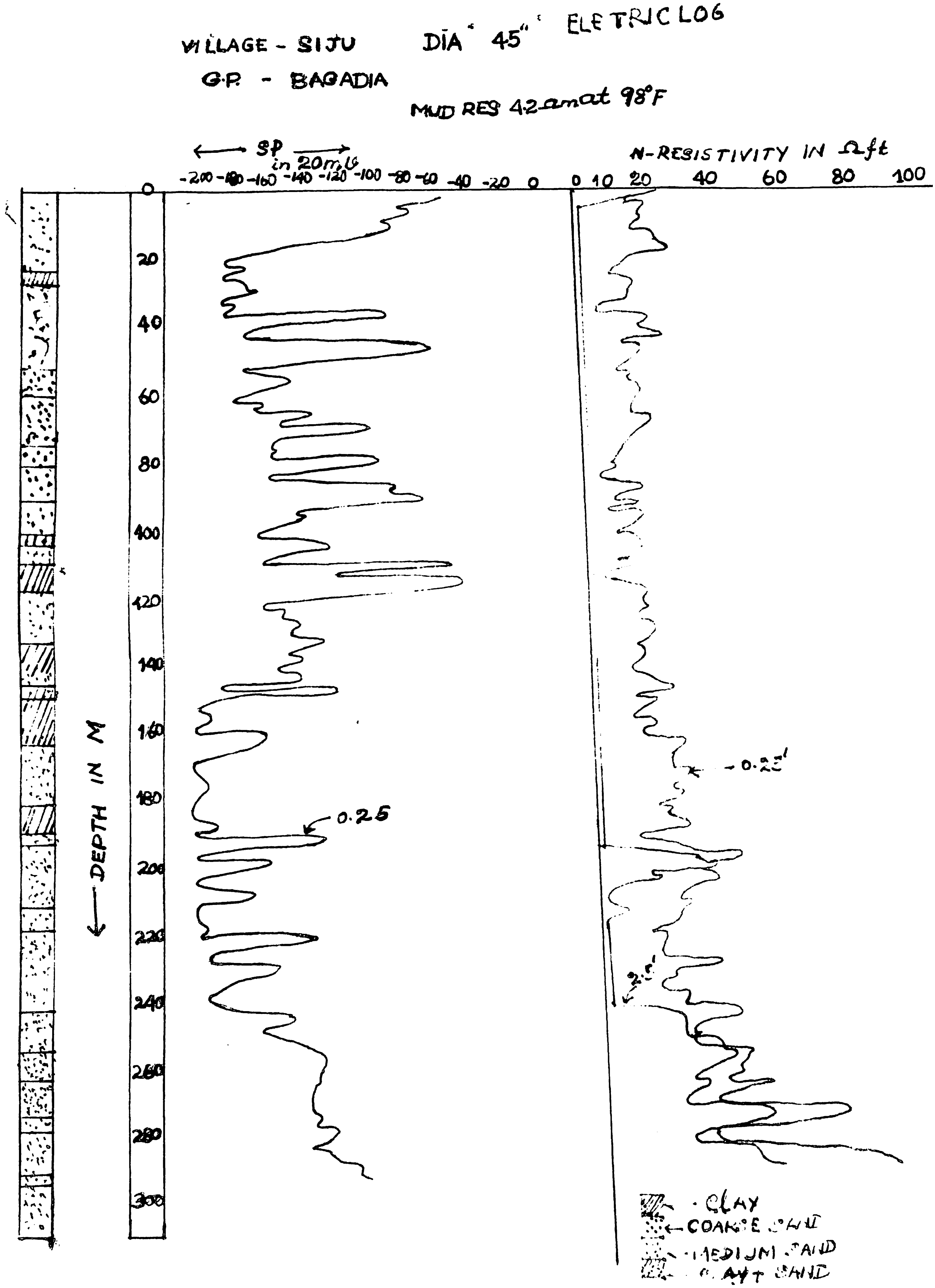

VILLAGE - SIJU
DIA 45"
ELETRIC LOG
G.P. - BAGADIA
MUD RES 4.2 am at 98°F
SP in 20mV
-200 -180 -160 -140 -120 -100 -80 -60 -40 -20 0
N-RESISTIVITY IN Ωft
0 10 20 40 60 80 100
0 20 40 60 80 100 120 140 160 180 200 220 240 260 280 300
DEPTH IN M
0.25
0.25'
2.5'
CLAY
COARSE SAND
MEDIUM SAND
CLAY + SAND

FIG NO- 5.9

ELECTRIC LOG

VIL - ADHANKURA
GP. - PANDUA

DIA - 4.0"
MUD RES - 7 ohm at 30°C

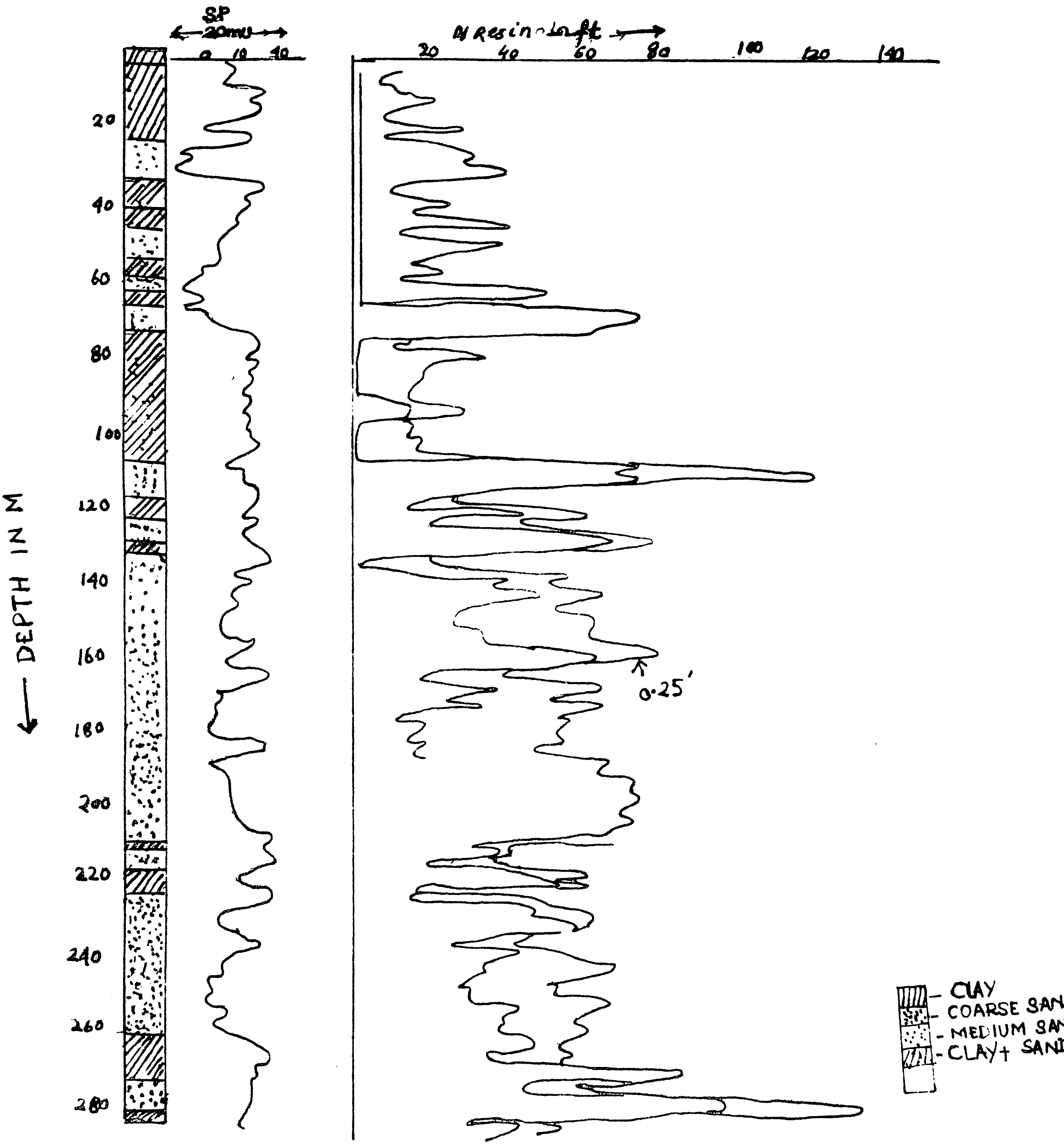


FIG NO- 5.10

VILL BAGADIA
G.P. BAGADIA

ELECTRIC LOG

DIA : 4"

MUD RESISTIVITY :27 Ωm at 86°F

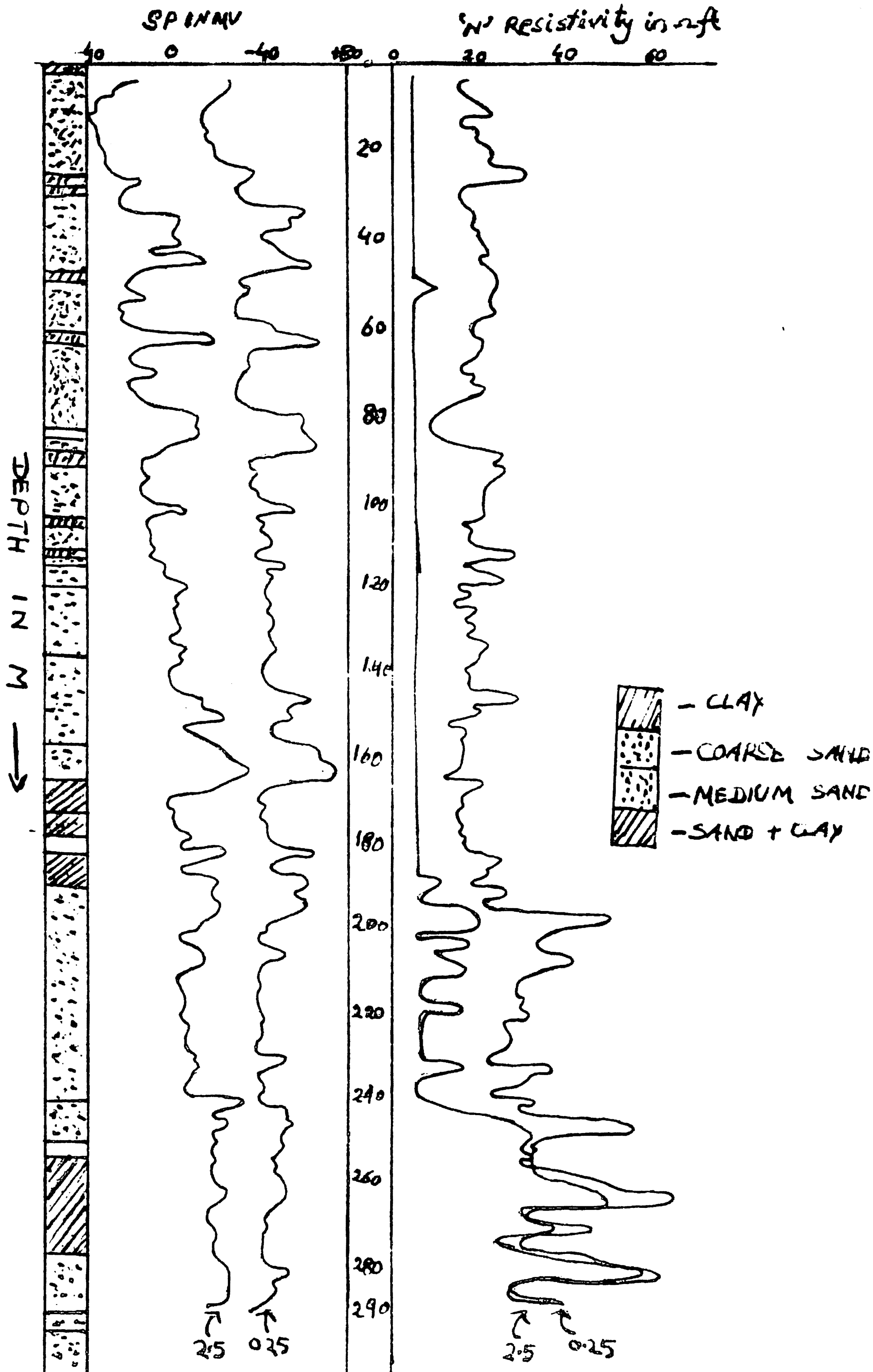


FIG NO - 5.11

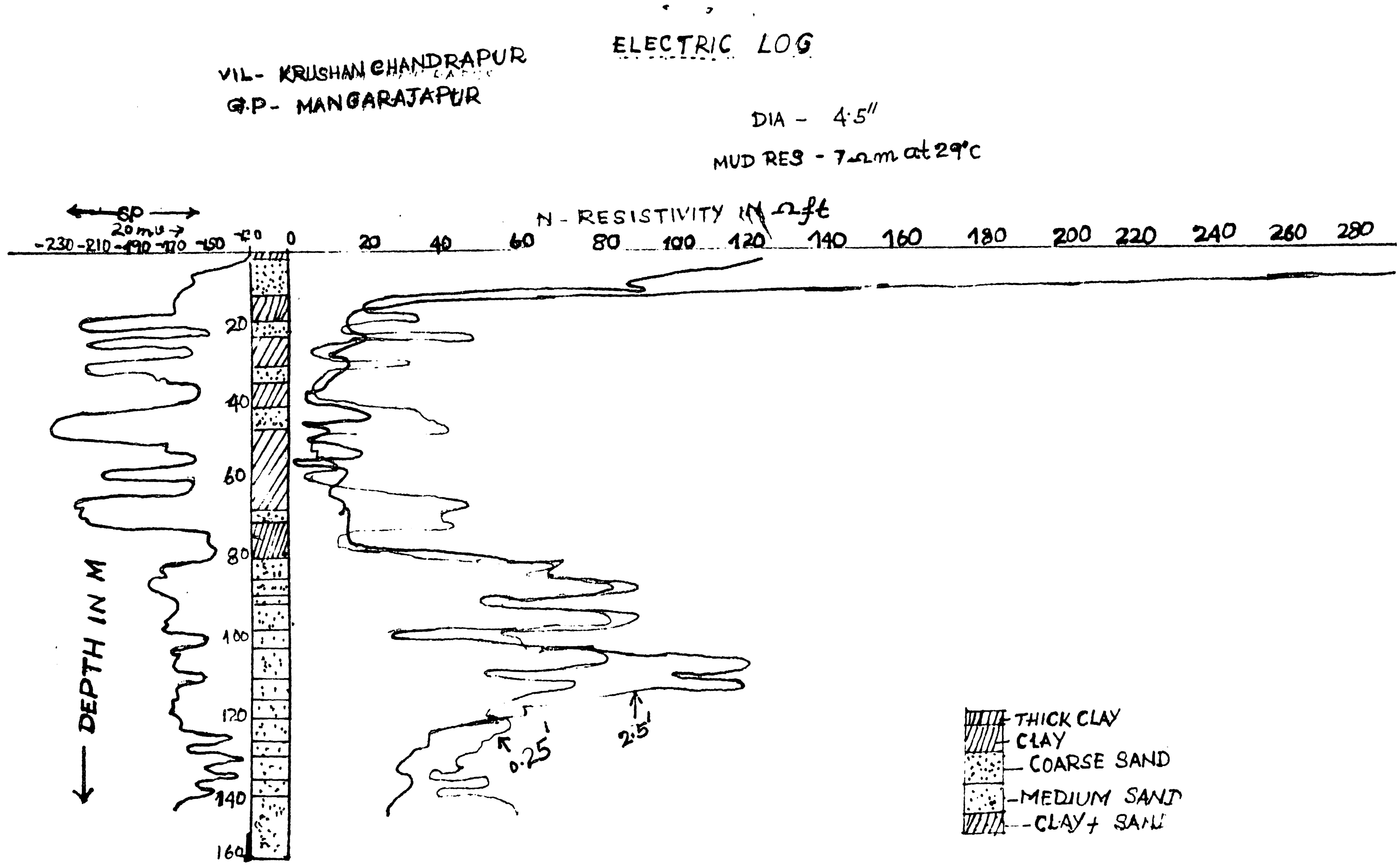

ELECTRIC LOG
VIL- KRUSHANCHANDRAPUR
G.P- MANGARAJAPUR
DIA - 4.5"
MUD RES - 7 Ωm at 29°C
SP
20 mV
-230 -210 -190 -170 -150 -130
N - RESISTIVITY IN Ωft
0 20 40 60 80 100 120 140 160 180 200 220 240 260 280
20 40 60 80 100 120 140 160
DEPTH IN M
0.25'
2.5'
THICK CLAY
CLAY
COARSE SAND
MEDIUM SAND
CLAY + SAND

FIG. No. 5.12

ELECTRIC LOG

VILLAGE- BIJAYCHANDRAPUR DIA 45"

GP- NUAGARH

MUD RES 5.0 Ωm at 70°F

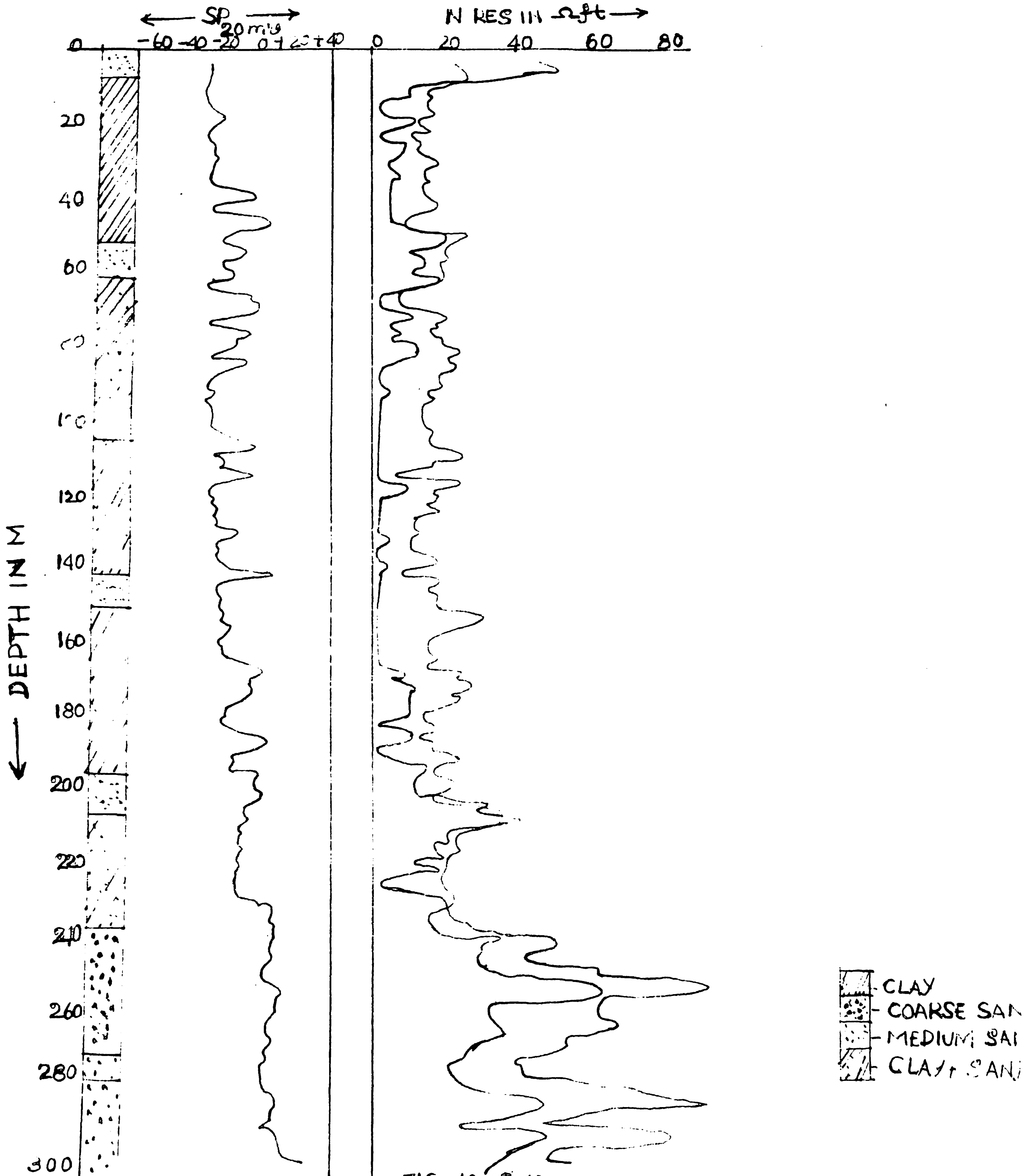


FIG NO 5.13

VILLAGE-MUSADIA
GP - PARADEEPGARH DIA - 45"

- ELECTRIC LOG

MUDRESISTIVITY -3 ΩM AT 2?°C

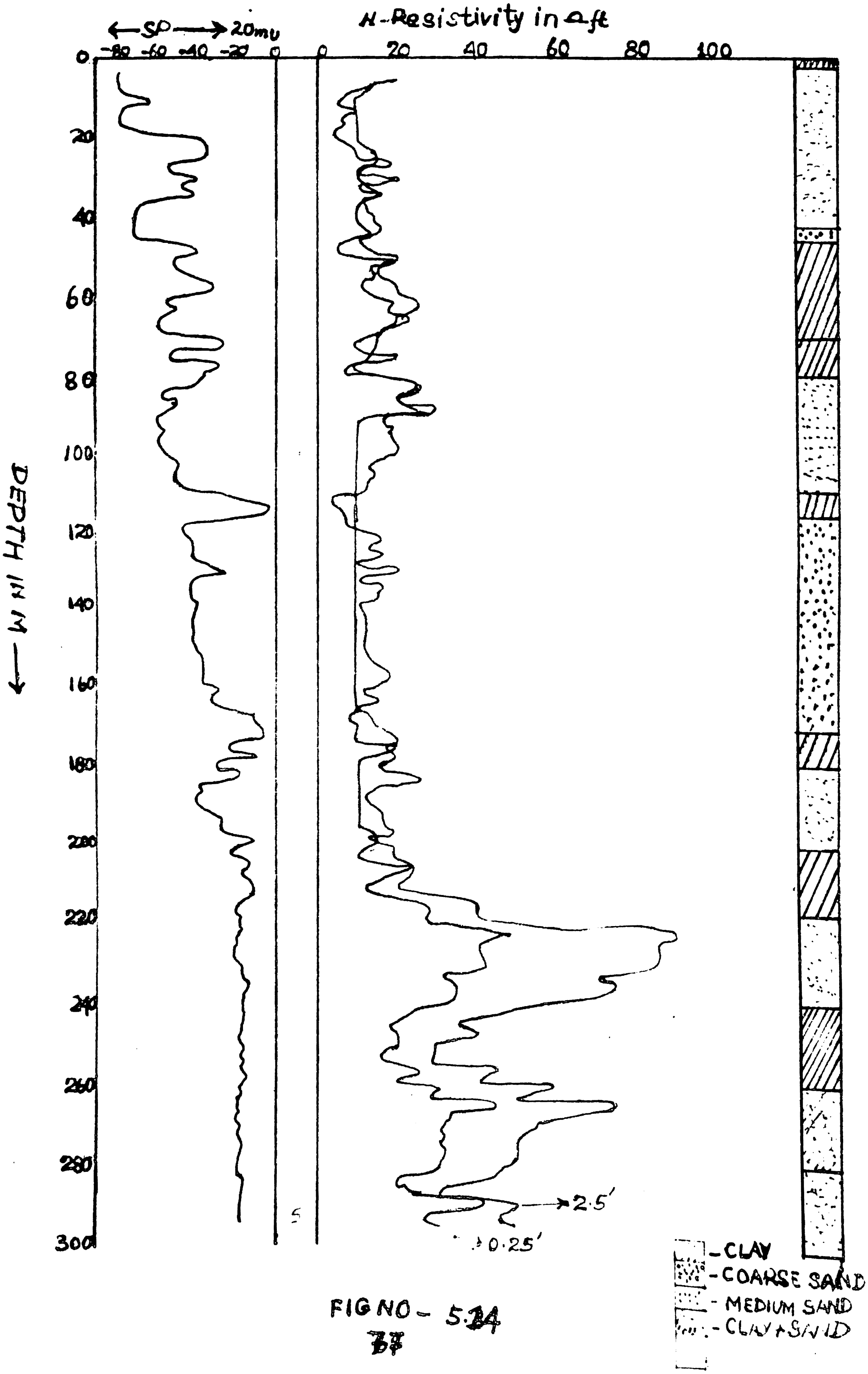


FIG NO - 5.24

VILLAGE SANDHAPUR ELECRIC LOG
G.P. KUJANG

DIA - 8½"
MUD RESISTIVITY - 4.2 at 25°C

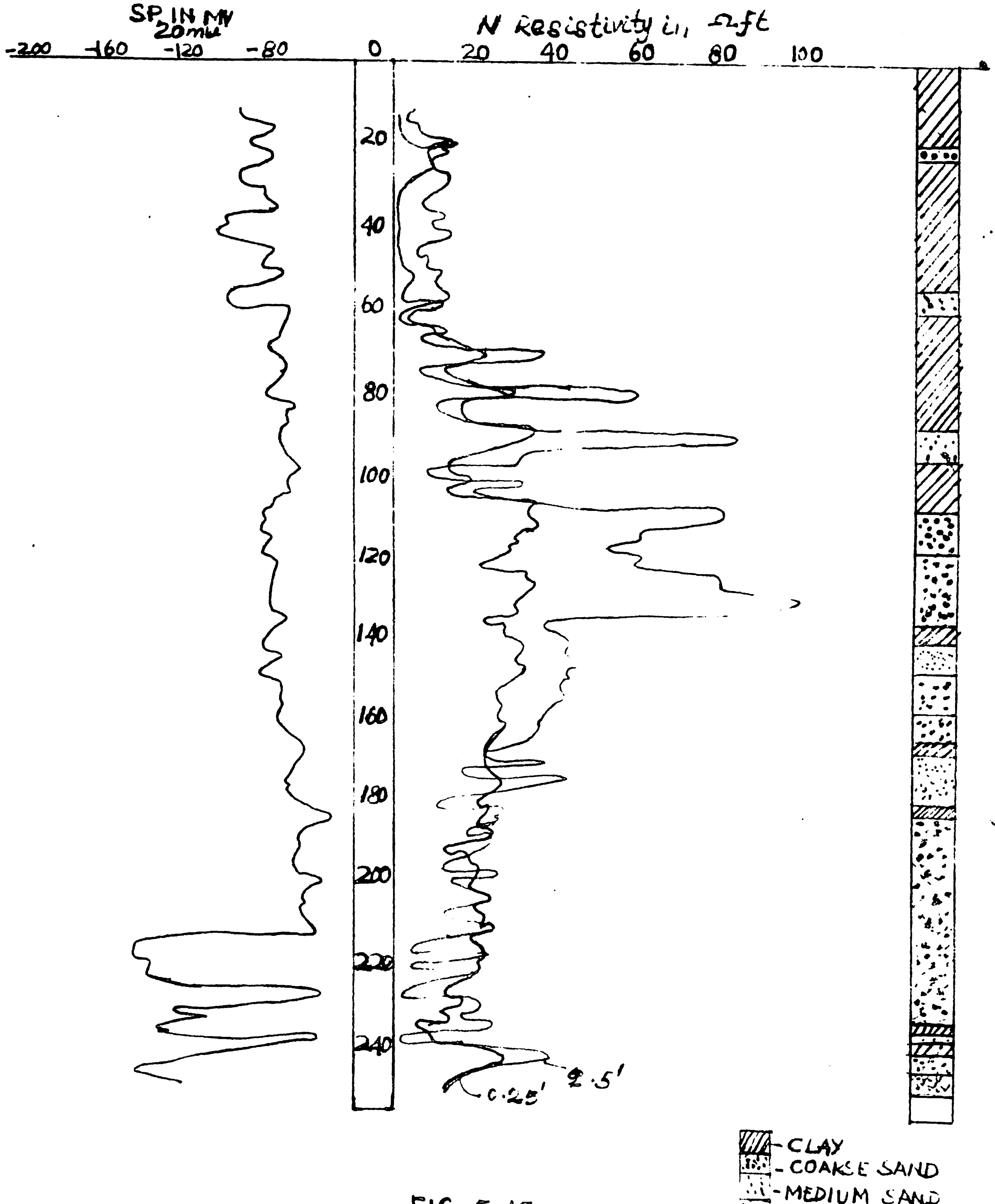


FIG 5.15

VILLAGE -
G.P.- MALASAHI

ELECTRIC LOG

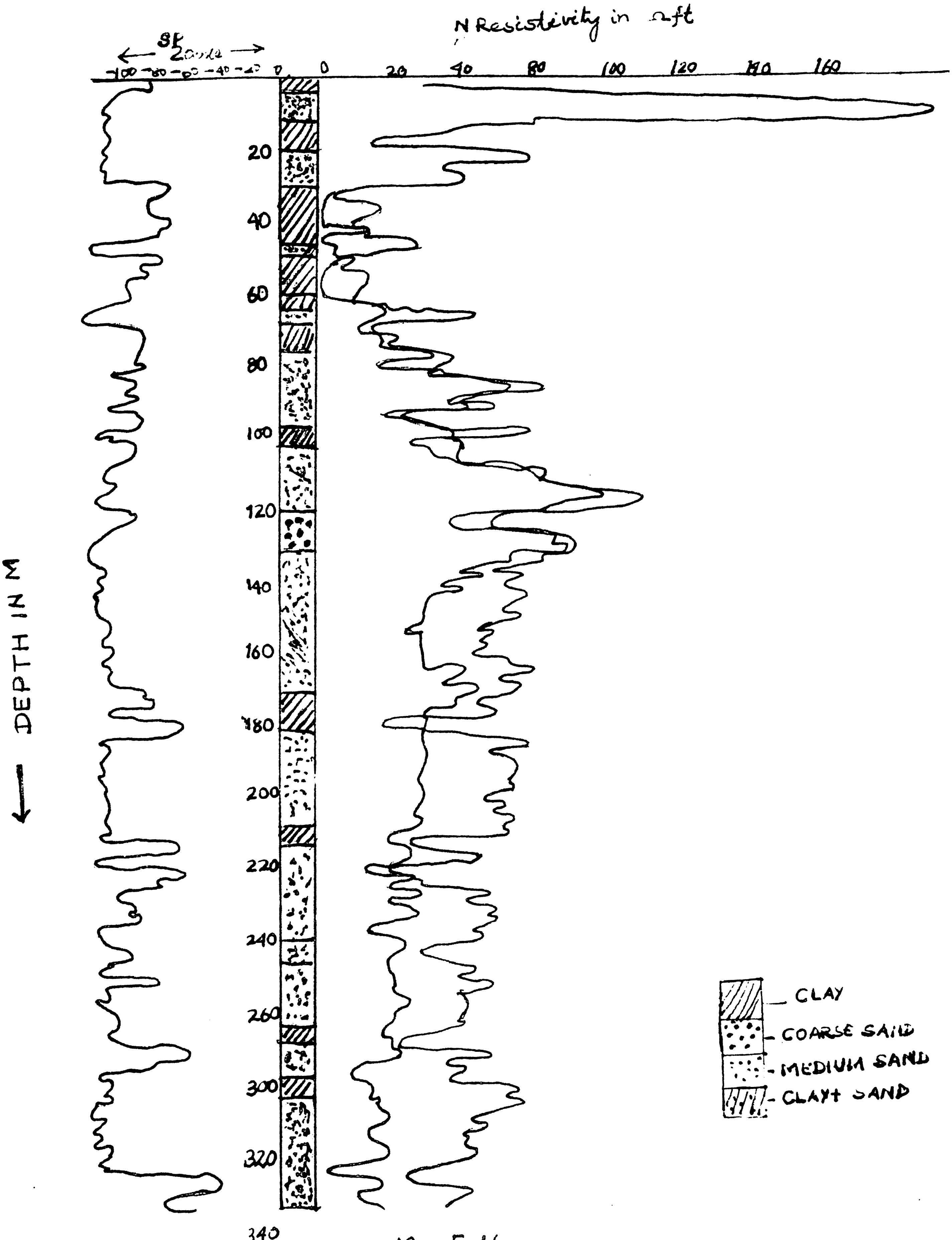


FIG NO - 5.16

VILLAGE- [illegible]

G.P:A- GORADA

ELCTRIC LOG

DIA- 4"0"

MUD RES 0-5 Ω at 28°C

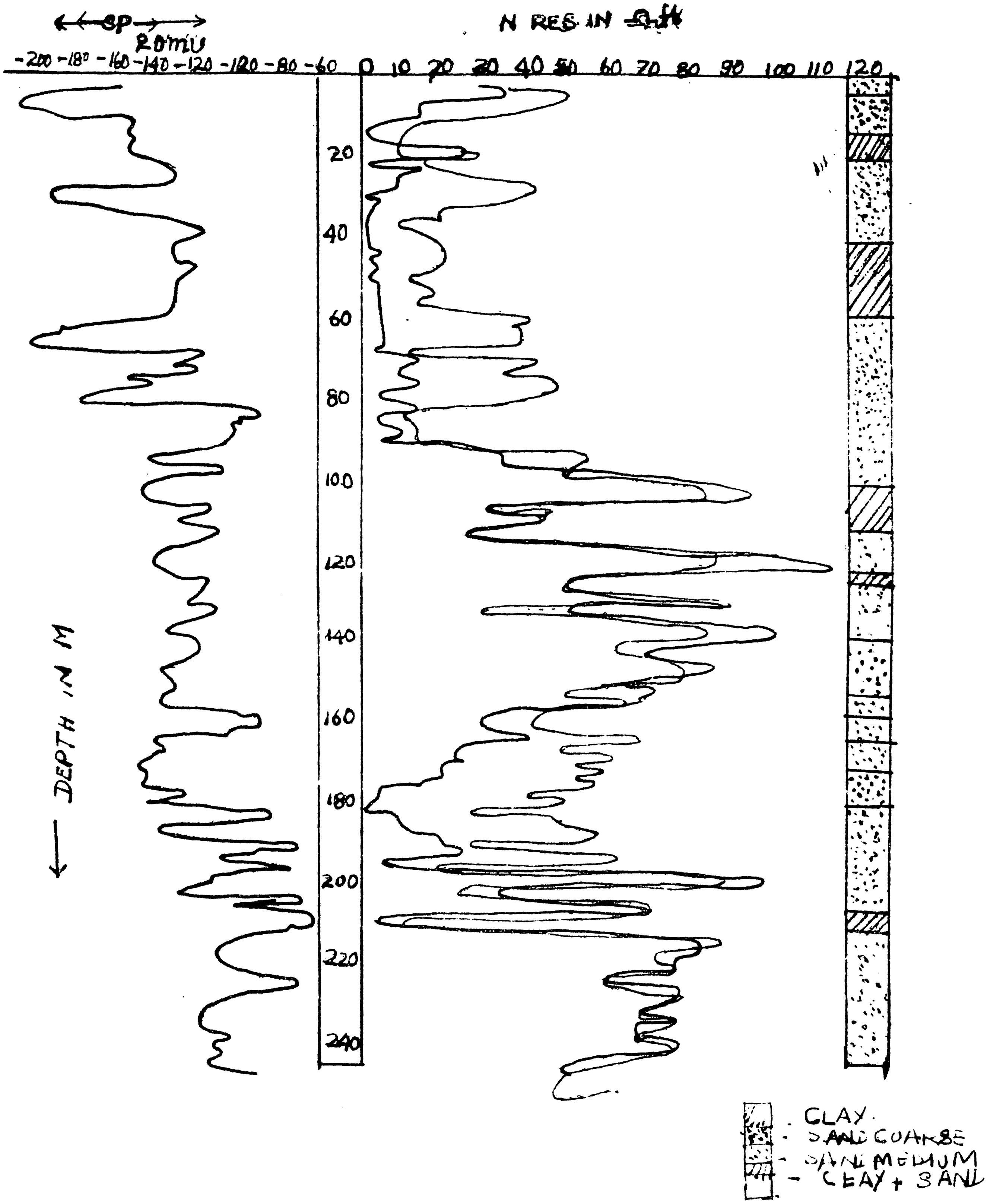


FIG NO - 5.17

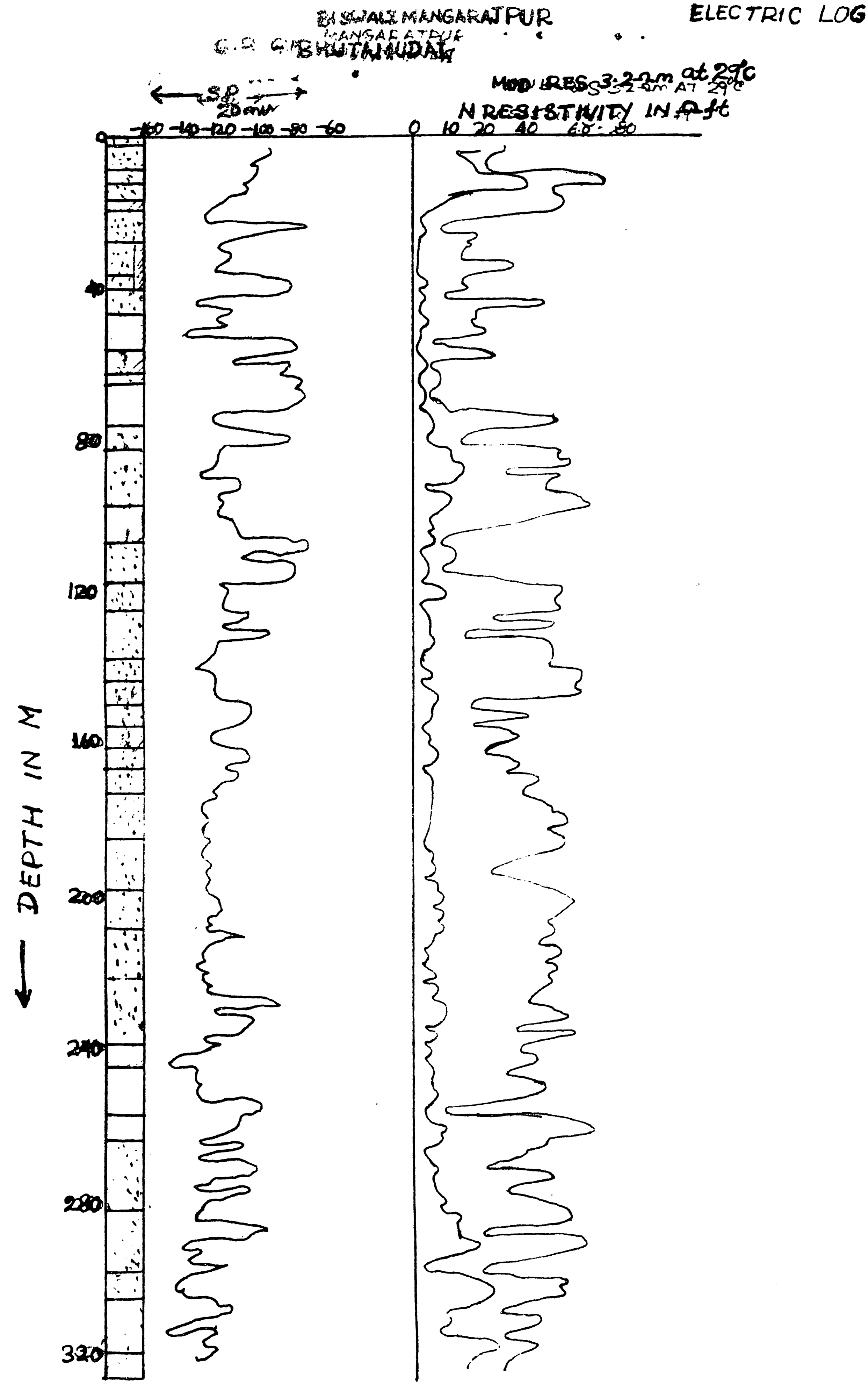

BISWALI MANGARATPUR
BHUTAMUDAI
MUD RES 3.2 Ωm at 29°C
S.P. 20 mV
N RESISTIVITY IN Ω-ft
-160 -140 -120 -100 -80 -60
0 10 20 40 60 80
0
40
80
120
160
200
240
280
320
DEPTH IN M

FIG 5.18

ELECTRIC LOG

VILLAGE ALOKHOLANGA-II
G. P. - PANDUA

MUD RES - 6·5ΩM AT 30°C

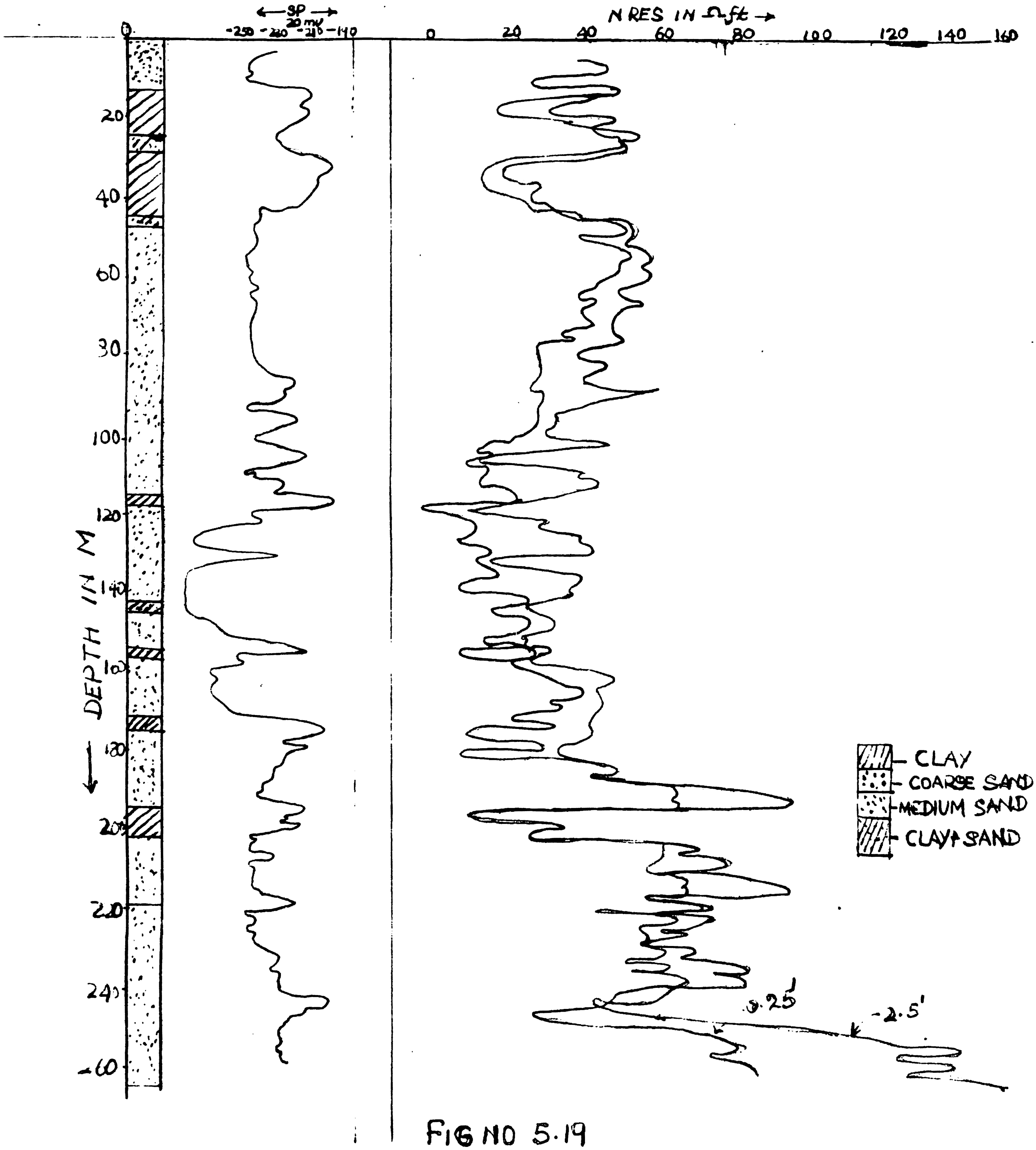


FIG NO 5.19

For example, in Fig. No. , for Sandhapur Village

0.20 m. - clay, 20-23 m. i.e. 3 m. - Medium Sand ;

23-55 m. - Clay; 55-60 m. - Sand ; 60-9 om. clay ;
(medium)

90-95 m. - Sand; 95-107 m. - Clay with fine sand ;

107-117 m. - Sand (Coarse), 117-135 m. - sand (medium)

135-140 m. - clay, 140-147 m. - sand (medium)

147-158 - sand (coarse), 158-162 m. - Sand (medium + fine)

162-165 m. - sand (coarse) 165-168 m. - clay, 168-172 - sand:

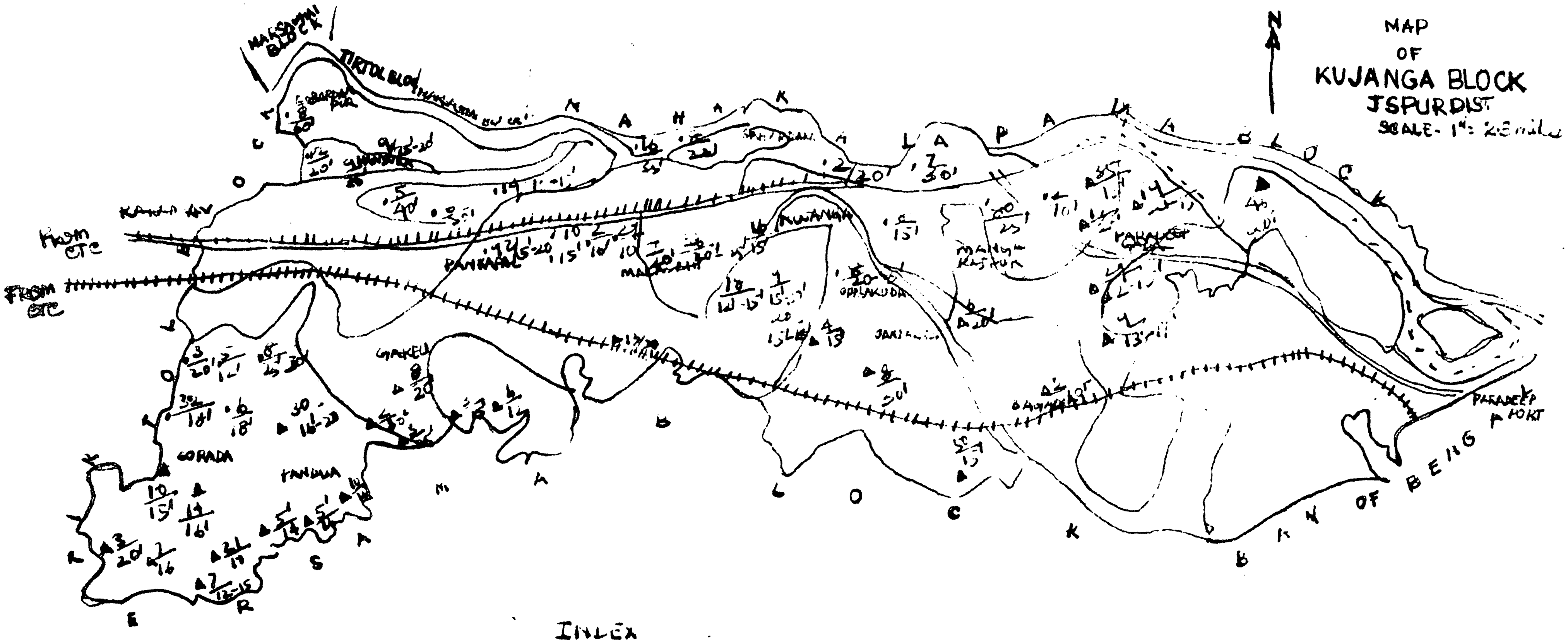
172-175 - sand (coarse)	175-180 - sand (medium + coa
180-183 - clay	183-193 - sand (medium)
193-210 sand (coarse)	210-212 sand (medium)
212-214 sand (medium)	214-216 sand (coarse)
216-230 sand (coarse)	230-250 (clay + sand)

From the electrical logging, it was revealed that from 107-117 m. i.e. 10 m. and from 117-135 m. i.e. 18 m. contains fresh aquifer. Electrical logging tells about the protective layer, the layer up to which the strainer and blind pipe to be provided, whether further development of the well required etc.

Analysis of Hydrogeologic Regime :

A picture of the groundwater regime in the Kujang Block was drawn from numerous drilling, electrical logging, well construction, water quality analysis data of various Organisations viz., RWSS, Orissa, C.G.W.B., Govt. of India, O.L.I.C. Ltd. etc. The fence diagram prepared out of these data is given at Fig. No. 5.23. A panel diagram showing the

DISTRIBUTION OF DUGWELLS IN KUJANG BLOCK



INDEX

• — FRESH DUG WELL
▲ - SALINE DUG WELL

FIG NO 5.20

MAP SHOWING SHALLOW FRESH AQUIFERS

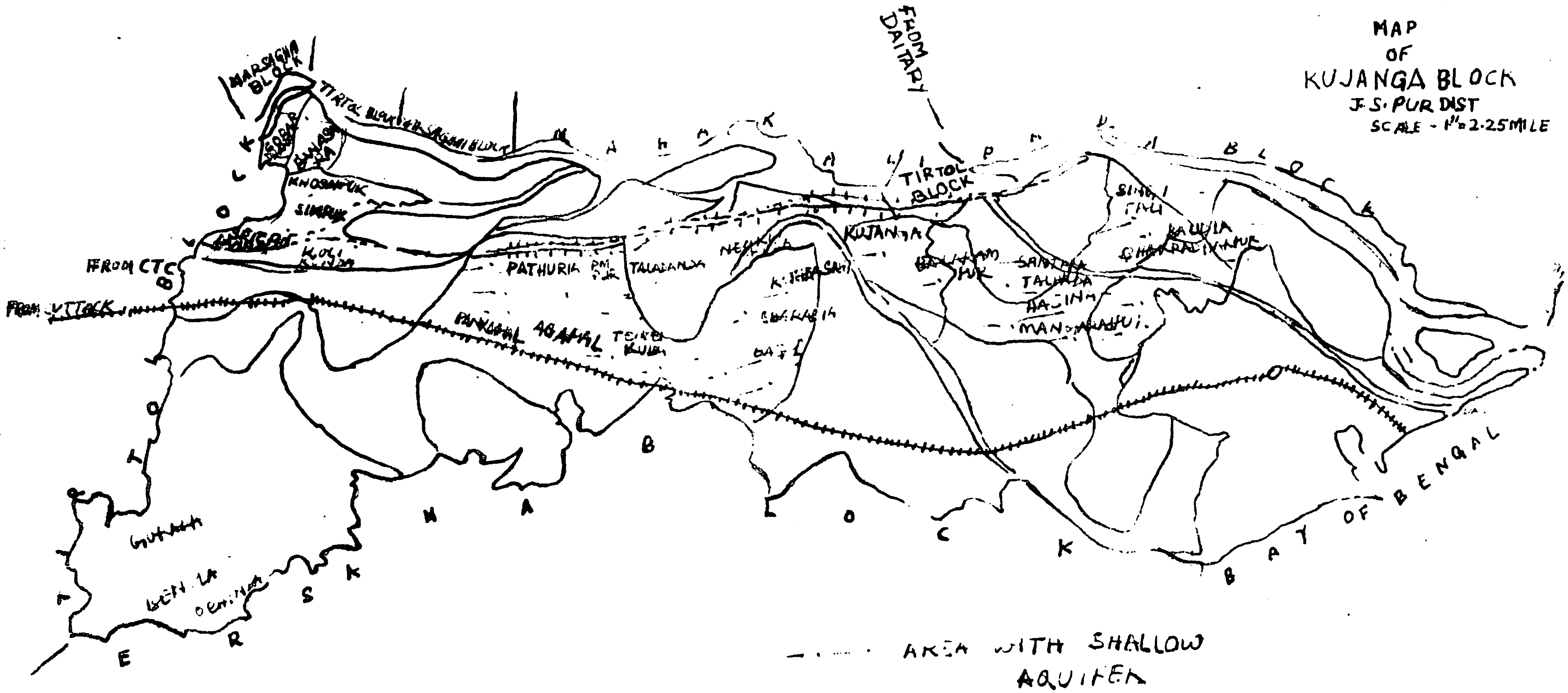


FIG NO :- 5.20A

HYDRO CHEMICAL PROFILE CUTTACK-PARADEEP SECTION

SCALE: HOR 1: 500,000
VER 1CM = 50M

INDEX: FRESH
SALINE

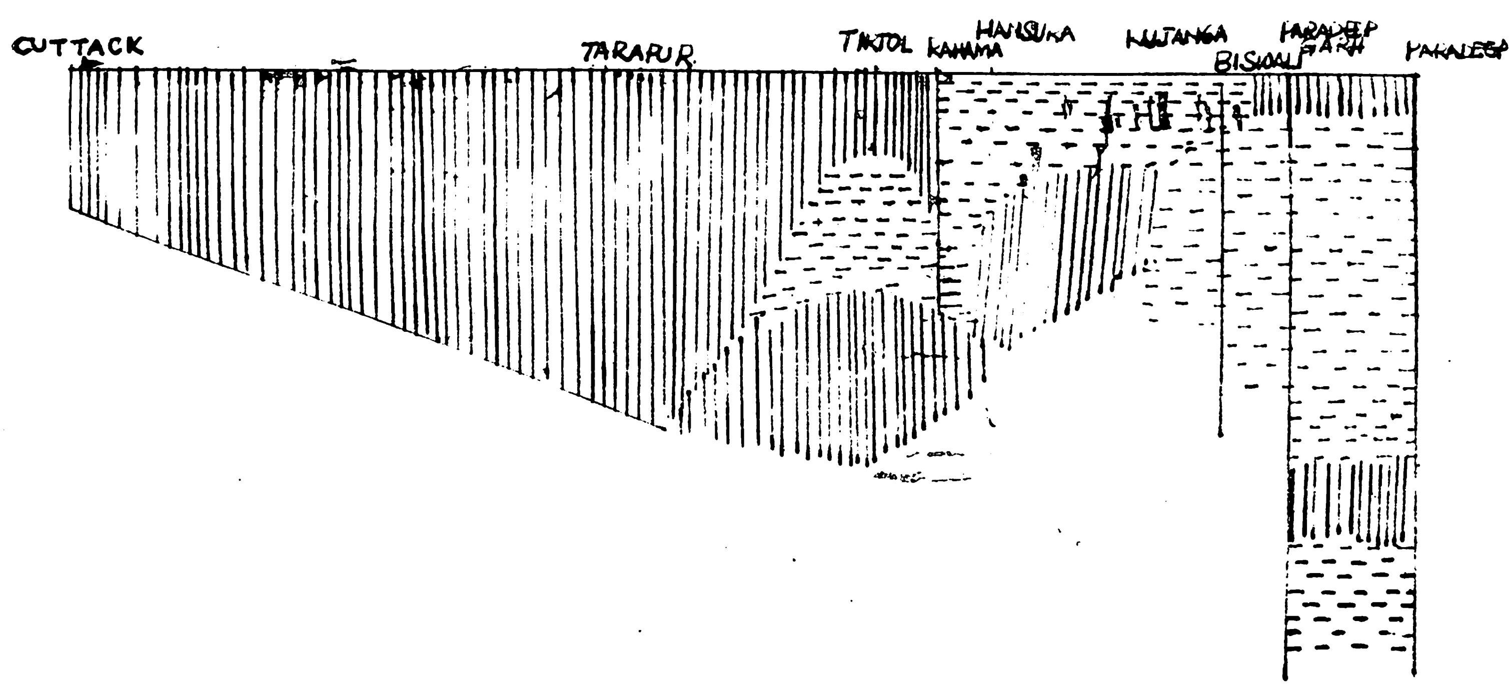


FIG NO. 5.21

PANEL DIAGRAM SHOWING THE DISPOSITION OF SALINE AND FRESH GROUNDWATER BODIES IN THE COASTAL TRACTS OF ORISSA

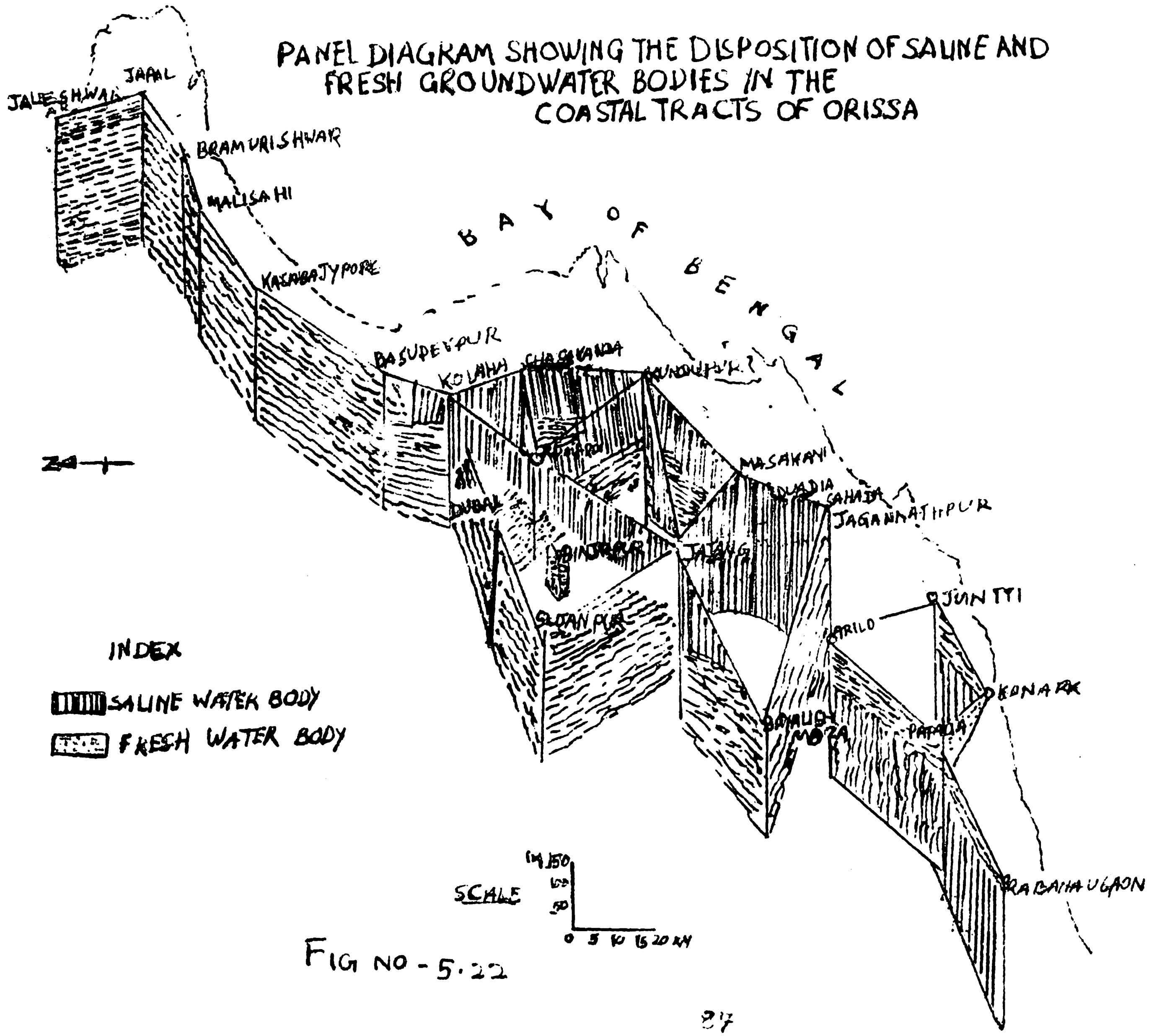


FIG NO - 5.22

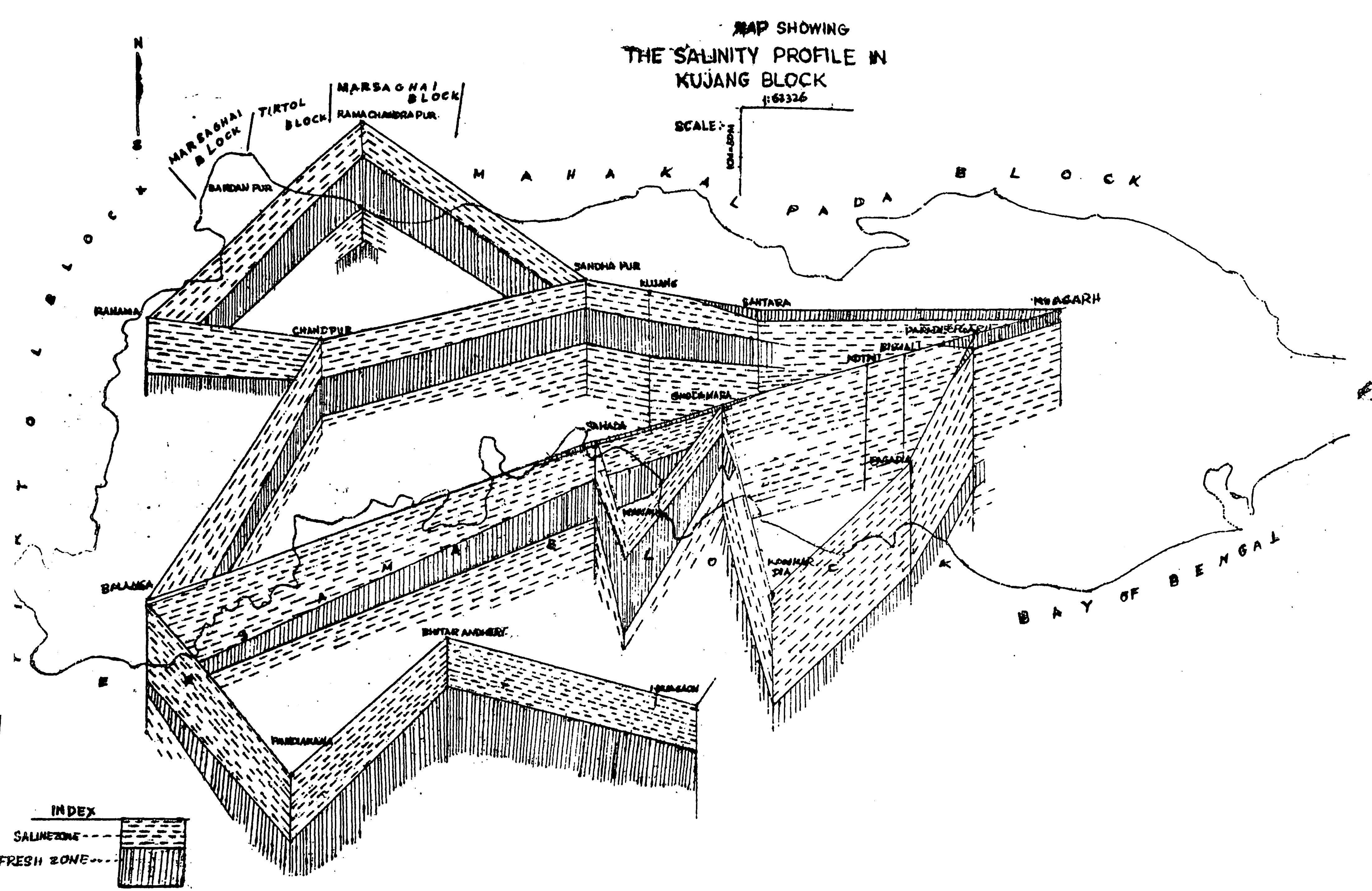

MAP SHOWING
THE SALINITY PROFILE IN
KUJANG BLOCK
SCALE:
1:63326
MAHAKALPADA BLOCK
MARSAGHAI BLOCK
TIRTOL BLOCK
MARSAGHAI BLOCK
RAMACHANDRAPUR
BANDAN PUR
SANDHA PUR
KUJANG
SANTARA
NUAGARH
PARADEEPGARH
BIGHALI
NOTNI
SHOLAMARA
SAHADA
PAGADA
KONKHAR DIA
BALANGA
RAHAMA
CHANDPUR
BHITAR ANDHERI
PANDIAKANA
BAY OF BENGAL
KUJANG BLOCK
INDEX
SALINE ZONE
FRESH ZONE
N
S

FIG NO 5.23

In the study area the exploratory tube-wells indicates that in the Western part of the block the groundwater below 70 m. depth is fresh and there is no possibility of getting fresh water above this depth. The central part of the area comprises thin fresh water aquifer from 60 m. to 135 m. In the Villages - Biswali, Bhutamundai and Nuagada fresh water zone is not available down to depths ranging from 212 m. to 300 m. However, a shallow aquifer within 0 to 20 m. is indicated at Bhutamundai and Nuagada Village. In the eastern part of the block, fresh water aquifer occurs around 200 m. to 260 m. below ground level as observed from exploratory drilling at Sandhakuda, Bagadia and Paradeepgarh. In the central part of the block, the villages namely Pankapal-I, Badapal, Bagoi (Baunsapada), Pankapal-II, Gaurapada, Samtra Balia, Tenteikudi, Ranipada, Boniki, etc., have shallow fresh aquifer. In all these cases, medium to coarse sand zones varying in thickness from 4.00 m. to 12.0 m. were encountered within the depth of 20 m. below ground level. In the Village, Arakhia and Paidasta, the aquifer zone was very thin, i.e. 0.5 m. to 0.6 m. followed by clayey zone. In these villages from the VES data, it was indicated that saline water exists beyond 20 m. below ground level.

From the distribution of dug wells inventory in Kujang Block, it appeared that fresh water dug wells were localised at the northern part of the block. The fresh water dug wells were scarce in the rest of the block. The VES results tallied with the saline and fresh aquifer zones probably due to presence of Taladanda main canal.

From the above study, it is concluded that the deep aquifers follow a specific trend and can be inferred for large areas. The shallow fresh aquifers on the other hand are localised to specific areas such as Palaeo channels, sand dunes etc. which are favourable geomorphic respositories for fresh groundwater. These kind of situations are seldom dascerible ordinarily.

Chemical quality analysis :

The chemical quality of groundwater in any area depends upon the local lithology, climatic conditions including rainfall and topography and varies from place to place. In the hand rock terrain comprising the major parts of the State, the quality of groundwater is generally portable and suitable for domestic, irrigational and industrial purposes. Brackish water encountered in a few places in the semi-consolidated and consolidated formations is due to localised pollution and contamination by industrial wastes excess application of fertilisers and pesticides and bacterial pollution and contamination from human and animal excreta. The groundwater in the State can be said to be slightly alkaline as indicated by the pH values ranging from 6.4 - 8.65.

The quality of groundwater in the shallow aquifers in the deltaic and coastal plain is characterised by a gradual deterioration towards sea, as revealed by a steady increase in specific conductance, chlorides, total hardness etc. It is soft to extremely hard and the upper range touches as high as 3,554 ppm. and has low to high chloride content which also touches the upper value of 3,390 ppm. (In general, in the deeper aquifers pH of groundwater ranges from 6.6 to 9 TDS (total dissolved solids by electrical conductivity), ranges from 265, to 1034 ppm. Hardness as $CaCo_3$ from 21 to 263 ppm. bicarborate from [illegible] to 463 ppm. chloride values from 14 to 307 ppm., iron content from 0.02 to 1.5 ppm., managanese content from 0.03 to 0.4 ppm. calcium content from 1.5 to 7.8 ppm. and sulphate content from 3 to 149 ppm. per cent sodium is found to vary from 22.5 to 88.7 and sodium adsorption ratio values (SAR) from 0.54 to 8.2. Quality classification of water for irrigation purpose after wilcox is as follows (Todd; 1980).

Water class	Per cent sodium	$Ecx10^6$ at 25°C
Excellent	20	250
Good	20-40	250-750
Permissible	40-60	750-2000
Doubtful	60-80	2000-3000
Unsuitable	80	3000

As the specific conductance values of most of the groundwater ranges from 97 to 762 micro mhos/cm. at 25°C or $Ec \times 10^6$ Mmho/cm., it comes under excellent, good to permissible ranges. Moreover, sodium percentage varies from 22.5 to 88.7, which comes mainly under good to permissible ranges.

But, in very specific cases, it is unsuitable for irrigation purpose.

The salinity laboratory of the Department of Agriculture U.S.A. recommends the sodium adsorption ratio (SAR) as prescribed below, because sodium is adsorbed directly by soil. Recommended water classifications for SAR :-

S.A.R.	Water class
10	Excellent
10-18	Good
18-26	Fair
26	Poor

For most of the deep-drilling groundwater, Sodium Adsorption Ratio (SAR) values from 0.54 to 8.2. Hence, on the basis of SAR almost all the explored groundwater is excellent for irrigation purposes.

The water quality data of the tube-wells constructed in the shallow fresh aquifers in the study area has been annexed at . As the tube-wells were utilised for drinking purposes, only iron and chloride contents of the water was analysed and given in the Table No. .

From the Table, it appeared as in Village Pankapala-I, there was slight increase of iron content in the tube-well. In Village Pankapala-II salinity was gradually increasing, Chloride (Cl.) and Iron (Fe) has increased from 110 mg./l. to 140 mg/l. and 0.10 mg/l. to 0.30 mg/l. respectively. In

TABLE -

WATER QUALITY DATA

Village - Pankapala :-I

G.P. : Pankapala

	3/87	4/87	5/87	6/87	7/87 (1-15)	7/87 (15-31)	8/87	12/87
Cl.(mg./l.)	20	10	40	-	40	-	-	20
Fe.(mg./l.)	15.2	3.8	4.2	-	4.6	-	-	12.6
MPN/100 ml.	-	-	Nil	-	Nil	-	-	-

Village : Pankapala - II
G. P. : Pankapala

[illegible]	3/87	4/87	5/87	6/87	7/87 (1-15)	7/87 (15-31)	8/87	12/87
Cl.(mg./l.)	110	110	120	-	-	-	-	140
Fe (mg./l.)	0.10	0.10	1.1	-	-	-	-	0.30
MPN/100 ml.	-	-	Nil	-	-	-	-	-

Village : Badapal

G.P. : Pankapala

	4/87	5/87	1.7.87	18.7.87	8/87	12/87
Cl.(mg./l.)	100	90	-	120	-	90
Fe.(mg./l.)	0.95	2.7	-	2.6	-	2.4
MPN/100 ml.	-	Nil	-	Nil	-	-

Village : Gaurapada
G.P. : Mallasahi

	5/87	1.7.87	17.7.87	8/87	12/87
Cl.(mg./l.)	20	-	10	-	10.0
Fe.(mg./l.)	2.9	-	2.10	-	2.10
MPN/100 ml.	Nil	-	Nil	-	-

Village : Bagoi (Baunsapara)
G.P. : Kujanga

	3/87	4/87	5/87	6/87	7/87 (1-15)	7/87 (16-31)	8/87	12/87
Cl.(mg./l.)	-	80	30	-	-	80	-	-
Fe.(mg./l.)	-	0.55	0.5	-	-	0.5	-	-
MPN/100 ml.	-	-	Nil	-	-	Nil	-	-

Village : Bagoi
G.P. : Kujanga

	4/87	5/87	1.7.87	18.7.87	8/87	12/87
Cl.(mg./l.)	980	-	-	1,010	-	980
Fe.(mg./l.)	0.50	-	-	1.7	-	5.30
MPN/100 ml.	-	-	-	Nil	-	-

VILLAGE : SANTARA
G.P. : MANGARAJPUR

	4/87	5/87	6/87	7/87 (1-15)	7/87 (16-31)	8/87	12/87
Cl.(mg./l.)	-	90	-	-	70	-	50
Fe.(mg./l.)	-	0.7	-	-	0.40	-	0.70
MPN/100 ml.	-	Nil	-	-	Nil	-	-

Village : Ranipada
G.P. : Patapur

	5/87	6/87	7/87 (1-15)	7/87 (16-31)	8/87	12/87
Cl. (mg./l.)	10.0	-	-	-	-	-
Fe.(mg./l.)	10.0	-	-	-	-	-
MPN/100 ml.	-	-	-	-	-	-

Village : Balia
G.P. : Balia

	3/87	4/87	5/87	6/87	7/87		8/87	12/87
					(1-15)	(15-31)		
Cl.(mg./l.)			40	-	40	50	-	70.0
Fe. (mg./l.)			5.4	-	2.5	3.4	-	6.9
MPN/100 ml.			-	-	Nil	Nil	-	-

Village : Tenteikuda
G.P. : Mallasahi

	3/87	4/87	5/87	6/87	7/87 (1-15)	7/87 (16-31)	8/87	12/87
Cl.(mg./l.)			60	-	90	90	-	60
Fe. (mg./l.)			1.1	-	0.25	0.25	-	1.20
MPN/100 ml.			-	-	Nil	Nil	-	-

Village : Bonikhi (Telepatna)
G.P. : Patapur

	3/87	4/87	5/87	6/87	7/87 (1-15)	7/87 (16-31)	8/87	12/87
Cl. (mg./l.)			20	-	30	-	-	-
Fe. (mg./l.)			5.5	-	2.55	-	-	-
MPN/100 ml.			-	-	Nil	-	-	-

Village : Pipala
G.P. : Bhutamundai

	3/87	4/87	5/87	6/87	7/87 (1-15)	7/87 (16-31)	8/87	12/87
Cl.(mg./l.)				530	570	580	-	640
Fe.(mg./l.)				4.40	17.80	17.6	-	3.4
MPN/100 ml.				-	Nil	Nil	-	-

Village Badapal, Gaurapada, Bagoi (Baunsapara), Santara and Kathada (Thakurdia) the water quality was good, chloride and iron contents were low. In the village Bagoi, the tube-well turned saline. Chloride content in the monsoon was more than that of pre-monsoon and post-monsoon. In the village Balia, salinity was gradually increasing. Iron content was high in the pre-monsoon and post-monsoon period. In village Tenteikuda during monsoon chloride content was increasing and iron content was decreasing. In village Bonikhi (Telepatna), high iron content was noticed during pre-monsoon. In village Pipala, salinity has increased, iron content was very high during monsoon. In village Kathada (Thakurdia) iron content was slightly more. In village Arakhia chloride and iron content in the post-monsoon was slightly more than that during monsoon.

From the above, it appeared that the tube-wells have not followed a particular fashion in increasing or decreasing of Cl., and Fe. Hence, the reliability of the aquifer in some of the cases are doubtful. The tube-wells which were turned saline was due to overdraft of the aquifers, thin protecting layers. Faulty construction may also be one cause of such failure.

Groundwater Assessment :

In recent times basin-wise evaluation of groundwater resources considered to be the most scientific of all methods, has assumed lot of importance and is widely adopted for quantification of (basin-wise). Groundwater being an underground

Water Level Fluctuation - 1987

Sl. No.	Name of the village	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Fluctuation in May level - Dec level
		Month-wise water level (bgl) in M.												
1.	Pankapala-I	-	-	-	-	3.0	-	2.6	1.4	-	-	-	1.95	1.05
2.	Pankapala-II	-	-	-	6.3	6.1	-	5.6	5.35	-	-	-	5.05	1.05
3.	Badapal	-	-	-	3.80	3.1	-	2.05	0.60	-	-	-	1.45	1.65
4.	Gaurapada	-	-	-	-	2.3	-	1.82	0.72	-	-	-	1.02	1.28
5.	Bagoi (Baunsapara)	-	-	-	3.5	2.4	-	1.4	1.20	-	-	-	1.15	1.25
6.	Bagoi	-	-	-	3.90	2.04	-	1.25	1.10	-	-	-	0.90	1.14
7.	Santara	-	-	-	-	2.10	-	1.80	1.35	-	-	-	1.95	0.75
8.	Ranipada	-	-	-	-	2.07	-	1.99	1.87	-	-	-	1.45	0.62
9.	Balia	-	-	-	-	2.9	-	1.35	2.45	-	-	-	1.70	1.20
10.	Tenteikuda	-	-	-	-	2.10	-	1.35	1.40	-	-	-	1.20	0.90
11.	Bonikhi	-	-	-	-	2.10	-	1.37	1.32	-	-	-	1.05	1.05
12.	Pipala	-	-	-	-	1.75	-	0.95	0.95	-	-	-	1.10	0.65

Average fluctuation of water level - 0.90 M.

Table - 5

Water Level Fluctuation - 1988

Sl. No.	Name of the village	Month-wise water level (bgl) in M. Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Fluctuation May level - Dec. level
1.	Pankapala-I	1.95	2.05	2.5	2.8	3.0	-	2.8	1.6	-	-	-	1.95	1.05
2.	Pankapala-II	5.05	6.10	6.10	6.3	6.3	-	5.8	5.35	-	-	-	4.90	1.40
3.	Badapal	1.45	-	-	-	3.1	-	2.05	0.60	-	-	-	1.45	1.65
4.	Gaurapada	1.30	-	1.6	-	2.3	-	1.82	0.72	-	-	-	1.02	1.28
5.	Bagoi (Baunsapara)	-	1.5	-	2.2	2.4	-	1.4	1.20	-	-	-	1.15	1.25
6.	Bagoi	0.98	1.20	-	2.0	2.04	-	1.20	0.90	-	-	-	0.90	1.19
7.	Santara	1.95	-	2.20	-	2.70	-	1.80	1.35	-	-	-	1.95	0.75
8.	Ranipada	1.60	1.65	1.70	-	2.07	-	1.99	1.87	-	-	-	1.45	0.62
9.	Balia	1.85	1.90	2.0	-	2.90	-	1.45	2.60	-	-	-	1.70	1.20
10.	Tenteikuda	-	1.45	1.60	1.75	2.10	-	1.40	1.40	-	-	-	1.20	0.90
11.	Bonikhi (Telepatna)	1.10	1.30	1.45	1.60	2.10	-	1.37	1.32	-	-	-	1.05	1.05
12.	Pipala	0.80	0.85	1.20	1.40	1.60	-	0.95	0.95	-	-	-	0.90	0.70

Average fluctuation of water level - 0.92 m.

Water Level Fluctuation - 1989

Sl. No.	Name of the village	Month-wise water level (bgl) in M. Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Fluctuation May level-Dec. level
1.	Pankapala-I	1.95	2.10	2.6	2.8	3.0	-	2.8	1.6	-	-	-	1.95	1.05
2.	Pankapala-II	5.05	5.50	5.80	-	6.10	-	5.7	5.40	-	-	-	4.80	1.30
3.	Pattapal	1.48	-	2.5	-	3.10	-	2.10	0.70	-	-	-	1.45	1.65
4.	Gaurapada	1.30	1.45	1.65	1.70	2.30	-	1.82	0.80	-	-	-	1.00	1.30
5.	Bagoi (Baunsapal)	1.40	1.5	-	2.3	2.45	-	1.40	1.10	-	-	-	1.15	1.30
6.	Bagoi	1.00	1.20	1.60	2.0	2.15	-	1.25	-	-	-	-	0.90	1.25
7.	Samtara	1.9	-	2.30	-	2.80	-	1.90	1.60	-	-	-	2.00	0.80
8.	Ranipada	1.65	-	1.80	-	2.10	-	1.90	1.85	-	-	-	1.50	0.60
9.	Balia	1.75	-	2.10	2.30	2.90	-	1.45	2.60	-	-	-	1.75	1.15
10.	Tenteikuda	-	1.50	1.60	1.70	2.10	-	1.48	1.40	-	-	-	1.10	1.00
11.	Bonikhi (Telepatna)	1.10	1.30	1.40	1.60	2.15	-	1.35	1.20	-	-	-	1.05	1.10
12.	Pipala	0.80	0.85	1.10	1.20	1.60	-	0.95	0.80	-	-	-	0.95	0.65

Average fluctuation of water level - 0.91 m.

TABLE - 5

ANNUAL RAINFALL OF KUJANGA BLOCK

Year	Rainfall in mm.
1988	1443.90
1989	1520.30
1990	1440.00
1991	1538.00
1992	1469.20
1993	1502.00

Average annual rainfall - 1485.56 mm.

system, not amenable for direct observation, it becomes necessary to take into account certain inherent factors to compute the actual recharge.

From the VES datas, it was appeared as the shallow aquifers occurred in the Village Gobardhanpur, Banasara, Khosalpur, Simpur, Mamoalpur, Srichandanpur, Parmandapur, Taladanda, Nenkhikuda, Pankapal, Agapal, Tenteikuda, Gaurapa, Malasahi, Charadia, part of Bagoi, Kujanga, Balarampur, Santara, Talapada, Hasina, Mansarajpur, Biswali, Koladia, Singitali.

From acrecomb and computation the area of the above Villages came to 79.392 km^2.

The average annual rain fall from Table No. 1485.56 mm.

Recharge due to rain fall by Iq. No. 4.1

Area	Rain fall	Infiltration factor	
79.392	1485.56	20	2358831.59 m^3 2.36 MCM 236 Ha-m.

Recharge due to fluctuation of piezometric table by Eq. No. 4.2.

Area	Fluctuation of water level	Specific yield	
79.392	0.92	15	10956096 m^3 10.956 mcm 109.56 Ha-m.

Tapping 50 % of the recharge 54.78 Ha-m. of fresh water can be utilised for light duty corp, orchards etc.

From the Table No. 5.8a to 8.e, the average fluctuation of water level in the tube-wells 0.91m.

Fluctuation of water level is very nominal. Hence, the aquifers were sustained for this type of draft.

The method of delineating areas with possible shallow aquifers from study of toposheets seems to be reasonable and time saving approach and can be extended to other blocks in the saline coastal belt of Orissa.

CHAPTER-VI

SUMMARY AND CONCLUSION

CHAPTER - VI

SUMMARY AND CONCLUSION

The surface and sub-surface investigation of groundwater was conducted in a profile zone of Kujanga Block by geophysical method investigation. Surface investigation was conducted by vertical electrical sounding. Sub-surface investigation was done by electrical logging. The VES was done at fifty-six different places spreading the entire block. Electric logging of fourteen different deep wells were included in this study. Existing information available on geomorphology, hydrology, hydrometeorology, geology, hydrogeology, hydrochemistry and geophysical studies of the area has been reviewed and utilised in analysing the results of the investigation. Based on the results obtained from the investigation, the following conclusions are suggestions are made.

(i) A correlation has been established between the electrical resistivity values and lithological units, their water bearing characteristics. While the resistivity of 1-5 ohm-m. may indicate clay/sand saturated with saline water. The resistivity values of 4-15 ohm-m. may correspond to sand saturated with brackish water, or clay saturated with fresh water. The resistivity range of 11-20 ohm-m. is attributed to sand with clay intercalations saturated with fresh water (clayey aquifer). While resistivity value of 21-800 hm-m. or slightly higher and correlated with sand saturated with fresh water (moderate to granular aquifer). Beyond the resistivity value of 800 hm-m. it attributed to weathered Khandalite and Khandalite etc. The dry sand may be characterised by resistivity more than 700 ohm-m.

(ii) The results of the investigation giving layer parameters, thickness of fresh aquifer, its depth, nature of surface layer and protecting capacity etc. are furnished in Table-5.1. The whole area of fresh and saline zone have been shown by fence diagram. The general hydrochemical characteristics from Cuttack to Paradeep has been shown in a diagram.

(iii) The VES data presented illustrate the setting with (a) shallow fresh aquifer at the top layer and immediately below it saline aquifer ; (b) all saline from top to 5 om depth ; (c) brackish zone sandwiched between saline zones ; (d) thin shallow aquifer overlying clays.

(iv) The area demarcation of shallow fresh and saline aquifers has been done. The saline aquifers are occurring in the eastern part of the block. Saline aquifers are also occurring most of the southern parts of the block. A thin fresh aquifer occurs in central part of the block.

(v) The deep-drilling data indicates that in the Western part of the block, fresh aquifer occurs. Below 70 m. There is no possibility of getting fresh water above this depth. Fresh aquifers can be encountered around 200 m - 260 m. bgl. in the eastern part of the block. In Sadhakuda and Paradeepgarh village the exploratory drilling has gone down to a depth of 320 m. The central part of the area comprises thin fresh aquifer from 60 m. to 135 m. Particularly in Village Biswali, Bhutamundai and Nuagada fresh water zone is not available down to depths ranging from 212 m. to 300 m. However, a shallow aquifer within 0 to 20 m. is indicated at Bhutamundai and Nuagada only.

(vi) Out of 56 VES sites, only fresh aquifer zones encountered at 26 sites. Fresh aquifer ranges 5-10 m. in 6 sites, 10 - 15 m. in 8 sites, 15-20 m. in 8 sites, 20-25 m. in 1 site, 25-35 1 site and 35-40 m. in 2 sites.

(vii) The shallow vertical electrical sounding (VES) have enabled delineating of shallow fresh aquifers and determination of its depth, thickness, areal extent and nature; delineation of clay beds; assessment of salinity of formation water qualitatively; and determination of the nature of surface layer and assessment of its protecting capacity. The study has thus demonstrated that the shallow VES being fast, economical, easy and are useful to furnish solution to different related aspects and should invariably be carried out systematically for the investigation of shallow aquifers. This study can be extended to other saline affected areas of the State.

viii) It appears that the fresh water bearing deep aquifers existing in the study area are extensions of the thick fresh aquifers found inland towards Cuttack. The thickness of deep fresh aquifers in Kujanga block is found to be reduced due to interfingering occurrence of saline aquifers in between. The thickness of the deep fresh aquifers varies from 20 to 50 m.

(ix) The shallow fresh aquifers are 10 to 20 m. thick in general and are localised to the old channels and sand dunes. The shallow fresh aquifers localised to the old channels are made up of medium to coarse sand (0.5 to 2.00 mm.). The recharge to shallow aquifers is due to the rain fall. The areal extension and thickness of the shallow aquifer can yield 10.956 MCM. of fresh water which can be utilised for community drinking, water supplies and small scale irrigation for orchards, seasonal crops, vegetables etc. through sprinkler and drip irrigation practices.

(x) It is seen that the deep fresh aquifers follow a specific trend and can be inferred for large areas.

The shallow fresh aquifers on other hand are localised to specific areas.

(xi) SAR values for deep drilling groundwater varies from 0.54 to 8.2 which is excellent for irrigation purposes.

xii) The chloride and iron content of shallow fresh aquifers are within the permissible limits of 200 mg/l. to 300 mg./l respectively for drinking and irrigation purposes.

xiii) Some of the tubewells in Pankapala-II, Bagoi, Balia, Pipala turned saline. The reasons may be faulty construction, overdraft etc. This may be studied further.

xiv) Based on results of shallow VES observation bore holes by hand-drilling is recommended. The pump test should be done to assess the discharge.

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APPENDICES

APPENDIX

COVERAGE OF THE STUDY AREA

Sl. No.	Gram panchayat	Revenue village
1.	Gorada	1. Gorada
		2. Sinida-I
		3. Kurilo
		4. Dhunpur
		5. Gainga
		6. Kaintol
		7. Dagarapada
		8. Ranita
		9. Kantapada
		10. Sarakhi
		11. Manisiagork
2.	Pandua	1. Pandua
		2. Patasura
		3. Benola
		4. Ochinda
		5. Mundiada
		6. Alana
		7. Kosti
		8. Naiguan
		9. Parudi
		10. Thilanapanga
		11. Hatikena
		12. Dhusala
		13. Patila
		14. Adhankura

Sl. No.	Grama Panchayat	Revenue Village
3.	Sailo	1. Sailo
		2. Shridhundijhailo
		3. Raigaon
		4. Behera Barada Hitharan
		5. Chhotibar
		6. Bharaja
		7. Bramanapur
		8. Khutala
		9. Talapada
		10. Nischintakoili
4.	Garei	1. Garei
		2. Bailo
		3. Sirola
		4. Lailanga
		5. Chandanpata
		6. Kothamuli
		7. Okala
		8. Bhainarkula
		9. Daradia
		10. Potonai
5.	Pankapal	1. Pankapal
		2. Pahana
		3. Paiksta
		4. Banitunda

Sl. No.	Grama Panchayat	Revenue Village
		5. Chhandpur
		6. Baruni
		7. Badapa
		8. Kalagop
		9. Pathuria
		10. Madhpur
		11. Jayasankha
		12. Jilanasa
		13. Tentuliakhamara
		14. Sahara
6.	Hansura	1. Hansura
		2. Srichandanpur
		3. Singhpur
		4. Gobardhanpur
		5. Banasara
		6. Kathakota
		7. Sarali
		8. Badabalikani
		9. Sahabalikani
7.	Mallasahi	1. Mallasahi
		2. Tenteikuda
		3. Agapala
		4. Paramanandapur
		5. Taladhanada
		6. Nenkoikuda
		7. Gaurpa
		8. Arakhia
		9. Chharadia

Sl. No.	Grama Panchayat	Revenue Village
		10. Pagoi
		11. Sandhapur
		12. Kothiasahi
		13. Kujanga
		14. Balarampur
8.	Balia	1. Balia
		2. Badabandh
		3. Jamukana
		4. Ghadamara
		5. Panapal
		6. Badagaon
		7. Samagola
		8. Duadia
		9. Baidigadi
9.	Patapura	1. Patapura
		2. Baulanga
		3. Karathutha
		4. Tentulia
		5. Ranipada
		6. Borikhi
10.	Gandhakipur	1. Gandhakipur
		2. Kharigotha
		3. Pratappur
		4. Nirighiakhanda

Sl. No.	Grama Panchayat	Revenue village
11.	Mangarajpur	1. Mangarajpur
		2. Talapada
		3. Santara
		4. Hasina
		5. Krushnachandra Pur
		6. Uchabandhapur
12.	Bagaria	1. Bagaria
		2. Jhimani
		3. Siju
		4. Kothi
		5. Bhutamundi
		6. Biswali
		7. Nrendrapur
		8. Pitambarpur
13.	Paradeepgarh	1. Paradeepgarh
		2. Musadhia
		3. Bijayachandrapur
		4. Udayachandrapur