ASSESSMENT OF GOOD QUALITY GROUNDWATER IN COASTAL HANDICAPPED ECOLOGY-A CASE STUDY OF PURI SADAR BLOCK

BY

Susanta Kumar Jena

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

MASTER OF TECHNOLOGY

(AGRICULTURAL ENGINEERING)

IN

SOIL AND WATER CONSERVATION ENGINEERING

DEPARTMENT OF SOIL AND WATER CONSERVATION ENGINEERING
College of Agricultural Engineering & Technology
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1994

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DEDICATED TO MY
BELOVED PARENTS

Dr. S.D.Sharma, Ph.D,
Dean,
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Dated: 26th Aug'94

CERTIFICATE

This is to certify that the thesis entitled "**ASSESSMENT OF GOOD QUALITY GROUNDWATER IN COASTAL HANDICAPPED ECOLOGY - A CASE STUDY OF PURI SADAR BLOCK**" 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 bonafied research work carried out by **Sri Susanta Kumar Jena** 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.

26/8/94
(S.D. Sharma)

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Susanta Kumar Jena

Place : Bhubaneswar
Date : 26th August 94.

(Susanta Kumar Jena)

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LIST OF SYMBOLS AND ABBREVIATIONS

Symbol/Abbreviation	Description
^{o}C	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 Technolgy
C.C.A.	Culturable command area
Cd	Cadmium
CGWB	Central Ground Water 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 I

INTRODUCTION

Groundwater is a precious and the most widely distributed resource of the earth and unlike any other mineral resource, it gets it's annual replenishment from the meteoric precipitation. The world's total water resources are estimated at 1.37×10^{8} million ha-m. Of these global water resources about 97.2% is salt water, mainly in oceans, and only 2.8% is available as fresh water at any time on the planet earth. Out of this 2.8%, about 2.2% is available as surface water and 0.6% as groundwater. Even out of this 2.2% of surface water, 2.15% is fresh water in glaciers and icecaps and only of the order of 0.01% (1.36×10^{4} M ha-m) is available in lakes and reservoirs, and 0.0001% in streams; the remaining being in other forms- 0.001% as water vapour in atmosphere, and 0.002% as soil moisture in the top 0.6 m of soil. Out of 0.6% of stored groundwater, only about 0.3% (41.1×10^{4} M ha-m) can be economically extracted with the present drilling technology, the remaining being unavailable as it is situated below a depth of 800 m . Thus groundwater is the largest source of fresh water on the planet excluding the polar icecaps 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 3000 times the amount in stream channels, at any one time (Raghunath, 1987). So it is very important to explorate groundwater which is a very precious commodity for crop production, drinking purpose and in industrial use etc. .

Utilisation of groundwater for irrigation purpose has many advantages over surface irrigation system. It does not need construction of any costly structure and there is no submergence of land resources as in case of surface irrigation schemes.It is not subject to any losses by evaporation or seepage. Since the farmer has to bear the cost of pumping, it is not applied in excessive quantities to the land, thus checks damage by way of water logging and salinisation. It creats no problem of displacement of human and animal population and no destruction of flora and fauna. It can be tapped at little cost by the farmer himself, unlike big storage projects which require many years and enormous financial investments before they come to function.

Above all, groundwater provides the farmer with a source of irrigation that is entirely under his own control thus enables him to irrigate his crops with proper quantity and in-time. It may be mentioned in this connection that on account of its dependability groundwater also lends itself beautifully to modern technologies like drip and sprinkler irrigation.

Enriched with abundance of water resources and vast expanse of fertile land, the coastal areas of the country have the maximum population concentration and are centres of urbanization, industrial growth and intensive agricultural activities. The strain on groundwater extraction in the coastal areas are obvious. Considering the above facts it can be well concluded that groundwater is the best option for irrigating land and increasing food production.Thus importance of groundwater exploration in coastal areas is obvious.

1.1 Groundwater Development

The contribution of rainfall to groundwater is influenced by the topography of the area, the depth of soil and its permeability and the nature of the vegital cover. Out of the annual volume of rainfall of 400 M ha-m in India, it is estimated that about 215 M ha-m infiltrates into the soil. A major part of it, amounting to about 165 M ha-m is retained as soil moisture, which is essential for growth of vegetation. Out of maximum utilisable irrigation potential of 113 M ha, 40 M ha is from groundwater and rest 73 M ha from surface water. The estimated utilisable groundwater potential of India is 41.85 M ha-m and the net draft is 9.99 M ha-m (23.88%) leaving a balance of 32.86 M ha-m (76.12%) of general water for future development (Anonymous, 1986).

Groundwater contribution to irrigated agriculture has increased from 4.0 M ha in 1911 to 6.5 M ha in 1951, where as it is increased rapidly to 28 M ha in 1984 (Anonymous,1986). The progress of irrigation development from groundwater is given in Table 1.1.

1.2 Groundwater Development in Coastal Tract of Orissa

The state of Orissa can be divide into four distinct areas where groundwater development can be taken up under geo-hydrological setup. The four areas are

(i) rainfed erosional plain,

(ii) rainfed alluvial plain,

(iii) coastal saline tract and

(iv) command area of flow irrigation projects.

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)	10.5
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)

The coastal saline tract is a narrow strip of alluvium bordering the Bay of Bengal on eastern side of the state. It extends over 5,000 sq.kilometers starting from the mouth of river Subarnarekha in north and continuing upto the lake Chilika in south. It includes a large number of swamps, sand bars and tidal rivers which intercept the tract at frequent intervals. In coastal areas one of the following conditions regarding groundwater occurrence prevails:

(i) a shallow fresh aquifer at top and saline aquifer below putting a constraint on groundwater extraction,

(ii) fresh aquifer at a greater depth and top aquifer is either brackish or saline, so proper sealing of top saline aquifer is required,

(iii) top layer is a fresh aquifer and a fresh aquifer is also encountered at a greater depth, according to requirement the screen should be given at proper depth.

1.3 Groundwater Resources of Puri District

The groundwater potential of Puri district, Orissa had been estimated by Central Ground Water Board (1988). The different irrigation structures present and groundwater resources of Puri district are given in Table 1.2.a and 1.2.b respectively.

Table 1.2.a Irrigation structures of Puri district

		No	C.C.A.(in ha.)
i)	Dug well with tenda etc	17,907	6,570 (i and ii together)
ii)	Dug well with pumps	724	
iii)	Shallow tubewells	789	2,930
iv)	Medium deep tubewells	7	50
v)	Electrical pumpset on dugwell and tubewell	1,245	
vi)	Diesel pumps sets on dugwell and tubewell	268	
vii)	Exploratory boreholes drilled by CGWB.	24	

[Source: CGWB report(1991).]

Table 1.2 .b Groundwater resources of Puri district

i)	Net annual groundwater recharge	:1,90,554 ha m.
ii)	Net annual groundwater draft	: 10,083 ha m.
iii)	Balance groundwater resources	:1,80,479 ha m.
iv)	No. of additional groundwater structures feasible	: 67,155 nos.
	a) Dugwells (energised)	: 63,070 nos.
	b) Borewells	: 2,655 nos.
	c) Shallow tubewells	: 1,200 nos.
	d) Medium deep tubewells	: 230 nos.
v)	Irrigation potential from groundwater resources	:1,67,280 ha.
vi)	Stage of groundwater development(1988)	: 5.2%

[Source: CGWB report(1991).]

From the above tables it is seen that groundwater utilisation for irrigation in the district is limited and the stage of groundwater development is only 5.2%. Thus there is enough scope for development of groundwater resources in the district not only for extending irrigated agriculture in all seasons, but also as an insurance against drought.

1.4 Coastal Handicapped Ecology

The Dictionary meaning of "ecology" is study of living organism (plants and animals) in relation to environment. But in case of groundwater study, coastal handicapped ecology relates to the study of problematic coastal environment in which ground water is to be exploited and used for better crop production.

The development and management problems of coastal aquifers are characteristically different from other aquifers because of their juxtaposition with sea water, as also its origin in marine depositional environment in the geological past. The delicate hydrochemical balance of salt water and fresh water requires a minimum flow of freshwater to sea. Overdraft not only depletes groundwater reservoir but brings in hazards of perennial decline of water levels, escalation of pumpage costs, reduction in well discharge, or drying of tube wells, deterioration in the quality of water, saline water ingress and in extreme cases land subsidence.

The coastal tract is called as coastal handicapped ecology as the coastal area has the inherent problems of water logging, salinity and sand dunes.

1.5 Objectives

Considering the above points like importance of ground water for irrigation , scope for development of groundwater in coastal area; to solve the problems of water logging, salinity etc. and to assess the good quality groundwater, studies were carried out in Puri Sadar block with the following objectives:

(i) to delineate shallow fresh aquifers and determining its depth, thickness, aereal extent and nature,

(ii) to demarcate the boundary of shallow fresh and saline aquifers,

(iii) to draw contours showing depth to the top and bottom of fresh aquifers,

(iv) to determine the nature of surface layer and its protecting capacity,

(v) to study the water quality of handpumps of the area and

(vi) to study the well-logging of few bore holes of the area.

CHAPTER-II

REVIEW OF LITERATURE

CHAPTER II

REVIEW OF LITERATURE

Groundwater is commonly understood to mean water occupying all the voids within the geological stratum. It constitutes one portion of the earth's water circulating system known as the hydrologic cycle (Todd,1980). Groundwater occurs in many type of geologic formations; known as aquifers which are generally areally extensive and may be overlain or underlain by a confining bed. The objective of any groundwater investigation is to evaluate the groundwater resources or to locate new areas to supplement the existing resources without creating undesired effect on hydrologic cycle. Exploration by test hole drilling involves high expenditure. Therefore prior to the actual drilling and construction of wells, it is necessary to know the nature of aquifers, their potential, geological characteristics, areal extension, their quality and quantity. The following paragraphs discuss about the history of groundwater assessment in India, research outcomes of different groundwater investigations in coastal tracts of India as a whole and Puri district in particular. It also discusses how geophysical approach was successful in assessment of groundwater-its quality and quantity.

2.1 History of Assessment of Groundwater Resources

Efforts to asses the water resources of India were made as early as 1901 by the First Irrigation Commission, followed by a similar assessment by Khosla (1949). These assessments were made for the entire water resources of the country, including the groundwater potential.

In India two agencies namely, the Geological Survey of India and Central Ground Water 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. With the merger of water wing of Geological Survey of India with the CGWB in 1972, these functions are being handled by the CGWB. Exploration by test drilling in the hard rock regions of the country, problems related to impregnation of coastal aquifers by saline waters, quantitative determination and budgeting of groundwater resources in arid, semi-arid and drought prone areas were also studied by CGWB. State Groundwater Directorates were established in 1963 whose functions are essentially to give support to the collection of hydrological information on day-to-day development programme, developing hydrological maps, engage in drilling and also initiate groundwater assessment studies in collaboration with the centre.

2.2 Geophysical Exploration

Geophysical exploration is the scientific measurement of physical properties of the earth's crust for investigation of mineral deposits or geologic structure(Kelly,1962 and Drobin,1976).

The prime aim in the coastal area has been to compliment the groundwater exploratory programme. It is employed to focus the target zone prior to drilling and to design the well properly to tap the fresh groundwater from mixed quality regime. Besides defining the sub-surface structure and lithology, it can identify the brackish/fresh groundwater interface, assess salinity stratification, demarcate area prone to sea water intrusion and many other interpretations(Chandra,1993) . In all such cases the application of geophysics is indirect and the purpose is to bring out a comparative picture of the anomalies and interpret them contextually.

2.2.1 Georesistivity survey

Georesistivity surveys are less expensive, and they are among the most widely used techniques in groundwater investigations(Swartz,1937; Bays,1950; Spicer,1952; Bhule,1953; Mc Ginnis and Kempton,1961; McDonald and Wantland,1961; Kelley,1962; Bierschenk,1964; Dudley et-al,1964; Zohdy,1965; Smith,1974; and Zohdy et-al,1974) . The method is particularly useful when combined with other studies, like areal photography, seismic surveys and test-well drilling. (Foster and Bhule,1951; McGinnis and Kempton,1961) . Underground cables, pipelines, transformers on power lines, metal fences and other conductors in contact with the soil interfere with the measurements and usually give erroneous results within the area of influence.

2.2.2 Groundwater assessment in coastal areas

East coast of India stretched over 3000 kms from Sunderban to the southern tip of Kanyakumari is rimmed by a ribbon of coastal and deltaic sediments. All along the east coast geophysical investigation were initiated in early sixties. While boundaries of the basin and sub-basins and the basement topography were demarcated by the seismic, the techniques of electrical resistivity was mostly used for assessing the quality of groundwater at shallow levels. Field examples from the coastal area illustrate the success as well as the limitations of the surface electrical resistivity technique and necessity of bore hole logging in confirming the non-conclusive findings and/or standardisation, and in designing the wells.

As a part of geophysical and hydrological investigation for groundwater in the upland areas of the west Godavari district, Andhra Pradesh, India, resistivity profiling was carried out along a 15 km stretch, with 70 observations spaced 200 m apart. After carrying out a preliminary study, it was found that the shallow aquifers occurred at depths of 15 to 20 m and the next deeper aquifers at depths of 50 to 60 m (Mathur and Bhimasankara ma,1976) . The significant results are of the coastal tracts of Pudukkottai district, Tamilnadu, where the occurrence of fresh aquifers in the cretaceous formation at depths of 250 to 350 m, immediately overlying the resistive crystalline basement was picked up by sounding (Chandra and RamKrishna,1979) .

In Ramanathapuram district of Tamilnadu, the sounding could pick-up the resistive crystalline basement at about 400m depth overlain by brackish water saturated zones(Chandra et -al,1982) .

In the coastal tracts of south Arcot district, Tamilnadu, which is mainly occupied by thick cuddalore sandstones of tertiary age, thick fresh groundwater zone associated with 29 ohm.m resistivity was delineated at 160 to 200 m depth right on the coast of Porto Novo(Chandra and Adil,1983) . It was confirmed by drilling and logging.

The results of deep resistivity sounding in the coastal tracts of East Godavari district, Andhra Pradesh reveal that while the entire depth section at most of the places along Bikkavolu-Tallaveru holds brackish groundwater, along Bikkavolu-Alamuru section the intermediate zone is saline, overlain and underlain by fresh groundwater zones(Chandra et-al,1983) .

At Auroville, towards north of Pondichery the cretaceous formation with 6 to 10 ohm.m resistivity hold potable quantity groundwater(Jaya Kumar et-al,1984) .

2.2.3 Groundwater interface

The occurrence of the interface and tidal water influence was identified by resistivity surveys in the coastal tracts of Tirunelveli district, Tamilnadu(Chandra and Ramakrishna,1979) . An interesting, successful and relevant application of resistivity survey was the delineation of fresh and saline groundwater pockets in the cyclone hit coastal tracts of Krishna district(Bhowmick et-al,1979). The similar studies were also taken in Cannanore district, Kerala(Chandra and Ramkrishna,1984) and in the coastal parts of Kerala under SIDA/CGWB Project(Ramchandran and Raman,1988) .

In the Coastal tracts of Midnapur district, West Bengal, between Haldia and Digha, the brackish/fresh groundwater interface could be delineated by deep resistivity surveys to a maximum depth of 300 m at Contai in the tertiary sediments. The fresh groundwater zones were delineated along the coast line also, by interpreting the surface resistivity data corroborated through geophysical logging results and quality of formation water(Chandra et-al,1989) .

2.2.4 Resistivity surveys in Puri 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 deep tubewells in the depth range of 300 m were constructed in parts of Balasore, Cuttack and Puri district(Radhakrishna and Dutt,1976) . This exploratory work paved the way for a realistic understanding of groundwater conditions, and a number of hydrological maps depicting the groundwater reservoir characteristics and their trends including the saline/fresh water relationship of the Orissa coast were prepared.

As regards earlier geophysical studies, the Oil and Natural Gas Commission(ONGC) carried out gravity and magnetic surveys in this region during 1965-68 (Sahid,1967-68) . Seismic studies, both refraction and reflection, by ONGC were carried out in parts of the Mahanadi delta during 1969-1974. Detailed seismic exploration in parts of the Mahanadi delta area were also taken up by Oil India Limited. Based on the gravity data, magnetic and limited seismic surveys, it was indicated that the basin is composite and comprises several basement depressions and ridges(Murty et-al,1973) .

Satapathy et-al(1976) carried out the electrical resistivity survey in some parts of Mahanadi delta covering also the Puri district for the delineation of fresh and saline aquifers by the National Geophysical Research Institute. Vast reservoirs of fresh water, supposed to be under unconfined to semi-confined conditions were discovered at shallow and moderate depths.

In year 1981 deep drilling(down to 600 m) was carried out in parts of coastal Orissa and number of wells including those of Agricultural farms, Puri and Sakhigopal were drilled in Puri district. The results revealed that fresh water and saline water relationship does not follow a fixed trend in the area and reversal in hydrochemical profile are noticed(Chakradar,1981). Under the Danish International Development Agency (DANIDA) assisted Orissa water supply project, very exhaustive groundwater exploration-cum-tubewell implementation programme has been done in the coastal area since 1985. According to Das and Sar(1989), in the narrow tract, close to the coast line extending from Chandaneswar in Balasore district to Brahmagiri in Puri district, Saline aquifers at several depths were encountered.

2.2.5 Electrical Logging

In electrical bore well logging very low values of resistivity of the order of 1.5 to 2 ohm.m represent the deterioration in quality of water only. Once the resistivity values are calibrated with clay content, water quality and formation temperature, the salinity stratification or iso-conductivity depth section could also be prepared(Lusczynski and Swarzenski,1966). According to Das and Sar (1989), in coastal Orissa the study of lithological and electrical logs and zone tests indicated occurrence of saline water, both above and below the fresh water.

2.3 Quality of Groundwater

Generally accepted criterion to judge the quality of groundwater for irrigation are total concentration of soluble salts(TDS), sodium adsorption ratio (SAR), residual sodium Carbonate (RSC), pH, electrical conductivity(EC) and presence of other elements and ions like boron, chloride, sulphate, florine, potassium and nitrates.

Scofield(1936) and Wilcox(1948) classified the groundwater on the basis of total salt concentration and soluble sodium percentage. Boron was also included as a factor for rating the suitability of water for irrigation, keeping in view its behavior with soil and plant. Kelly et-al(1940) suggested that the ratio of sodium to other cations(Ca^{++} and Mg^{++}) should not exceed one for good water.

Cassidy(1944) proposed index 'F'(Figures of merit) calculated by the ratio(Ca^{++} + Mg^{++})/(Na^{+} + K^{+}) in groundwater. A value of 0.5 or less was reported 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(EC) and sodium adsorption ratio(SAR), which is widely used as it takes into account both salinity and alkalinity hazards.

Duran(1955) in Algeria, Wilcox(1958) in USA, Kanwar(1961) and Ramamoorthy(1964) in India modified the classification suggested by USSL keeping in view the presence of high salt content in well water and its tolerance by crops.

Bernstich(1967) mentioned that a water has no inherent quality except for some extreme case, independent of the condition under which it is to be used and water quality can, therefore, be evaluated only in the context of a specified set of conditions including soil properties, irrigation management, climate and crops.

Rhoades(1972) pointed out that suitability of water for irrigation should be evaluated on the basis of its potential of creating soil conditions hazardous to crop growth.. He further concluded that water of a given quality may be suitable under one set of condion but unsuitable under another.

2.3.1 Groundwater quality in coastal aquifers

The major features of groundwater quality in coastal aquifers may be briefly catagorised as follows(Karantha,1987; Handa,1989):

(i) fresh water laterally grades into saline water either under water table or under semi-confined to confined conditions;

(ii) saline water underlies fresh 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 semi-pervious or impervious layer;

(v) fresh water aquifers alternate with saline water zones;

(vi) saline water percolates from the intermediate zone into the fresh water aquifer.

2.4 Closure of Review

Relevant geophysical investigations carried out in differnt parts of India and coastal tracts of India for assessment of good quality groundwater have been reviewed in the fore going pages. Also quality of groundwater for irrigation including the existing pattern of water quality regime in coastal ecology have been reviewed. 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 good quality groundwater in coastal areas in pockets and importance of groundwater exploration, this study can find a good scope to demarcate the area rich in fresh aquifer in Puri Sadar block.

CHAPTER-III

THEORETICAL CONSIDERATIONS

CHAPTER III

THEORETICAL CONSIDERATIONS

This chapter deals with different theoretical considerations needed for groundwater exploration. Out of many approaches for groundwater exploration, geophysical method is the most suitable method. The 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 electro-magnetic methods. Sub-surface method is by well logging method. Out of all these methods electrical resistivity method is suggested for groundwater assessment in coastal handicapped ecology for its advantages over other methods. So details of the electrical resistivity method is described in this chapter. Guidelines for getting different results and the interpretation of electrical survey data for assessment of good quality groundwater are also discussed in this chapter.

3.1 Groundwater Exploration

Groundwater exploration can be made through different stages like:

I. Reconnaissance,

II. Prospecting,

III. Development.

3.1.1 Reconnaissance stage

At this stage a geological map of the concerned area is prepared by thorough geological investigation as identification of different rock types, geological formations and the existing structures. If possible mapping of water table and aquifers are made. With the knowledge of possible hydrological situations of the concerned area under study, choice of most suitable geophysical method depending on the existing rock type and mode of occurrence of the aquifer is made.

3.1.2 Prospecting stage

Geophysical data collection and interpretation is made; correlation between the prevailing data and lithology and geological section is prepared 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 Electrical Method for Groundwater Exploration

The electrical methods of exploration for groundwater have got the greatest popularity among the other geophysical methods. The surface electrical methods are still widely used for regional and detailed surveys due to its low cost, wide range of applicability and well developed theory and methodology.

3.2.1 Electrical resistivity method

Resistivity method takes a significant role among the electrical methods. The resistivity of geological formations vary very widely. With the increase in water saturation in the rocks of formation resistivity decreases.

Resistivity variation in the sub-surface can be studied from the surface observations by two methods, i.e., profiling and vertical electrical sounding(VES).

3.2.1.1 Electrical profiling

Electrical profiling investigations are used for the study of the variations of apparent resistivities of rocks along a traverse on the earth's surface with a fixed distance between the current and potential electrodes. In a particular area electrode spacing for profiling work is selected on the basis of soundings conducted to give optimum response of the rock formation.

3.2.1.2 Vertical electrical sounding

Sounding can be carried out along profiles or in grid pattern and the station intervals are chosen according to the need of survey and complexity of the problem. Sounding carried out along different azimuths at a fixed place are called radial soundings, which allow the study of the main direction of fractures of joints, the variations in the degree of fracturing with depth.

By using above methods apparent resistivity values of the medium is obtained and from this one can know the lithological character of the sub-surface formations, their water bearing capacity with some degree of approximation.

3.2.1.3 Electrode configuration

Certain type of electrode configurations are followed for the electrical resistivity methods. They are

(i) Wenner array,

(ii) Schlumberger array,

(iii) Three point system,

(iv) Dipole-Dipole system and

(v) Lee configuration.

But wenner array and Schlumberger array are generally used.

(i) Wenner array (fig.3.1.a)

In the Wenner array, the separation between adjacent electrodes are equal and the apparent resistivity(ρ) is given by

$$\rho = 2\pi a (\Delta V/I)$$

where, a is the uniform separation in m,

ΔV is the potential difference between MN,

I is the current strength introduced into ground through AB.

(ii) Schlumberger array(fig.3.1.b)

In case of Schlumberger array, if 2L is the distance between AB and 2l is the distance between MN, then apparent resistivity(ρ) is $\rho = \frac{\pi}{4}\left(\frac{L^2 - l^2}{l}\right)(\Delta V/I)$

Theoretically, L>>l, but for practical application good results can be obtained if $L \geqslant 5l$.

3.3 Instruments and Accessories.

The resistivity surveys is done for assessment of groundwater and its quality. There are two types of instruments used in resistivity method. One is A.C. resistivity meter and other is D.C. resistivity meter.

i) A.C resistivity meter

In this type of equipment the resistance of the earth can be measured. Then apparent resistivity is calculated by

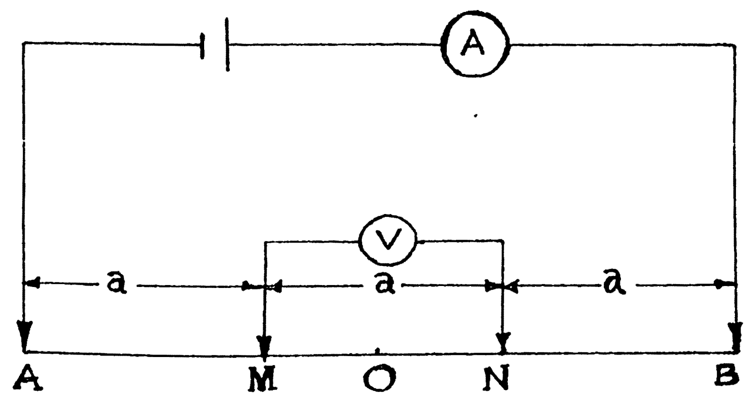


Fig. 3.1.a Wenner array

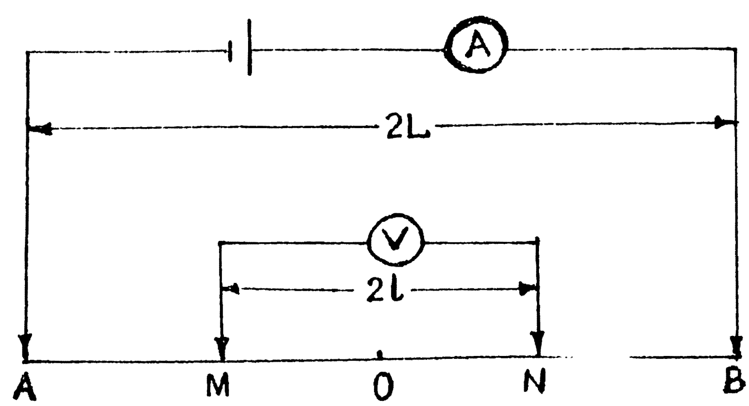


Fig. 3.1.b Schlumberger array

Fig. 3.1 Electrode configuration

formula,

$$\rho = K.R$$

where, K= Kernel function, depends upon electrode spacing,

R= Resistance of earth.

(ii) D.C. resistivity meter

In this type of equipment both the potential difference and the current through current electrodes are to be recorded. In this type of meter non-polarised electrodes are used, as potential electrodes. The apparent resistivity can be calculated by

$$\rho = K\,(\Delta V/I)$$

where, K is the kernel function depends upon electrode spacing,

$\Delta V/\Delta I$ =Resistance

The different accessories needed with the resistivity meter are current and potential electrodes , battery/generator, sounding cable sets, porous pot, copper sulphate etc.

3.4 Resistivity Survey Procedure and Data Collection

Under electrical resistivity method two types of investigations are done. One is vertical electrical sounding(VES) and other is electrical profiling.

In vertical electrical sounding method, the electrodes are generally arranged in Schlumberger method of array. A current is applied with the help of battery/generator through current electrodes. Depending upon the instrument either resistance is directly read or potential difference and current are read separately. From these readings apparent resistivity values are calculated. At a single vertical electrical sounding point apparent resistivities are calculated corresponding to different spread length. These apparent resistivity data are plotted on a bi-logarithmic graph paper on the spot taking spread lengths along abscissa and apparent resistivities along ordinate. Interpretation is done at home or office.

Electrical profiling is done to demarcate precisely the extent of fresh aquifers. Generally Schlumberger method of electrode configuration is followed. The half current and potential electrodes separation are generally kept as 50 m and 10 m respec tively. The observations are taken at 10 m station interval.

3.5 Interpretation

The interpretation of the vertical electrical sounding curves are done through the procedure of partial curve matching using the masters and auxiliary curve set (Orellana and Money ,1966) . VES data can be interpreted qualitatively and quantitatively as described in following paragraph.

3.5.1 Qualitative interpretation

Qualitative interpretation tells about the lithology, quality of formation water and water bearing nature of the formations. Before analysing the resistivity values in terms of lithology, water bearing properties of the layer and quality of formation water, they are correlated with subsurface data available from existing bore holes where some test sounding are conducted. 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 Table 3.1 is given as a guide line.

3.5.2 Quantitative interpretation

The quantitative interpretation of vertical electrical sounding is done to determine the thickness and resistivities of different layers from field curves. The interpretation is based on comparing the field curves with the curves obtained theoretically or constructed graphically, having suitably chosen parameters. [The master and auxiliary curve set developed by Orellana and Money ,(1966) are the theoretical curves]. 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 impossible to have an album of theoretical curves representing all geological conditions met in the field. So following methods are adopted by scientists to interpret different types of field curves by the help of available theoretical curves to determine the parameters of a geo-electrical section from the surface measurement of the apparent resistivity data.

3.5.2.1 Interpretation of two layer curves

Two layer VES field curves may be of two types

1) $\rho_2 > \rho_1$, and

2) $\rho_2 < \rho_1$

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 (p) on the ordinate and AB/2 along the abscissa.

Table 3.1 Qualitative interpretation of VES investigation.

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 with fresh water (Clayey aquifers).
21-50	Sand saturated with fresh water (moderate to granular aquifer).
80-150	Weathered khondalite.
More than 300	Khondalites.
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 sometimes well co-rrelated 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.]

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

The co-ordinates of the origin of the master curves read on the field curve gives the value of ρ_1 and $h1$. 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.

3.5.2.2 Interpretation of three-layer curves

Interpretation of three layer vertical electrical sounding (VES) field curves can be achieved with the help of available two and three layer master curves and the auxiliary point charts.

For interpretation of three layer field curves, the following procedure may be adopted.

I) After the completion of the curve, 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 co-ordinates. The co-ordinates of the origin of the master curve, 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, $\mu_2 = \rho_2/\rho_1$ can be read. Since ρ_1 is known, ρ_2 can be calculated.

II) Matching of the curves with three layer master curves consists of the following steps.

i) Choosing of the right set of three layer master curves from the knowledge of ρ_1, $\mu_2 = \rho_2/\rho_1$, already noted in the previous step and the most probable value of (guessed at).

ii)The three layer field curve is superposed with the point on the origin of the three layer master curve set chosen in step (II-i), 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 logarithm scale may be done, if necessary.

iii) 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_1, μ_2 (hence ρ_2), ν_2 and ρ_3 are obtained, and the problem is then solved, since $h_2 = \nu_2 \times h_1$.

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

i) 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.

ii)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 .

iii) Now this point (h_e, ρ_e) is put on the origin of the two-layer master curves, and the right-hand part is matched with the suitable, two-layer curve, which gives ρ_3/ρ_1 .

Since ρ_e is known is step(III-iii), ρ_3 is calculated.

This gives a check on the value of ρ_3 .

(IV) The following procedure is recommended if the three layer curve for requisite parameters is not available and the principle of equivalence is applicable.

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

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

iii) The actual value ν_2' is obtained by the principles of equivalence, i.e. by keeping S_2/S_1 (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 "auxiliary point charts"- is recommended.

i) The values of ρ_1, h_1 and ρ_2 are found from the two layer master curves, as explained in step I.

ii) The last part of the curve is matched with a two-layer master curve. Put a cross-mark on the field curve, corresponding to the origin of the set of master curves. This gives ρ_e and h_e .

iii) The point (h_1, ρ_1) is marked on the origin of the auxiliary point charts and the value ν_2 is read corresponding to the cross-mark.

iv) From the knowledge of H_1, h_2 is obtained from ν_2.

If the bottom layer is a highly resistive basement, one can adopt the simplified procedure for interpretation - qualitative interpretation.

3.5.2.3 Interpretation of four-layer curves

Interpretation of four-layer field curves consists of the following steps:

(I) With the help of two-layer master curves, as in the case of three-layer interpretation, the values 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(I) and a suitable choice of ρ_3, the value of ν_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 thickness of the reduced layer, i.e. ρ_{e1} and h_{e1}, 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 ρ_{e1}, h_{e1}, ρ_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. The procedure for the rest of the curve is similar to that of a three-layer case.

3.5.2.4 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 more complicated if the number of layers are more.

[Source: "Master Tables and curves for VES over layered structures" by E.orellana and H.M. Mooney, 1966]

CHAPTER-IV
MATERIALS AND METHODS

CHAPTER IV

MATERIALS AND METHODS

This chapter deals with the description of study area including it's location, physiography, hydrometeorology, hydrology, geology, hydrogeology and hydrochemistry etc. It also describes about the instruments and accessories used for electrical resistivity survey, survey procedure, methods of field data collection and interpretation of the vertical electrical sounding data. Lastly it describes about other method of groundwater exploration i.e. electrical logging; how the electrical logging data were correlated for interpretation of vertical electrical sounding data and water quality report of handpump water of Puri Sadar block. In a broad sense, this chapter tells about the materials needed and methodologies applied for carrying out the research work for obtaining meaningful results.

4.1 Description of the Study Area

The study area comes under the Agro-climate zone of east and south-eastern coastal plain of the state. Physiographically the zone is located in the coastal belt and has an average elevation of 3 to 4m from the mean sea level with flat topography. The details of location, physiography, drainage, soil, land use, climate, rainfall, evaporation and evapotranspiration, hydrology, geology etc. are described in the following paragraphs.

4.1.1 Location

The location of study area is $19^{o}.46'$ to $19^{o}.57'$ north lattitude and $85^{o}.45'$ to $86^{o}.0'$ east longitude. The study area constitutes major portion of Puri Sadar block. Bay of Bengal lies in the south-eastern side of Puri Sadar block. Gop block, Satyabadi block and Brahmagiri block are neighbouring blocks respectively in eastern, northern and western side of Puri Sadar block. The location map of the study area is given in fig.4.1.

4.1.2 Geomorphology

Geomorphology deals with phisiography, drainage, soil and land use of the study area. These are described 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 also forms parts of the delta portion of the Mahanadi delta system. The landscape is generally plain to gently sloping with local variations in micro-relief. The study area suffers from triple problems of water logging, salinity and sand dunes. Level marshy lands prone to water logging for 2-6 months in rainy and post-rainy season are met. The coastal strip is covered by dune sands, where the topography becomes slightly undulating. These sand dunes are formed by wind action and slope gently towards sea and steeply towards inland.

4.1.2.2 Drainage

The study area includes two swampy zones namely Samang lake and Sara lake , sand bar and sand dunes. After the onset of

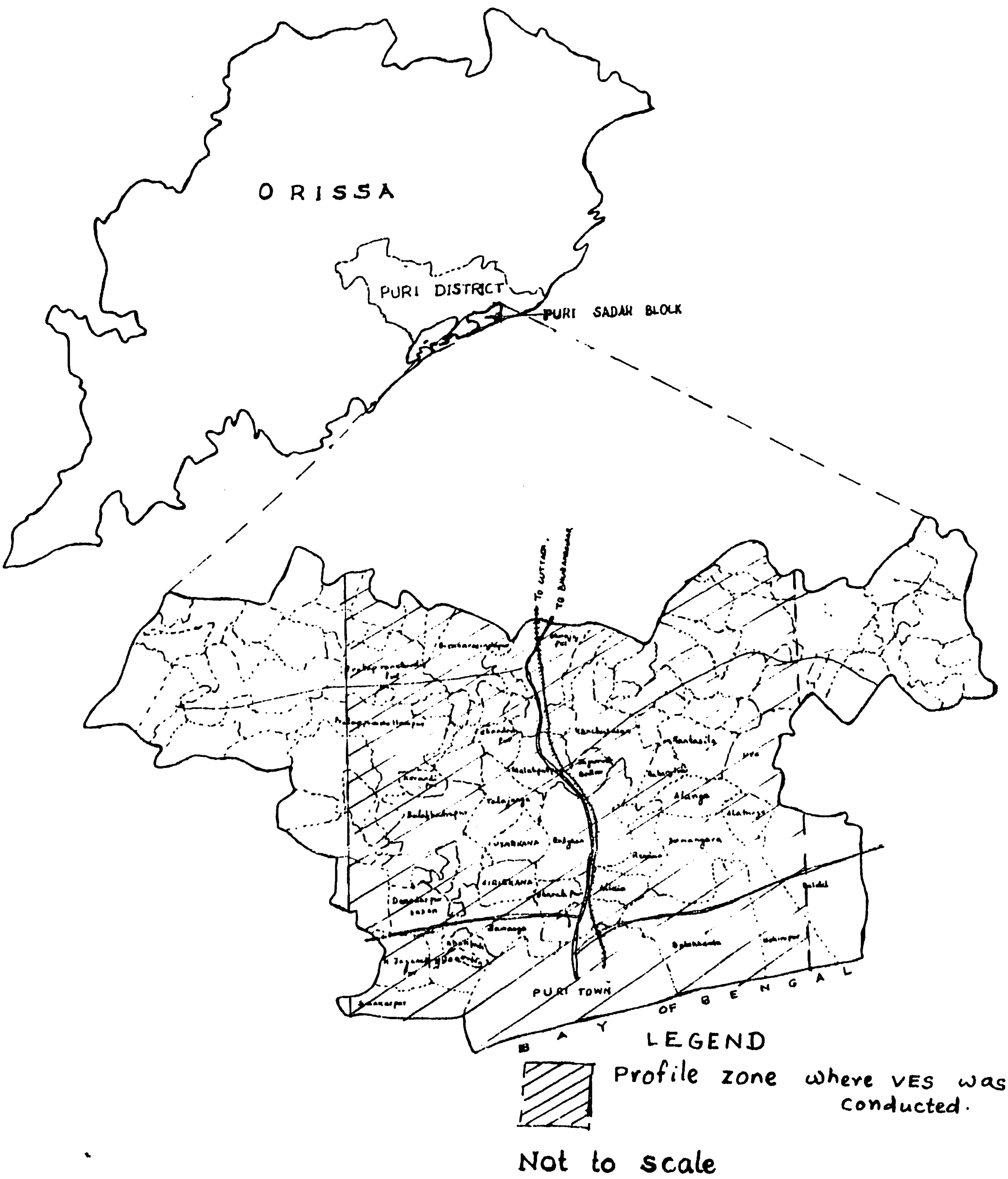


Fig. 4.1 Location map of Puri sadar block

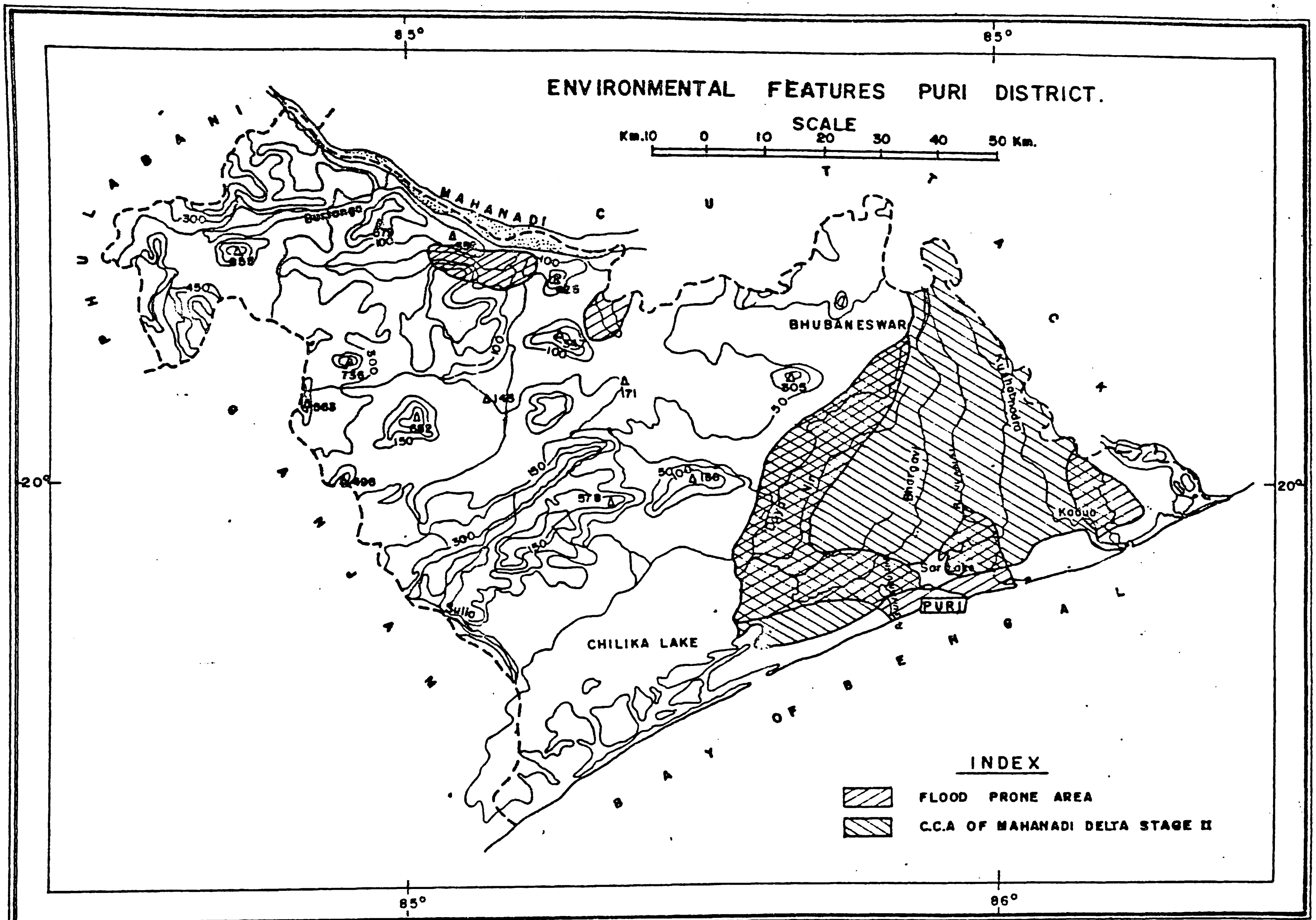
monsoon rain in the 2nd week of June, most of the area gets completely inundated to a depth varying from 1m to 3m due to lack of adequate drainage system.

The opening of Samang lake to the sea through the river Sunamuhin and that of Sara lake to the sea through the river Nuanai are too inadequate to keep these areas free from water logging. The other major rivers in the area are river Bhargabi and river Ratnachira flowing in western periphery of Puri Sadar block. The environmental features and drainage of Puri district are shown in fig. 4.2.

4.1.2.3 Soil

Soils form through the interaction of the major soil forming factors, i.e parent material, climate, biotic action, topography and time. The climate and the vegetation are the active forces and the topography modifies them. In the Puri district there are four types of soils. These are alfisols, ultisols, aridsols and entisols. But in study area the soils are mostly aridsols and entisols.

Aridsols: These are saline and saline alkali soils found along the coast. These are enriched with litheral deposits and blown sands. These soils can be reclaimed by making bunds which can prevent ingress of sea water. The sluices are constructed to allow the escape of rain water which can gradually wash away the salts from the soil. These soils are rich in calcium, magnesium and also contain half decomposed organic matter. These soils when reclaimed are rich in plant nutrients and can support a good crop of rice.



CGWB(SER), [illegible] 070, (A.DALAI).

Fig 4.2

Entisols: These include younger alluvial soils along western parts of Mahanadi delta and coastal alluvial and sandy soils occuring along coastal tract. These soils are deficient in nitrogen and phospheric acid and humus but not in potash and lime. The pH values are on the alkaline side. the texture varies from sandy to loamy sand. These are most fertile soils and can produce a wide variety of crops. The soil map of Puri district is given in fig. 4.3.

4.1.2.4 Land use

The study area has table land consisting of newer alluvium with finer deposits. It is occupied by agricultural land all along. Along the sea coast a strip varying 1 to 2 km. width is full of forest trees like casaurine, eucalyptus, cashewnut etc. . Horticulture is one of the main activities in the area. The principal fruit crops are coconut, mango, sapota, cashewnut, bannana and popaya. The study area includes two swampy zones namely Samanga lake and Sara lake, sand bar area and sand dunes. About 3288 hectares of area available for cultivation in Samang lake, and 950 hectares of land remains fallow due to water logging and flood during kharif season. In Sara lake 3012 ha of area available for cultivation and 1250 ha of land remain un-cultivated during kharif due to water logging and flood. The area with sand dunes, sand bar and sand tract occupy nearly 1635 ha. it occurs mainly as a narrow strip between the sea coast and the low lying swampy area(Appendix- II).

4.1.2.5 Cropping pattern

The area is blased towards cereal crops during kharif

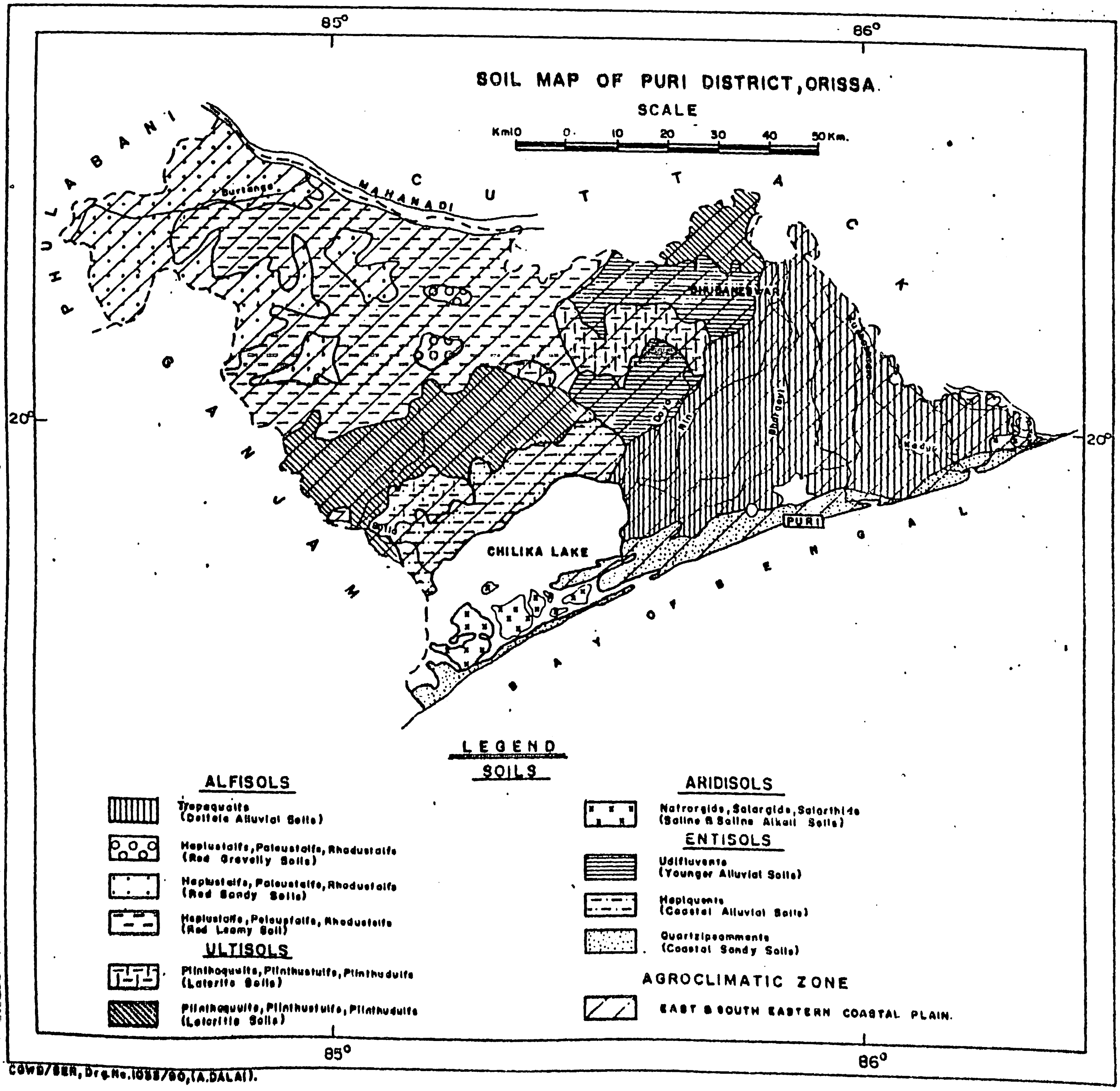


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Fig 4.3

followed by pulses, oil seeds and vegetables during rabi. Sugar cane is sparsely grown. Among the pulses blackgram and greengram are dominant where as groundnut is significant in the family of oil seeds. Yield rates of paddy, kharif and rabi are found to be 12.85 and 18.01 quintals per hectare. Where as yield rates of mung, groundnut and mustard are found to be 3.98, 13.0 and 4.16 quintals per hectare (Anonymous, 1993).

4.1.3 Hydrometeorology

Under hydrometeorology the climate, rain fall, evaporation and evapotranspiration of the study area is described.

4.1.3.1 Climate

Tropical monsoon climate having three marked seasons in a year, namely, winter, summer and rainy seasons prevail over the district of Puri. Winter season has a short duration and usually starts from November extending till the middle of February. It is followed by summer season lasting upto the middle of June. A series of norwesters characterised by heavy rains for short spells are usually witnessed between the months of March and May. The rainy season begins with the arrival of south-west monsoon by mid of June and continues upto middle of October. The mean daily maximum temperature during heat season is 35.0 ^{o}C and during the cold season it is only 17.1 ^{o}C. The relative humidity shows 72.75% in average being 88.29% in morning and 56.88% in afternoon. Mean wind speed is 15.3 km./hr at Puri.

4.1.3.2 Rainfall

The mean annual rainfall for Puri is 1488 mm with highest rainfall of 2221.5 mm (1991) and lowest rainfall of 1071.4 mm (1987) about 74% of annual rainfall is received from south-west monsoon during June to September with maximum rainfall in July. Mean monthly rainfall during rainy season varies from 168 mm to 322 mm. Average number of rainy days in a year are 71.

4.1.3.3 Evaporation and evapotranspiration

The mean daily evaporation is assesed to range from 3.3 mm (December) to 9.3 mm (May).The mean annual evaporation is estimated to be of the order of 1877.6 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 occu-rrence, circulation and distribution of water of the earth and earth's atomosphere.

Besides the drainage system of the area a large number of ponds with different dimensions occur in the area. These ponds do not have well defined streams feeding them, and generally derived their storage due to or through inundation/run off from the areas around. The ponds are generally of small capacity. Also there are number of dug wells and tubewells in the area.

4.1.5 Geology

It is of recent origin, the soil has developed from alluvial deposits. The recent and sub-recent alluvium is largely made up of sand, silt, clay and gravel of varying age groups. Part of alluvial deposits are characterised by the deposition of finer aggregates which could have their marine origin as also evidenced by occurrnce of fossils. With the transgression and regression of the sea and deltaic sediments getting deposited, the inter fingering of marine and river borne alluvium could also be infered to have taken place. The thickness of alluvium increases towards the coast.

Sand dunes of varied relief occur adjacent to coast line. Dunes are found by wind blown sands and often run for long distances parallel to the coast. The depth to basement, as infered from earlier investigation, may about 1500 m near the coast.

4.1.6 Hydrogeology

In the major part of the area medium to coarse sand and fine gravel zones of varying thickness form the main water bearing formations. These aquifers are often extensive. In general a multistoried aquifer system exists. The top aquifer, occuring under water table conditions consists of river sand, dune sand and other grannular materials. This shallow aquifer has potential to provide continuous supply at some places; e.g. the water supply of the Puri township is based on this aquifer. The thickness, depth as well as deterioration of the water quality of aquifers increases towards the coast. The study area encompasses the hydrogeological areas with following three different aquifer profiles in regard to salinity:

i) shallow fresh water above saline water,

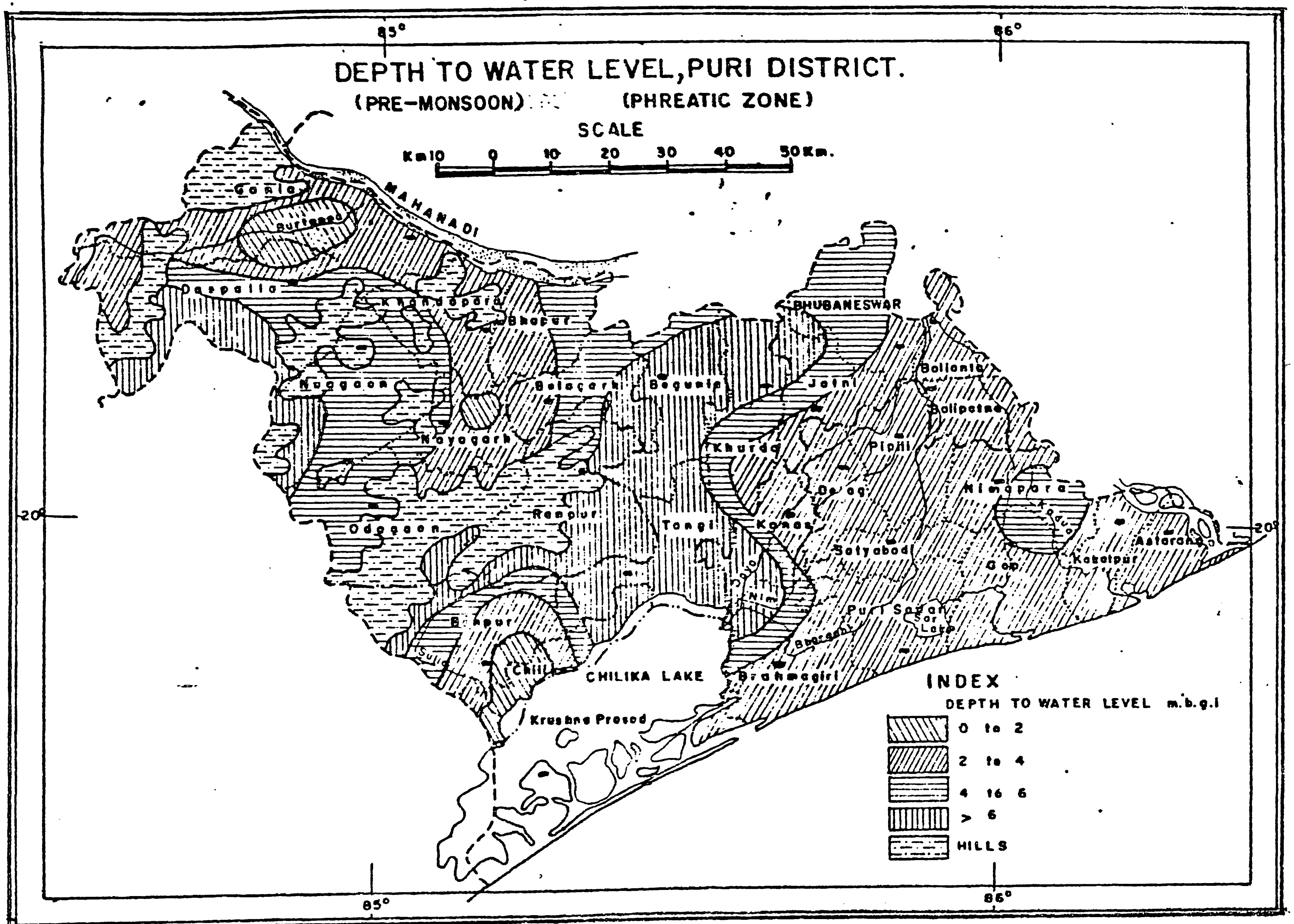
ii) shallow fresh water above a thick saline zone and fresh water aquifer under and

iii)thick saline zone above a fresh water zone.

The measurement of aquifer parameters in the area has been carried out to a very limited extent. Some pumping tests are carried out in the area (Car Bro,1989) . The test result 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) . The average discharge of the small diametre wells with 4.0m strainer length is reported to be of the order of 0.2 to 2.0 l/s for maximum draw down of 24.4 m. As per the esti mation, the transmitting capacity of the aquifers decreases towards the sea (Kittu et-al ,1983) . Depth to water level below ground level varies 2 to 4 m in pre-monsoon period and 0 to 2 m in post-monsoon period. The depth to water level below ground level of Puri district is given in fig. 4.4 for pre-monsoon and in fig. 4.5 for post-monsoon period.

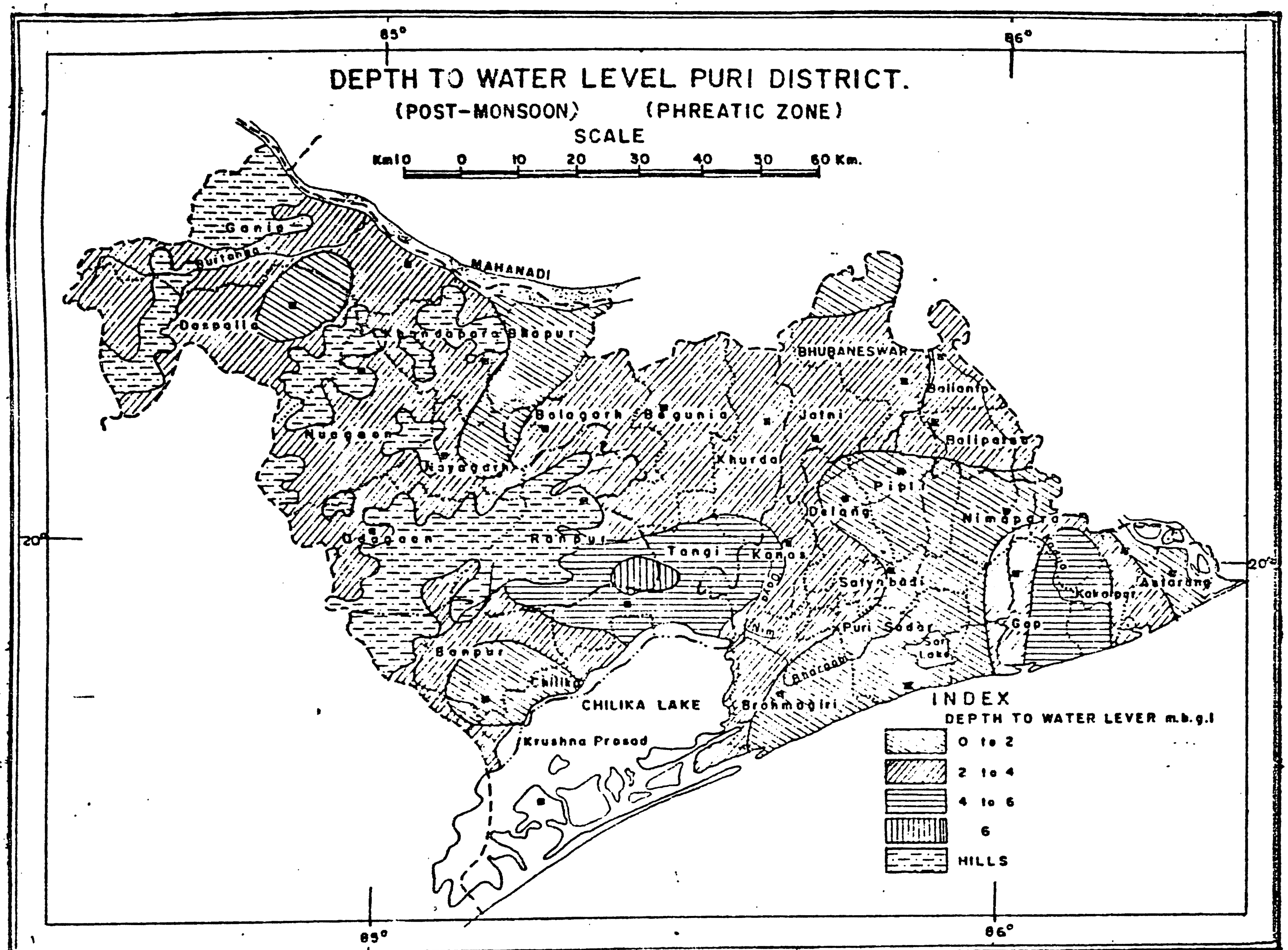
4.1.7 Hydrochemistry and water quality

The water quality is found to vary widely in the area. There is increasing degree of deterioration in water quality from inland to coast. However, the shallow aquifers at Puri town is found to yield water of reasonably good quality and is relatively free from iron. The highest electrical conductivity(EC) value of 10170 ms/cm and chloride = 3005 mg/l was observed (Naiguen) resulting probably due to mixing with saline aquifer waters in the handpump water in this block, but in most of the samples the EC value was less than 3000 ms/cm corresponding to chlorides less



C.G.W.B.(S.E.R.)Drg.No 1069/90 (G.D.Patra)

Fig. 4.4



C.G.W.B. (S.E.R.) Drg. No 1061/90 (G.D. Patra)

Fig. 4.5

than 1000 mg/l. However the prevalence of high soluble ferrous iron content is not so significant. The Hydrogen sulphide was encountered in some handpump waters.

4.2 Instrumentation

The ABEM Terrameter SAS 300 was used for vertical electrical sounding and electrical profiling in the study area. The specification, description of the instrument, accessories needed and operation of the instrument are given in 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.	160 V (320 V P-P)
Receiver voltage measurement:	Input impedence	10 M ohm, min
	Input ranges	1, 10, 100, 500 V
	Precission	±0.00001 V (1V range)
	Noise rejection	95 dB at 50-60 Hz 85 dB at 16-20 Hz
Receiver resistivity measurement:	V/I ranges	1 ohm,100 ohm,10 kohm 1 M ohm
	V/I precission	0.0005 ohm (1 ohm range, 20 mA, one reading)
System data :	Selectable cycle times	3.6,7.2,14.4 seconds
	Selectable total averaging period (1-64 readings)	3.62-920 sec.
	Accuracy.	± 2 % + precission
Temperature range:	Within specification	0........+ 60 c
	Operating	-10......+ 70 c
Power supply :		Rechargeable 12 V battery
Battery capacity:		3500-5000 single cycle measurements per charge.
Weight:		5-6 kg incl. battery
Dimensions:		W x L x H 105 x 325 x 300 mm.

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

iii) Desiccator Cartridge - The desiccator cartridge that screws into the lower right hand corner of the control panel helps prevent moisture from attacking the circuitry inside the instrument.

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 interpret the displayed information.

4.2.3 Accessories

The different accessories required along with the instrument to conduct the resistivity survey are given below.

i) NI-Cd battery pack : The instrument was provided with rechargeable nickel-cadmium(Ni-Cd) battery pack that clipped conveniently onto the bottom of the instrument.

ii) Steel electrodes : Resistivity surveys were conducted using current electrodes and potential electrodes made of stainless steel.

iii) Sounding cable set: The sounding cable set consists of :

Current cables : Wound on two separate plastic reels, each containing 750 m lengths of 1 mm^2 wire.

Potential cables: Two separate 50 m lengths of 1 mm^2 wire wound in parallel on a single reel that 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 followed(Table 4.1). For the 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(M and N). terminal P_1 and P_2 were connected to M and N respectively with ABEM sounding cable set with the conductors separated at the electrode end.

- The current electrodes(A and B) were connected to terminals C1 and C2 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 'MEASURE' button was pressed.

If every thing was satisfactory, the measurement procedures were started automatically and when measurement was complete, the result was displayed on the display.

If any error code appeared on display, then corresponding corrections and checkings were made following 'ABEM -Terrameter SAS 300 operating manual'.

4.3 Electrical Resistivity Survey Procedure

For assessment of groundwater, shallow vertical electrical sounding (VES) had been conducted in a profile zone employing the Schlumberger configuration of electrodes, with maximum current electrode separation of 300 m. The VES were conducted roughly along the cross sections running across the profile zone extending upto 2.5 km on either side of Puri-Sakhigopal road(Fig. 4.6). The VES were sited mainly towards the outer 1 km strips on either side of the profile zone considering that its central strip will be filled up with deep VES, and the VES to be conducted at the sites of investigation and observation boreholes. However, shallow VES in the central part were also carried out, wherever the VES on either side of the main road showed considerable variations. All the VES points with their alignment are shown in (fig.4.6).

The VES were conducted deploying the ABEM 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

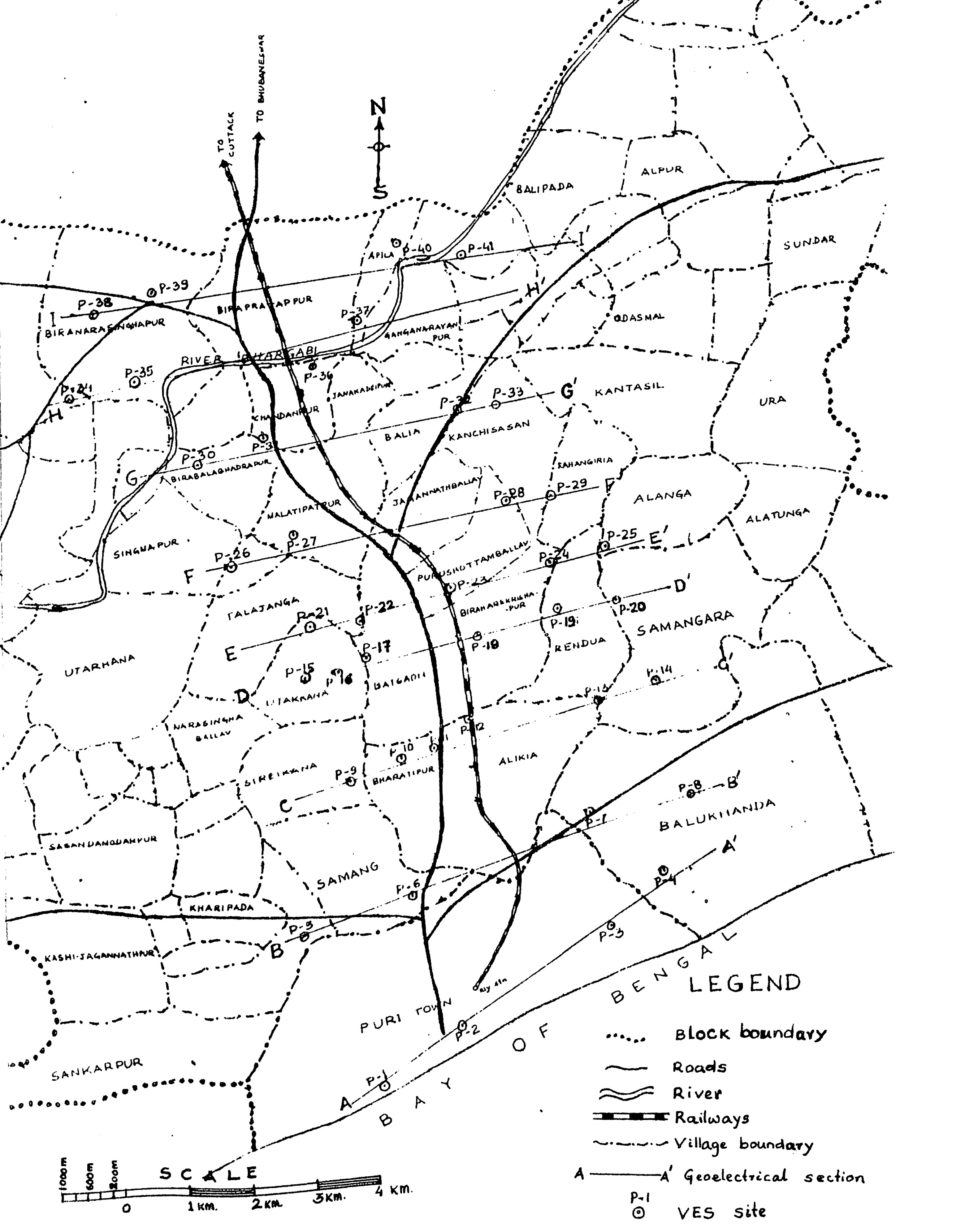


FIG 4.6 ALLIGNMENT OF VES POINTS

Resistivity profiling was also carried out in the study area. One resistivity profile with Schlumberger configuration of electrodes was carried out to demarcate precisely the extent of fresh aquifers near Mangarajpur. The half current elec trode separation(AB/2) and potential electrodes separation (MN/2) were kept at 50 m and 10 m respectively. The observations were *taken out 10 m station interval. Total 56 no. of observations were taken traversing a total length of 650 m(Fig.5.6).*

4.4 Collection of Electrical Resistivity Field Data

The vertical electrical sounding data which are incorporated in this thesis were collected by the help of "Hydrogeological Investigation Unit" of Rural Water Supply and Sanitation department, Government of Orissa , Bhubaneswar.

In the area where VES were conducted, 9 sections were considered. The total number of VES points were 41. The Schlumberger field lay-out plan is given in table 4.1. At a single VES point the resistance values corresponding to different spread lengths were noted. The apparent resistivities(ρ) corresponding to different spread lengths were calculated by the formula:

$$\rho = K.R$$

where K= Kernel function depends upon spread length,

R= Resistance,

Then graphs taking spread lengths (AB/2) along abscissa and

Table 4.1 VES data sheet

Sl. no.	AB/2 (m)	MN/2 (m)	K	R (ohm)	ρ (ohm.m)
1	1.5	0.5	6.28		
2	2.0	0.5	11.80		
3	3.0	0.5	27.50		
4	4.0	0.5	49.40		
5	4.0	1.0	23.50		
6	6.0	1.0	54.90		
7	8.0	1.0	99.00		
8	8.0	2.0	47.12		
9	10.0	2.0	75.00		
10	15.0	2.0	173.00		
11	15.0	5.0	62.83		
12	20.0	5.0	118.00		
13	25.0	5.0	188.50		
14	30.0	5.0	274.80		
15	40.0	5.0	494.50		
16	40.0	10.0	235.62		
17	50.0	10.0	376.80		
18	60.0	10.0	549.50		
19	60.0	20.0	251.32		
20	80.0	20.0	471.24		
21	100.0	20.0	753.60		
22	150.0	20.0	1735.73		
23	150.0	50.0	628.32		
24	200.0	50.0	1178.00		
25	250.0	50.0	1884.96		
26	300.0	50.0	2748.89		
27	400.0	50.0	4948.00		
28	400.0	100.0	2356.19		
29	500.0	100.0	3769.91		

corresponding apparent resistivities along ordinate were plotted on the spot on transparent bi-logarithmic papers (62.5 mm modules). These points were then joined by smooth curves. These curves were then used for interpretation.

In case of electrical profiling the current electrode separation was 100 m and potential electrode separation was 20 m fixed, i.e., AB/2 = 50 m and MN/2 = 10 m. the resistances were noted at 10m station interval . The corresponding apparent resistivities were calculated 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/brackish zone was determined.

4.5 Interpretation of Vertical Electrical Sounding Data

The shallow vertical electrical sounding curves which were plotted in the field were interpreted later to find out the layer parameteres including the thickness of different layers and their corresponding resistivities. These interpretations were also done to know the thickness of fresh aquifer, depth to fresh aquifer, nature of surface layer, their protecting capacity and depth to water table. Interpretations were done by matching the field curves with master and auxiliary curves, developed by Orellana and Mooney(1966) (Art.3.5).

4.6 Electrical Logging

A number of tubewells were drilled by DANIDA for drinking water purpose in Puri Sadar block. In those tubewells electrical logging were done by DANIDA to find out the lithology of aquifers and also to find out the quality of water at different depths of drilling. These data were collected from RWSS department of Orissa government. These data tells about the depth ofdrilling, and the water quality(fresh/saline/brackish) encountered at different depths of drilling. The result is described in Subsequent chapter.

4.7 Water Quality of Study Area

Handpump waters of Puri Sadar block were analysed by DANIDA for determining the iron and chloride content. All those handpump waters are used for drinking purpose. So only the iron and chloride content data are available. Also the total depth of drilling, the position and length of screen provided were collected. All these data were correlated while doing the qualitative interpretation of VES. These results are given in subsequent chapter.

CHAPTER-V

RESULTS AND DISCUSSIONS

CHAPTER V

RESULTS AND DISCUSSION

Georesistivity sounding was done in a profile zone for assessment of good quality groundwater in Puri Sadar block. Electrical profiling was also done to demarcate the fresh aquifers precisely. Well logging data of some boreholes of Puri Sadar block were also used for supporting the interpretation of georesistivity sounding. The water quality report of handpump waters used for drinking purpose were also collected. The results obtained from all above observations are discussed in the following paragraphs.

5.1 Georesistivity Sounding

Vertical electrical sounding(VES) was carried out at 41 points which passed through 9 sections of the study area. The configuration in which VES was carried out is shown in Fig 4.6. The interpretation of VES data gives two type of results (i) quantitative results and (ii) qualitative results.

5.1.1 Results of shallow VES (Quantitative interpretation)

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

In Table 5.1 column (1) is for vertical electrical sounding number. Since there are 41 VES sites, these are named as P-1, P-2,.....P-41. Column (2) tells about the location of the

VES site. Column (3) to (8) tell about the resistivity of different layers in ohm.m, e.g p1 indicates the resistivity of land surface. Similarly p2, p3, p4, p5 and p6 indicate the resistivity of 1st, 2nd, 3rd, 4th and 5th layer of aquifer respectively. Also h1, h2, h3, h4 and h5 represent the thickness in meter of 1st, 2nd, 3rd, 4th and 5th layer respectively.

For better understanding of the table, one VES site, namely P-8 is explained in detail. Location of P-8 is in Baliguali village. Here p1 = 824 , p2 = 64, p3 = 42, p4 = 60 and p5 = 10 in ohm.m. So the resistivity of land surface is 824 ohm.m. The resistivity of 1st, 2nd, 3rd and 4th layer is 64,42,60 and 10 ohm.m respectively. The thickness of 1st, 2nd, 3rd and 4th layer is 1.1, 1.3, 5.3 and 28.0 m respectively. These quantitative interpreted results of shallow VES lead to qualitative results.

5.1.2 Results of shallow VES (Qualitative interpretation)

Shallow 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 (p1) tells about the nature of surface layer. This interpretation is supported by visual observation of top soil at VES sites. When resistivity of a layer is more than 20 ohm.m (Table 3.1), the layer is assumed to be a sandy aquifer saturated with fresh water. Thus the depth to 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 to water table are given in

Table 5.1 Results of shallow VES (Quantitative interpretation)

VES No.	Location	Layer parameters										
		Resistivities (ohm.m)						Thickness(m)				
		P1	P2	P3	P4	P5	P6	h1	h2	h3	h4	h5
P-1	Swargadwar	10	2	7	16	29	8	1.2	2.7	1.8	2.7	18.1
P-2	S.C.S. College (Puri town)	E	R	R	A	T	I	C	D	A	T	A
P-3	DANIDA office (Puri town)	6600	726	220	67	9		3.3	1.5	17.7	10.6	
P-4	Pump House (Puri town)	17000	1600	500	258	157		2.3	1.0	12.1	17.7	
P-5	Mangalahat	90	40	65	23	5		1.5	5.6	15.5	10.5	
P-6	Khandiabandh	8	18	31	44	25	6	2.0	2.4	9.4	6.5	9.5
P-7	Balighat	90	70	30	50			1.3	1.6	6.3		
P-8	Baliguali	824	64	42	60	10		1.1	1.3	5.3	28.0	
P-9	Kripasagarpatna (Near Samanglake)	5	8.5	6	1			2.0	4.4	23.4		
P-10	Kripagarpatna	3	4	2	5			1.8	6.7	31.2		
P-11	Mangarajpur (Betn. P-10 & P-12)	7	3	8	12	4		1.0	2.3	3.8	8.3	
P-12	Mangarajpur	6	8	12	19	14	3	1.8	4.0	2.7	9.8	8.5
P-13	Nuapatna	2.5	5.5	12	40	10		2.7	1.2	1.9	21.0	
P-14	Pokharimura	62	22	31	15	32	18	0.8	0.8	3.5	6.0	22.7
P-15	Uttarakana	300	31	17	26	19	2	1.4	0.7	2.4	26.0	14.2
P-16	Nuagaon (Betn. P-15 & P-17)	560	11	12	10	3	2	1.2	2.7	1.8	2.7	18.1
P-17	Nuagaon	16	3	7	2	6		0.9	3.5	5.0	20.4	
P-18	Biraharekrishna Pur	44	9	20	45	29	4	0.9	1.1	2.4	9.4	6.5
P-19	Panchamuhan	27	21	24	12	3		1.5	3.3	10.6	7.2	
P-20	Rendua	37	18	6				2.3	2.5			
P-21	Talajanga	23	12	17	3			2.0	4.3	13.6		
P-22	Nuagaon (North part)	12	6	3	5	3		0.8	0.3	4.1	11.4	
P-23	Malatipatpur	11	8	11	8	6	1	1.5	1.8	3.8	15.5	10.5
P-24	Rahangiria (Towards north)	16	9	14	25	4		1.6	3.5	2.4	16.3	
P-25	Rahangiria (Towards N.E.)	22	10	4.5	9	6	2.5	0.8	0.3	6.4	8.7	7.6
P-26	Singhmapur	9	14	6	2	8		1.5	5.6	3.4	12.6	
P-27	Tulasichaura	7	2.5	5				0.8	2.8			
P-28	Purusottamballabh (N.E. of village)	15	20	17	11	5	2	1.2	4.5	2.7	3.9	5.8
P-29	Purusottamballabh (S.E. of village)	28	12	6	9	6	2	0.8	0.4	1.4	9.7	5.7
P-30	Tikarsarbha	25	35	20	8	11	2	1.5	3.4	2.2	8.3	17.7
P-31	Birabalabhadra Pur	23	7	11	14	8	1	0.8	6.7	3.6	5.2	7.2
P-32	Peteipur	5	3	7	12	6	2	1.7	3.6	6.0	13.1	11.4
P-33	Kanchi Sasan	14	30	18	10	13	4	1.4	2.9	2.0	7.2	6.4
P-34	Biranarasingha Pur(West of village)	4	9	18	13	3	5	1.5	0.2	2.5	2.2	14.9
P-35	Biranarasingha Pur(Close to village)	7	3	2				1.5	13.9			
P-36	Birapratap Pur	63	18	13	10	1		1.1	1.3	5.3	3.6	
P-37	Ganganarayan Pur(In the village)	8	5	3	7	11	4	0.9	1.1	2.8	4.4	4.3
P-38	Karari	2	1.5	3	2			1.3	7.3	18.5		
P-39	San Tentulia	12	3	2	3	4		0.7	3.8	9.6	30.6	
P-40	Ganganarayan Pur	110	14	8	4	1		1.5	1.8	3.8	26.0	
P-41	Barabari	20	10	2	5.5	2		1.1	2.2	12.1	17.7	

Table 5.2. For better understanding of the result presented in Table 5.2 one VES site P-8 is explained in detail (Art 5.1.1). The depth to 1st, 2nd, 3rd and 4th layer from land surface is 1.1, 2.2, 7.7 and 35.7 m respectively.The depth to water table is found to be 2.9 m below ground level. The top layer resistivity is 824 ohm.m, which represents the nature of surface layer is dry sand(Table 3.1) having weak protecting capacity. The resistivities of 1st, 2nd and 3rd layer lies between 42 to 64 ohm.m. As per Table 3.1 these values indicate the aquifer to be a sandy aquifer saturated with fresh water. Thus the depth to top and bottom of fresh aquifer is determined. The thickness of fresh aquifer is determined by subtracting the depth to the top of fresh aquifer from depth to bottom of fresh aquifer. In this case the depth to fresh aquifer is 3.0 to 35.7 m and hence the thickness of fresh aquifer is 32.7 m. Nature of Surface layer and protecting capacity of overburden as presented in Table 5.2 are explained in detail in section 5.7 and 5.8 respectively.

5.2 Type Curves

Fourty-one VES carried out in the study area gave 41 curves between resistivity in ohm.m verses electrode spacing (AB/2), or depth in meter of aquifers. From amongst these 41 curves, total of 4 having identified to represent the various hydrogeological conditions encountered in the area. These 4 type curves are explained in subsequent sections.

5.2.1 Type curve-1 (Top dry coastal sand, fresh aquifer and clays)

The VES P-3 conducted in Puri town near DANIDA office refers to a situation with dry sand overlying the fresh shallow

Table 5.2 Results of shallow VES (Qualitative interpretation)

VES No.	Location	Depth to fresh aquifer (m)	Thickness of fresh aquifer (m)	Depth to water table (m)	Nature of surface layer	Protecting capacity	Remarks
P-1	Swargadwar	6-26	20	6	Sandy	V.good	
P-2	S.C.S. College (Puri town)	E R R A T I C D A T A					
P-3	DANIDA office (Puri town)	5-33.1	28.1	2.0	sandy	weak	
P-4	Pump House (Puri town)	15-40	25	1.5	sandy	weak	gran. aqf
P-5	Mnagalahat	5-33	28	5.0	sandy	avg.	gran. aqf
P-6	Khandiabandh	3-30	27	3.0	clayey	v.good	
P-7	Balighat	2-40	38	2.0	sandy	weak	
P-8	Baliguali	30-35.7	32.7	2.9	sandy	weak	
P-9	Kripasagarpatna (Near Samanglake)	-	nil	-	clayey	v.good	
P-10	Kripagarpatna	-	nil	-	clayey	v.good	
P-11	Mangarajpur (Betn. P-10 & P-12)	-	nil	4.0	clayey	v.good	
P-12	Mangarajpur	6-26.8	20.8	2.5	clayey	good	clayey aqf
P-13	Nuapatna	5.8-26.8	21	3.2	clayey	c.good	gran. aqf
P-14	Pokharimura	5-40	35	2.0	sandy	avg.	
P-15	Uttarakana	2.5-44.7	42.2	2.5	sandy	weak	
P-16	Nuagaon (Betn. P-15 & P-17)	-	nil	2.5	sandy	good	
P-17	Nuagaon	-	nil	-	clayey	v.good	
P-18	Biraharekrishna Pur	2-20	18	1.5	sandy	avg.	moderate to gran. aqf
P-19	Panchamuhan	2.5-22.6	20.1	2.5	clayey	good	clayey. aqf
P-20	Rendua	-	nil	-	clayey	avg.	water logging.
P-21	Talajanga	2-20	18	1.0	clayey	weak	

P-22	Nuagaon (North part)	-	nil	-	clayey	v.good	
P-23	Malatipatpur	-	nil	-	clayey	good	
P-24	Rahangiria (Towards north)	5.1-23.8	18.7	3.0	clayey	v.good	
P-25	Rahangiria (Towards N.E.)	-	nil	3.0	clayey	v.good	
P-26	Singhmapur	2-7.0	5	2.0	clayey	good	clayey. aqf,thin & shallow
P-27	Tulasichaura	-	nil	-	clayey	good	
P-28	Purusottamballabh (N.E. of village)	3-9	6	3.0	clayey	good	shallow. & thin aqf
P-29	Purusottamballabh (S.E. of village)	-	nil	2.0	clayey	good	
P-30	Tikarsarbha	2-7	5	1.5	clayey	avg.	thin. & shallow aqf
P-31	Birabalabhadra Pur	-	nil	2.5	clayey	v.good	brakish aqf
P-32	Peteipur	-	nil	1.5	clayey	v.good	brakish aqf
P-33	Kanchi Sasan	2-6& 13.5-20	4+ 6.5=10.5	2.0	clayey	good	
P-34	Bira Narasingha Pur (West of village)	4-7	3	4	clayey	v.good	
P-35	Bira Narasingha Pur (Close to village)	-	nil	3.2	clayey	v.good	
P-36	Birapratap Pur	3.1-7.5	4.4	3.1	sandy	good	thin clayey & shallow aqf
P-37	Ganganarayan Pur (In the village)	-	nil	3.2	clayey	v.good	
P-38	Karari	-	nil	2.5	clayey	v.good	
P-39	San Tentulia	-	nil	1.5	clayey	v.good	
P-40	Ganganarayan Pur	2-3.3	1.3	3.2	sandy	good	thin & shallow aqf
P-41	Barabari	-	nil	2.9	clayey	v.good	

aquifer underlain by clays. Fig (5.1). The top layers with very high resistivity (726.31 to 10281.8 ohm.m) represent the dry sand expected to continue up to 4.9 m . The geoelectric layers occurring below 4.9 m and continuing down to 33.1 m are characterised by resistivities 67.3 to 261.32 ohm.m attributable to fresh water aquifer. The granular nature of the aquifer is also revealed by corresponding higher resistivity values associated with it. The bottom layer with 9.3 ohm.m resistivity occurring below 33.1 m depth may be attributed to clays and/ or sand with brackish water.

5.2.2 Type curve-2 (All saline aquifer)

The VES P-27 (Fig.5.2) conducted at Tulasichaura represents a setup where the entire subsurface section down to 50 m depth from ground surface is indicated to be saturated with saline water as the resistivity of the layers range between 2.0 and 6.2 ohm.m. The surface layer with 7.4 ohm.m resistivity indicated the clayey nature of top layer. The increase in layer resistivity from 4.3 ohm.m to 5.0-6.2 ohm.m below 11.3 m depth is not of much significance.

5.2.3 Type curve-3 (Thin shallow aquifer overlying clays)

The situation of thin shallow aquifer is represented in VES P-28 conducted at Purushottamballabh (Fig 5.3). The aquifer characterised by resistivity 16.58-32.16 ohm.m occurs between water table (3.0 m) and 9.4 m depth below which the presence of clays associated with resistivities 7.2-13.18 ohm.m is revealed.

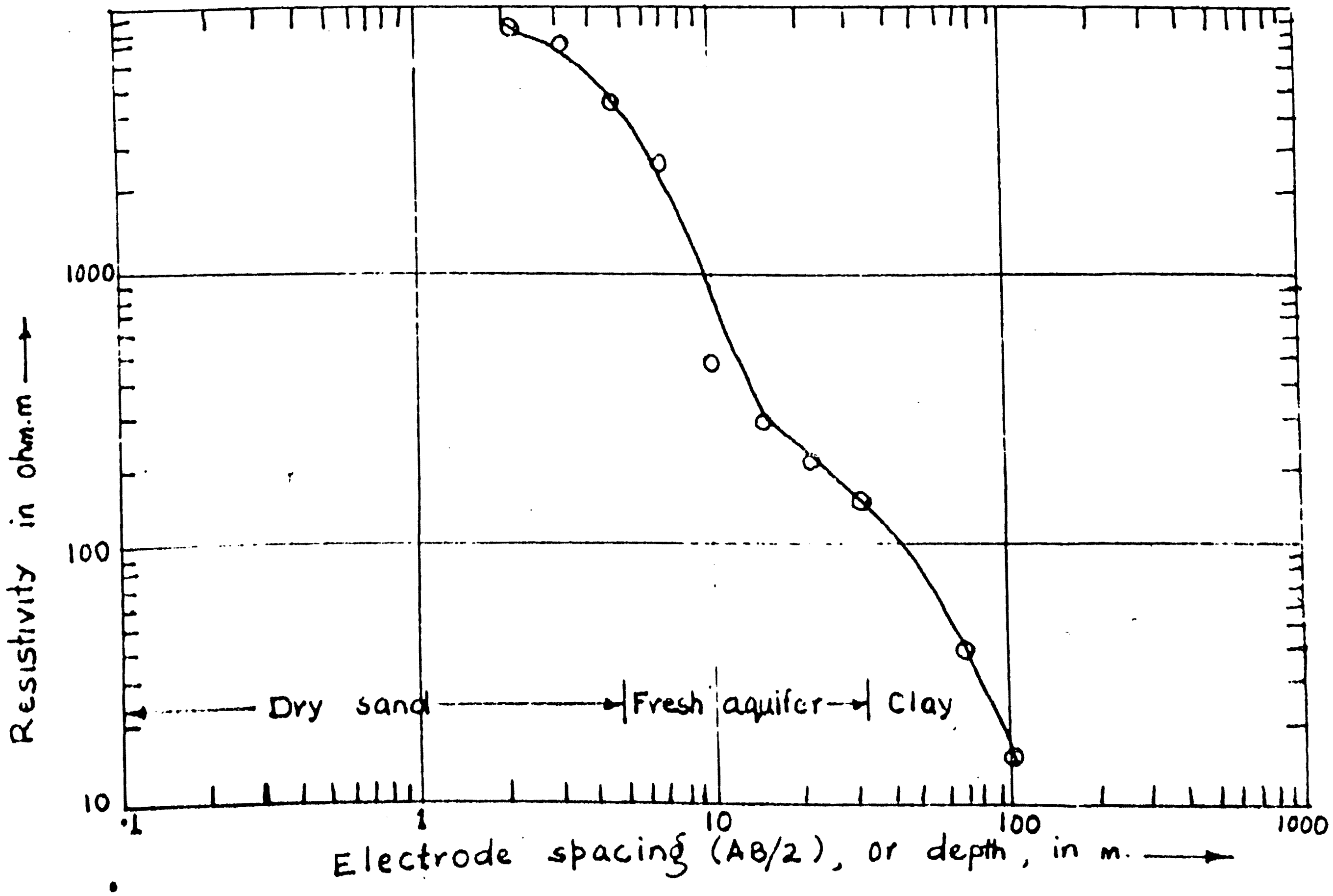


Fig 5·1 Type curve-1
(VES with top dry coastal sand, fresh aquifer and clays)

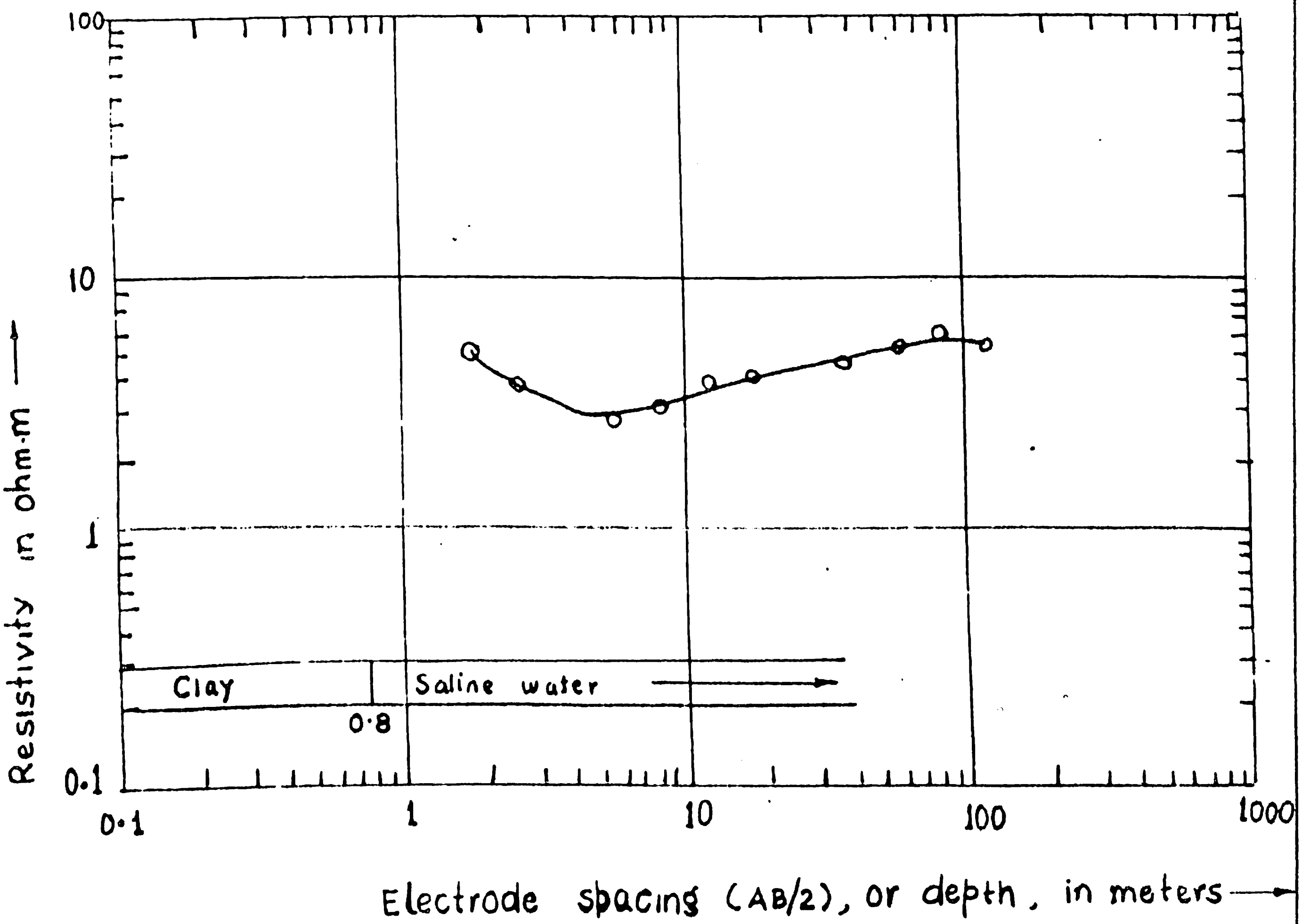


Fig 5·2 Type curve-2 [All saline]

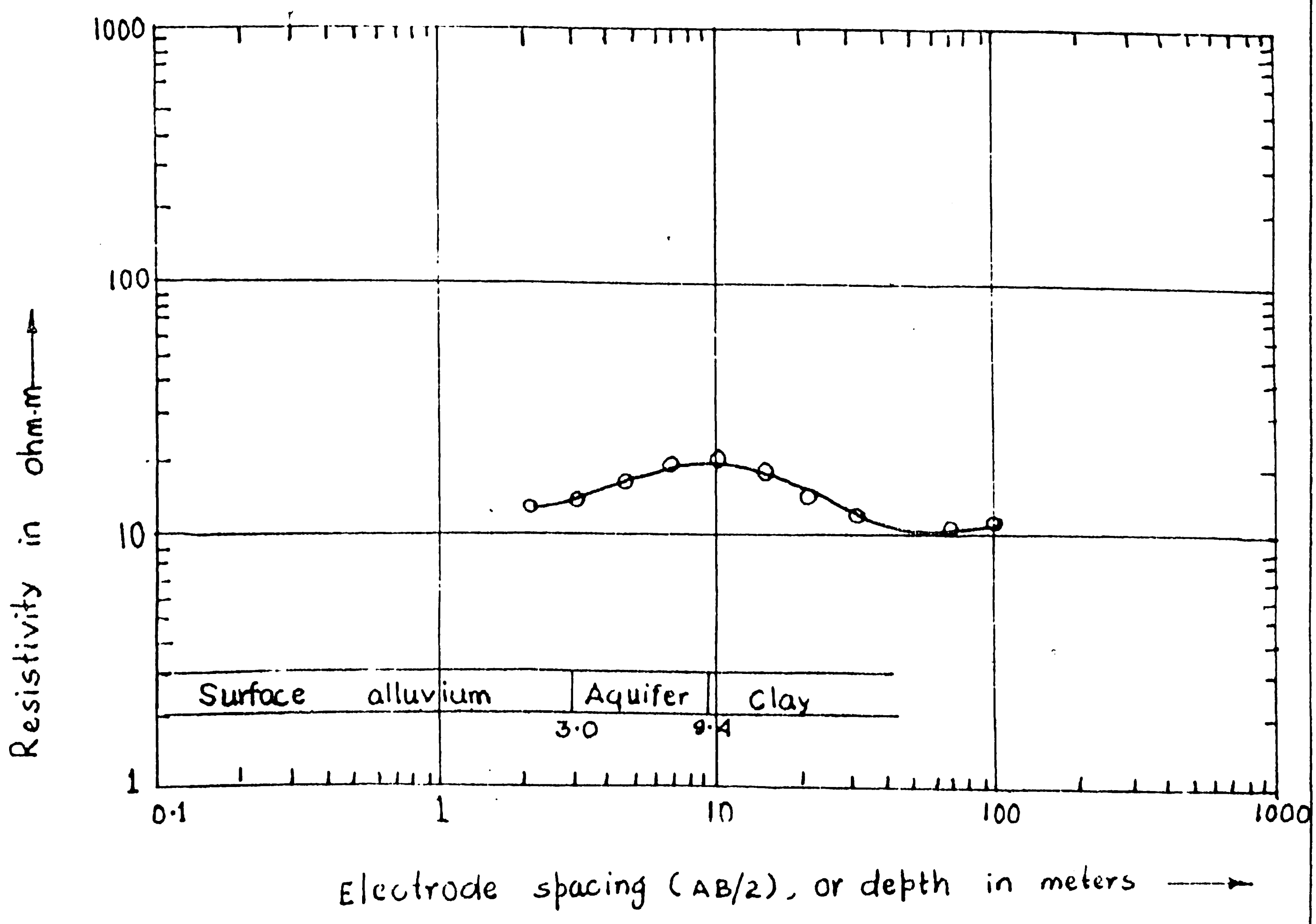


Fig 5·3 Type curve - 3 [Thin shallow aquifer overlying clays]

5.2.4 Type curve-4 (Brackish zone sandwiched between saline zone)

At Piteipur, the presence of brackish water conditions sandwiched between saline water zones has been revealed in VES.P-32 (Fig 5.4). The layer resistivities from ground surface to 7.7 m depth range from 3.0 to 5.8 ohm.m indicating saline water conditions near surface. But the layer resistivities increase to about 12.0 ohm.m between 11.3 and 24.4 m depth which could be attributed to brackish water saturation of sediments. The layer at 7.7-11.3 and 24.4-35.8 m depths characterised by 9.0 and 6.3 ohm.m resistivity respectively represent clays separating the brackish zone from over and underlying saline water zones. The lower saline zone (below 35.8 m depth) is found associated with resistivity less than 2.0 ohm.m.

5.3 Electrical Logging Results

Electrical logging done by DANIDA in few bore wells of Puri Sadar block reveals the depth of drilling and the depths at which fresh aquifer, saline aquifer or brackish aquifer occurs. The results are given in Table 5.3.

5.4 Cross-sections

Synthesizing the results of vertical electrical sounding with the local sub-surface conditions, depth to water table in dugwells and electrical logs of the few boreholes within the sounding area, geoelectrical-hydrological sections have been prepared along 9 sections (A-A', B-B',....I-I') shown in fig 5.5. These cross-sections illustrate the disposition of shallow fresh-saline aquifers and clay beds within 50 m depth below ground

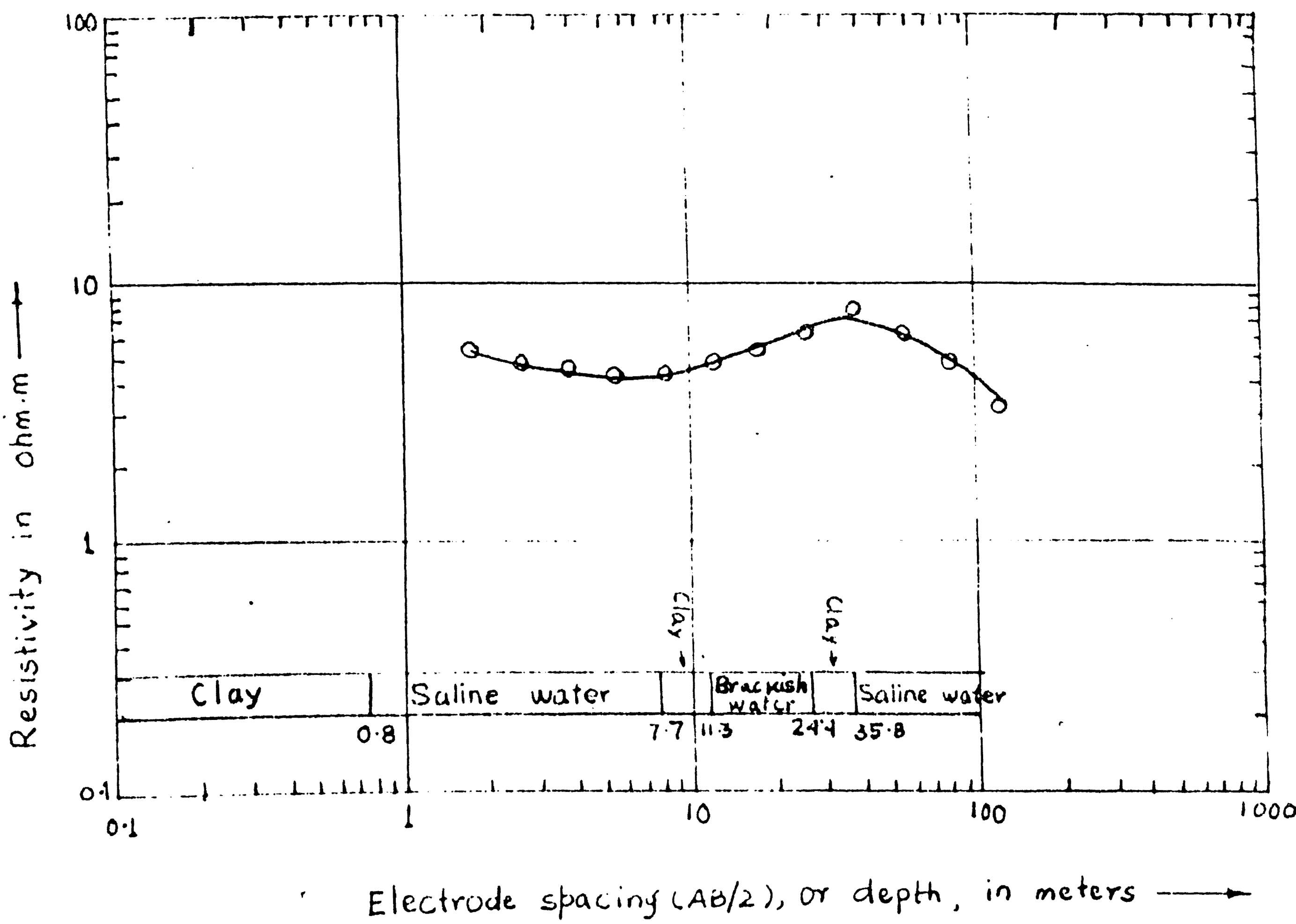


Fig 5.4 Type curve - 4 [Brackish zone sandwiched between saline zo

Table 5.3 Well-logging result of Puri Sadar block.

Sl. No.	Location	Total depth of drilling(m)	Depth of Aquifers (m)		
			Fresh	Saline	Brakish
1	Balukhanda	20	0-20		
2	Ballavananda Pur	163	2-22 & 135-162	22-135	
3	Chhotarapur	165	4-20 & 135-165	20-135	
4	Dasbatia	151	118-151	0-110	110-118
5	Gadhiapatna	20	0-20		
6	Karpur Harichandan Pur	150	4-20 & 130-50	20-130	
7	Kashi Jagannath Pur	20	0-20		
8	Khadipada	19	0-19		
9	Khandiabandha	20	0-20		
10	Narasingha Ballav	160	4-18 & 142-160	18-142	
11	Puri town	40	0-40		
12	Rebatiraman	148	2-35	35-148	
13	Samangara	20	0-20		
14	Sankar Pur	19	0-19		
15	Sasan Damodar Pur (N.E.)	160	4-19 & 135-160	19-135	
16	Sasan Damodar Pur	170	136-170	14-136	4-14
17	Ura	141	100-141	4-100	

surface. The surface elevations, although known to vary to some extent have been assumed as uniform. The results as obtained in different cross-sections are discussed below.

The two southern sections A-A' and B-B' passing through Puri town depict the prominence of shallow fresh aquifer occurring along the entire stretch of the sections. The aquifer characterised by resistivity more than 30 ohm.m is indicated to have granular nature. It's thickness is estimated to vary from 20 to 40 m occurring directly below the water table. This is confirmed by the tubewell at Khandiabandh which has revealed the top fresh aquifer to continue upto 20 m. The tubewells at Puri town draw fresh water upto a depth of 40 m below ground surface. This aquifer is underlain by clays having resistivity 5-10 ohm.m.

In the cross-section C-C', the fresh aquifer covers about two third of it's eastern stretch, east of VES P-11 carried out at Mangarajpur. As confirmed from the result of resistivity profiling the fresh aquifer starts at a distance of about 200 m towards east from P-11. While in it's western stretch the aquifer is overlain by a thin clay layer, it occurs directly below water table at the site of VES P-14 (Pokharimura). At the latter site, the fresh aquifer which is characterised by resistivity 14-40 ohm.m in these parts, has a thickness of about 35 m.

In the section D-D', the fresh aquifer covers more than half of the stretch of the section. The thickness of the aquifer also increases in this section but it remains in two isolated occurrence between Batagaon and Panchamuhan (P-18 and P-19) and at Uttarkana (P-15).

In the section E-E', the fresh aquifer occurs in two isolated small bodies at Rahangiria (P-24) and Talajanga (P-21).

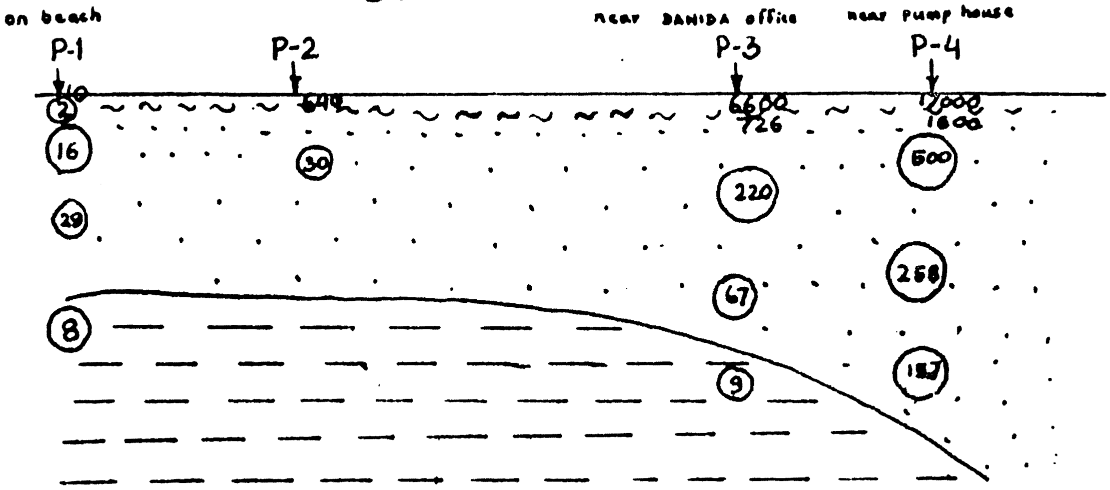
The section F-F' exhibits the occurrence of saline aquifer (resistivity 2-5 ohm.m) right from the water table for almost it's whole stretch except for localised shallow occurrence of fresh water near Singhmapur (P-26) and north-east of village Purushottamballabh (P-28). The fresh aquifer at these sites is characterised by 14-20 ohm.m resistivity and occurs between water table and 7-8 m depth (b.g.l.).

In the section G-G' presence of fresh aquifer at the western and eastern ends of the section has been indicated, while the major central portion is associated with brackish water conditions between 11.0 to 25.0 m depth (b.g.l.). This brackish aquifer occurring between the VES site P-31 (Bira Balabhadrapur) and P-32 (Piteipur) is characterised by resistivity 12-14 ohm.m . The clay layer with resistivity 6-11 ohm.m surrounds the brackish water lens and separates it from the under lying saline water zone characterised by resistivity 1-4 ohm.m.

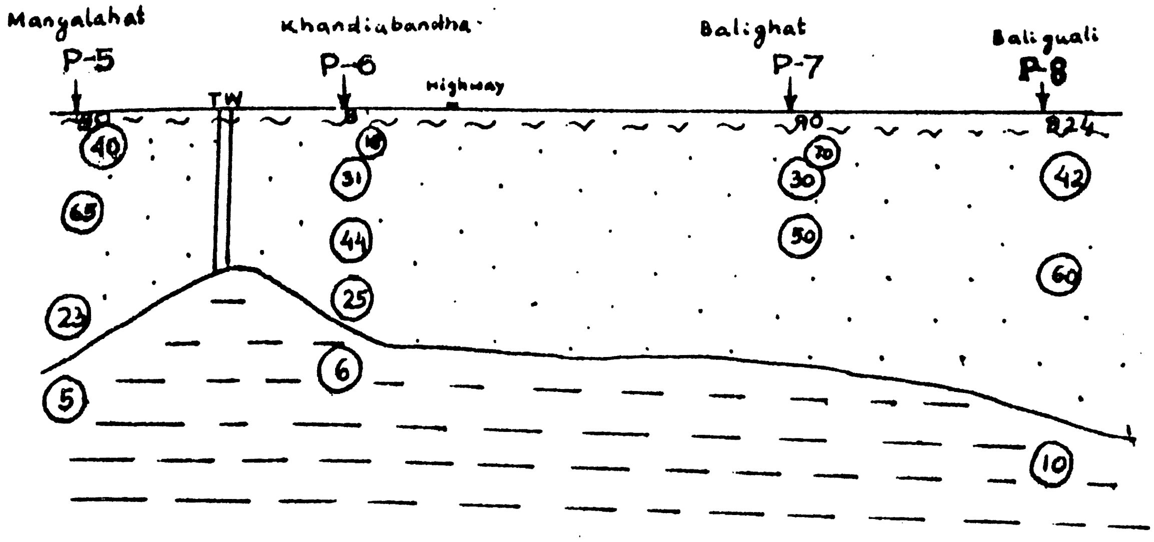
In section H-H' occurrence of two thin isolated fresh water lenses between water table and 8-10 m depth is found out. The rest of the column is associated with very low resistivity values (1-5 ohm.m) attributable to saline water saturation.

The northern most section I-I' exhibits the presence of saline water conditions from water table down to 50 m depth along the whole section.

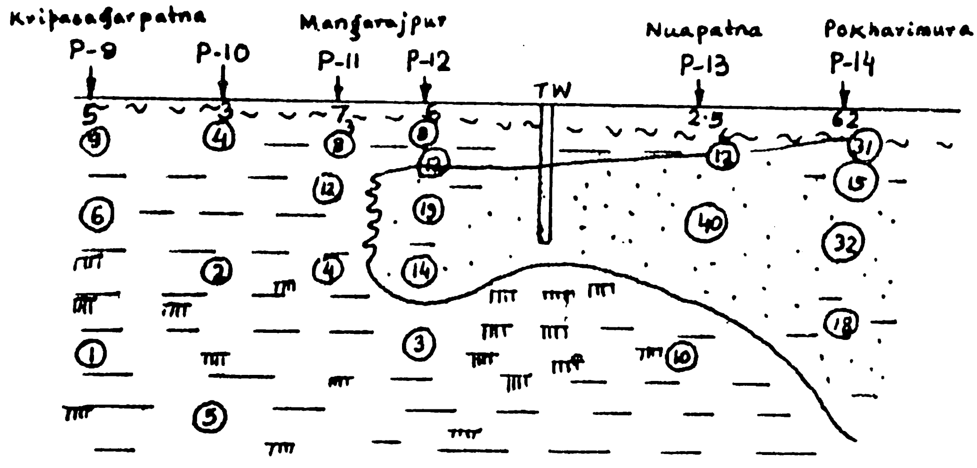
SECTION A-A′



SECTION B-B′



SECTION C-C′



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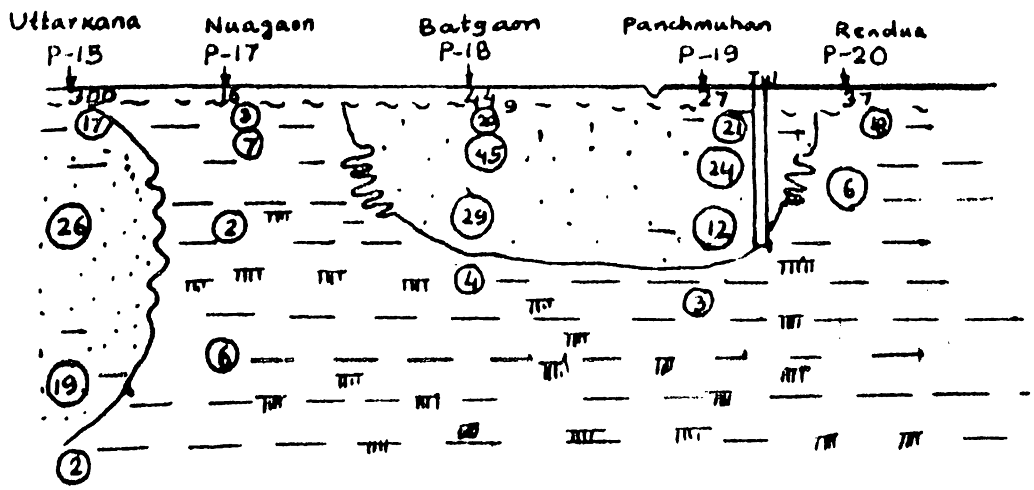
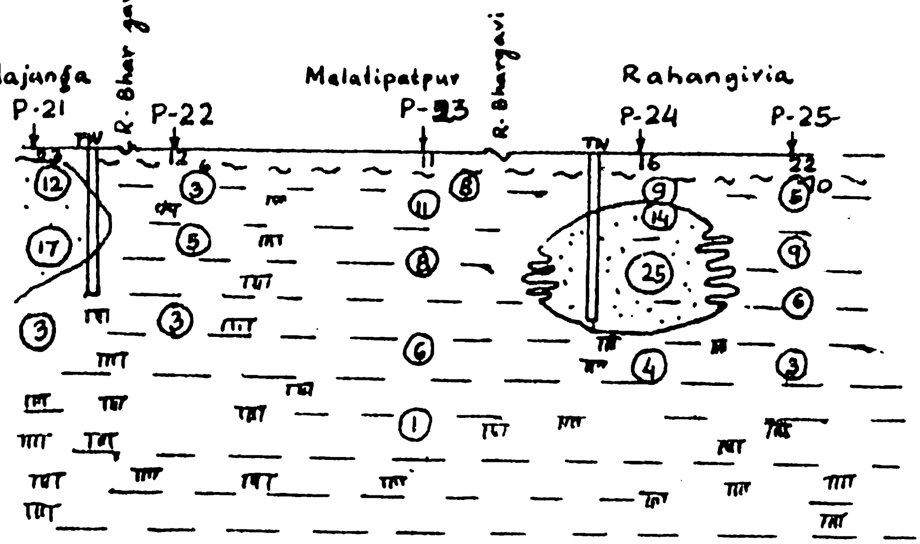


SECTION E-E′



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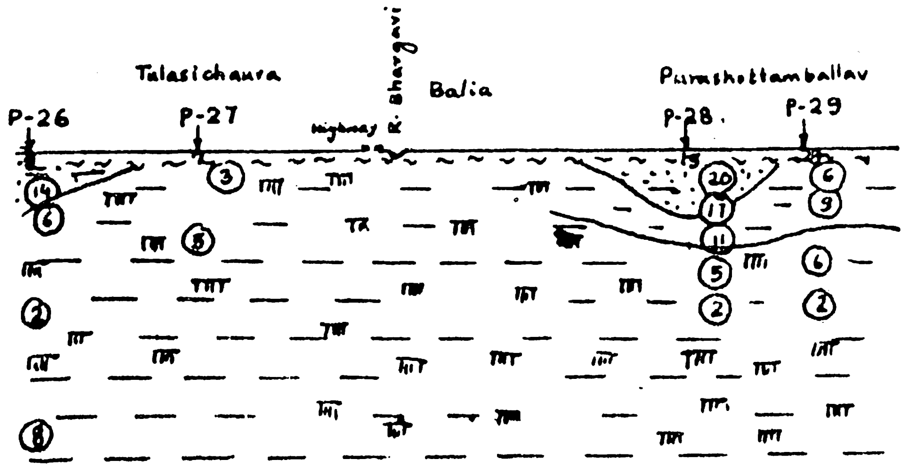
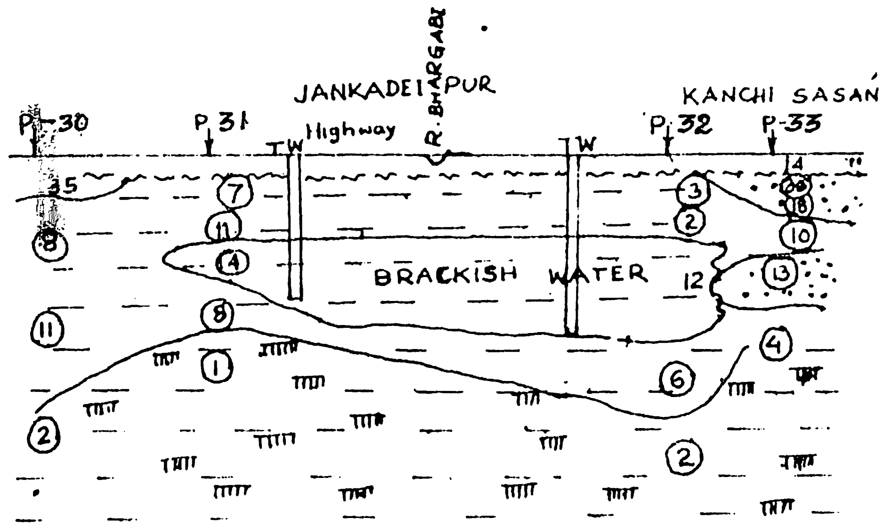
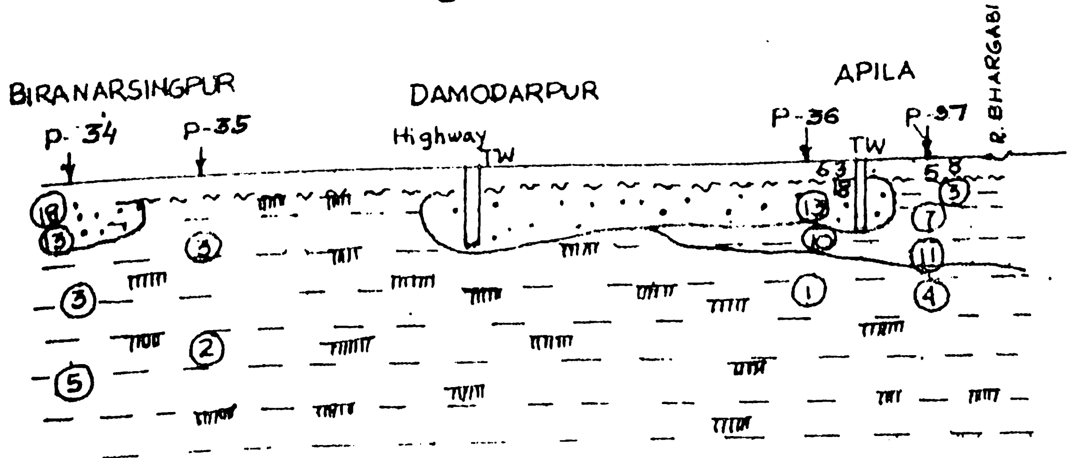


SECTION- G-G'



SECTION H-H'



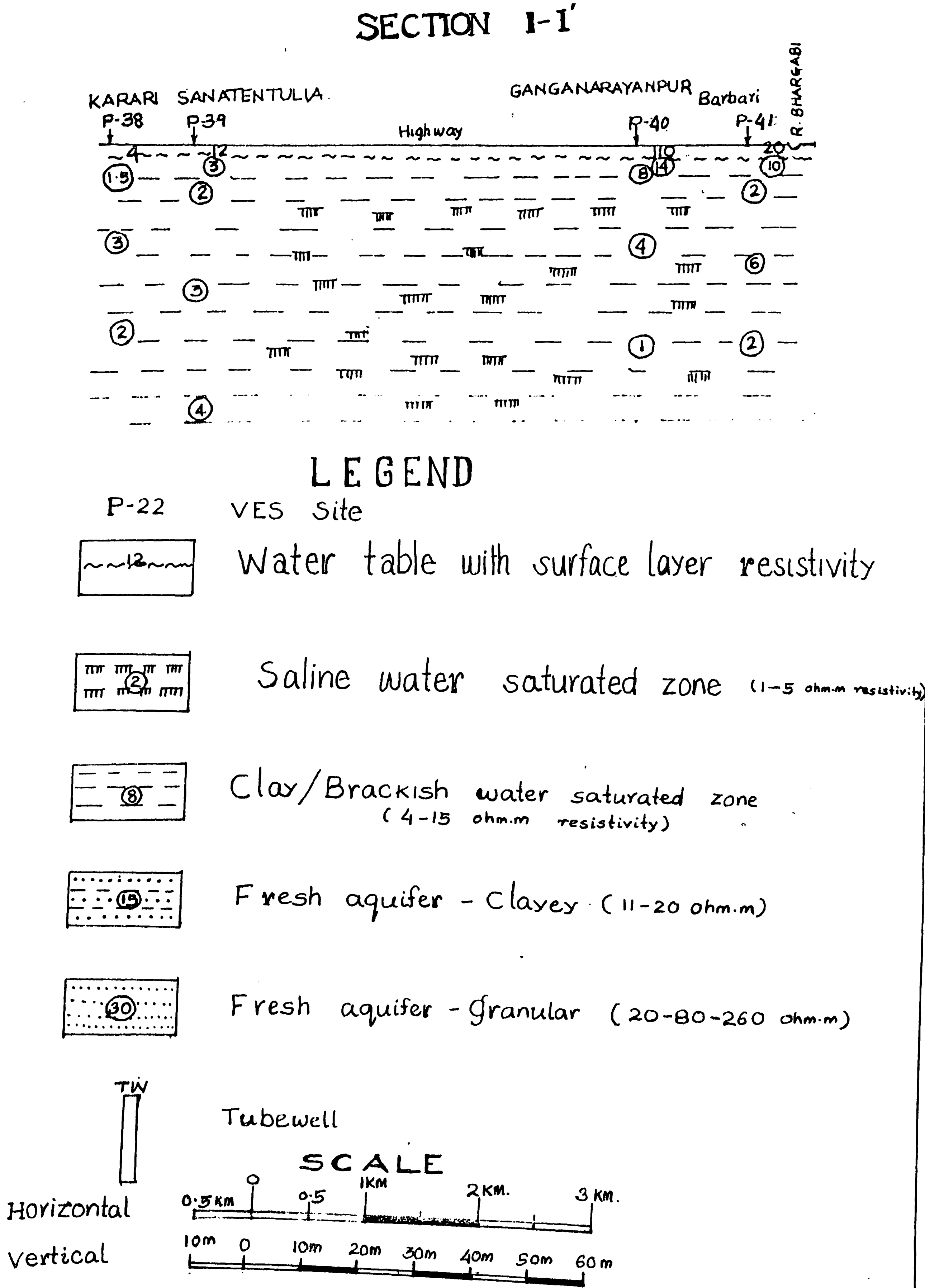


Fig. 5.5 **Cross-sections**

5.5 Resistivity Profiling

The resistivity profiling was carried out between VES P-12 and P-11 at Mangarajpur. In the VES P-12 presence of fresh water zone was revealed by layer resistivities of 19 ohm.m (between 8.5 and 18.3 m) and 14 ohm.m (between 18.3-26.8 m). While in the adjoining VES P-11, the corresponding layer resistivities of 12 and 4 ohm.m were obtained between 7.1 and 15.4 m and below that depth. The results show an apparent resistivity value of 9.5 ohm.m upto station P-12 after which it drops to an average level of 7.0 ohm.m within a distance of 30 m and continues upto the VES P-11 site. The transition zone between stations 37 and 40 could be attributed to clays beyond which saline water zone exists towards the VES P-11 (Fig 5.6).

5.6 Disposition of Shallow Fresh Aquifer

In Puri Sadar block, the saline water zone covers almost whole of the profile zone in the northern part extending in south up to Samanga lake with its width reduced to about 2 km only. Another saline water zone is encountered in the eastern parts around Rahangiria(P-25) and Rendua(P-20). Thus the shallow fresh aquifers in the block occur in western, east central and southern parts of the profile zone. Isolated fresh water occurrence around Birapratappur and Balia towards north is also encountered. The southern 3-4 km stretch of the entire profile zone around Puri town is overlain by shallow fresh aquifer. Thus the total area occupied by shallow fresh aquifer within the profile zone through Puri Sadar block may amount to 65-70%.

The depth to the top of fresh aquifer is found to vary

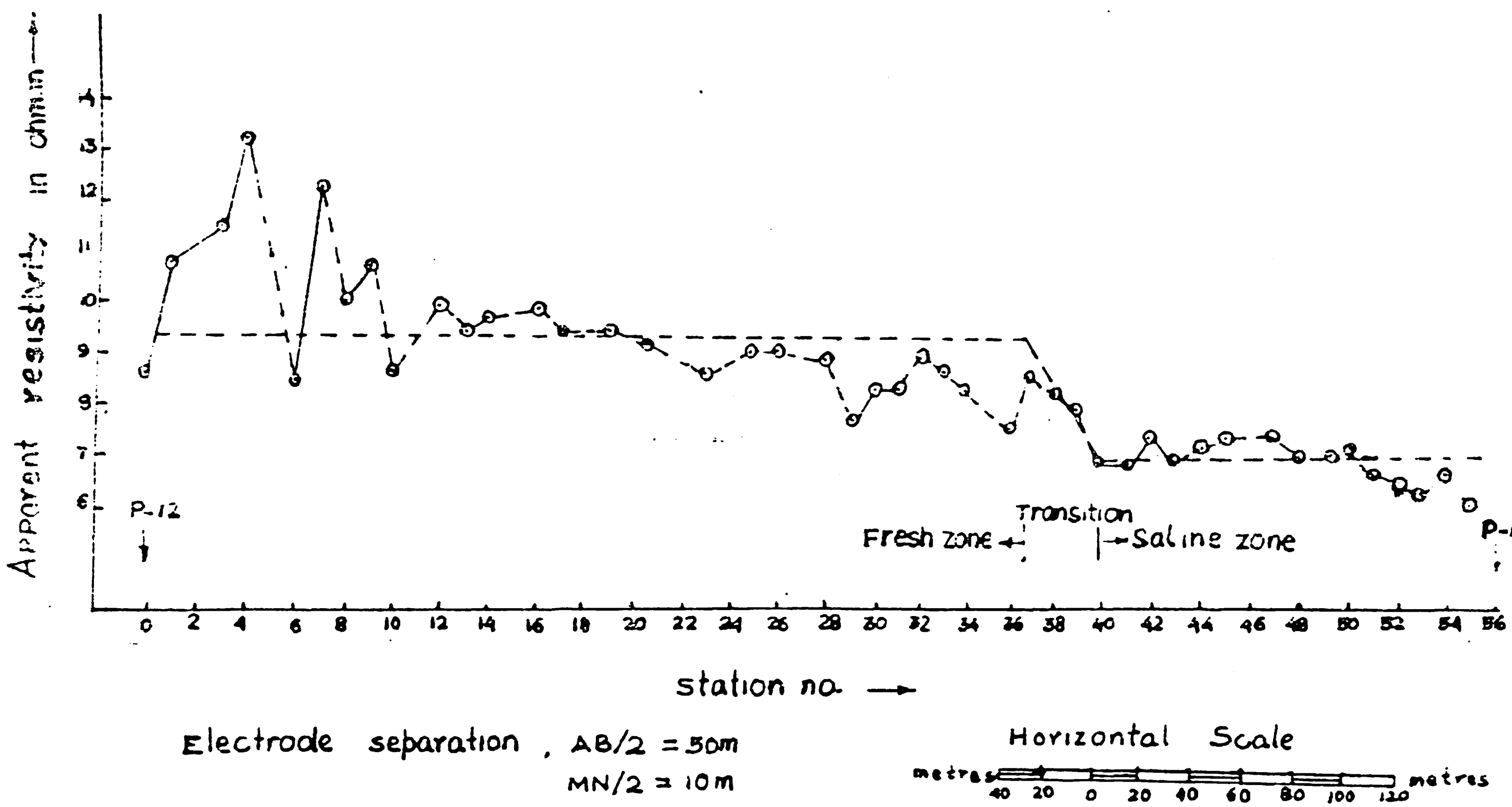


Fig 5·6 Schlumberger resistivity profiling mostly between 2 and 6 m below ground level coinciding in general with the water table.

The bottom of aquifer occurs within 5-20 m depth b.g.l. towards the northern parts but goes down to 30-40 m depth also towards central peripheral regions and in southern parts.

The areal distribution of fresh and saline aquifers has been shown in Fig 5.7 and Fig 5.8. Besides, Fig 5.7 exhibits the contours of the depth to top of fresh aquifer below ground level and Fig 5.8 exhibits the contours of the depth to the bottom of fresh aquifer. The thickness of the shallow fresh aquifer can be estimated at any site by taking the difference of depth from the contour values.

5.7 Nature of Surface Layer

Under the shallow VES investigations, observations were also made regarding the nature of top surface layer in the vicinity of the VES site. Besides the visual observation, the resistivity values obtained corresponding to top surface layer, also indicate its nature. While the value of more than 30 ohm.m for the top layer were attributed to its sandy nature, the resistivity values less than 30 ohm.m were taken for the clayey nature of surface layer.

Utilising these considerations, the nature of surface soils has been marked against each VES site from results furnished in Table 5.2, taking the p1 values from column (3) and also taking the clues from visual observations in the field. thedemarcation of sandy and clayey surface layers is then made

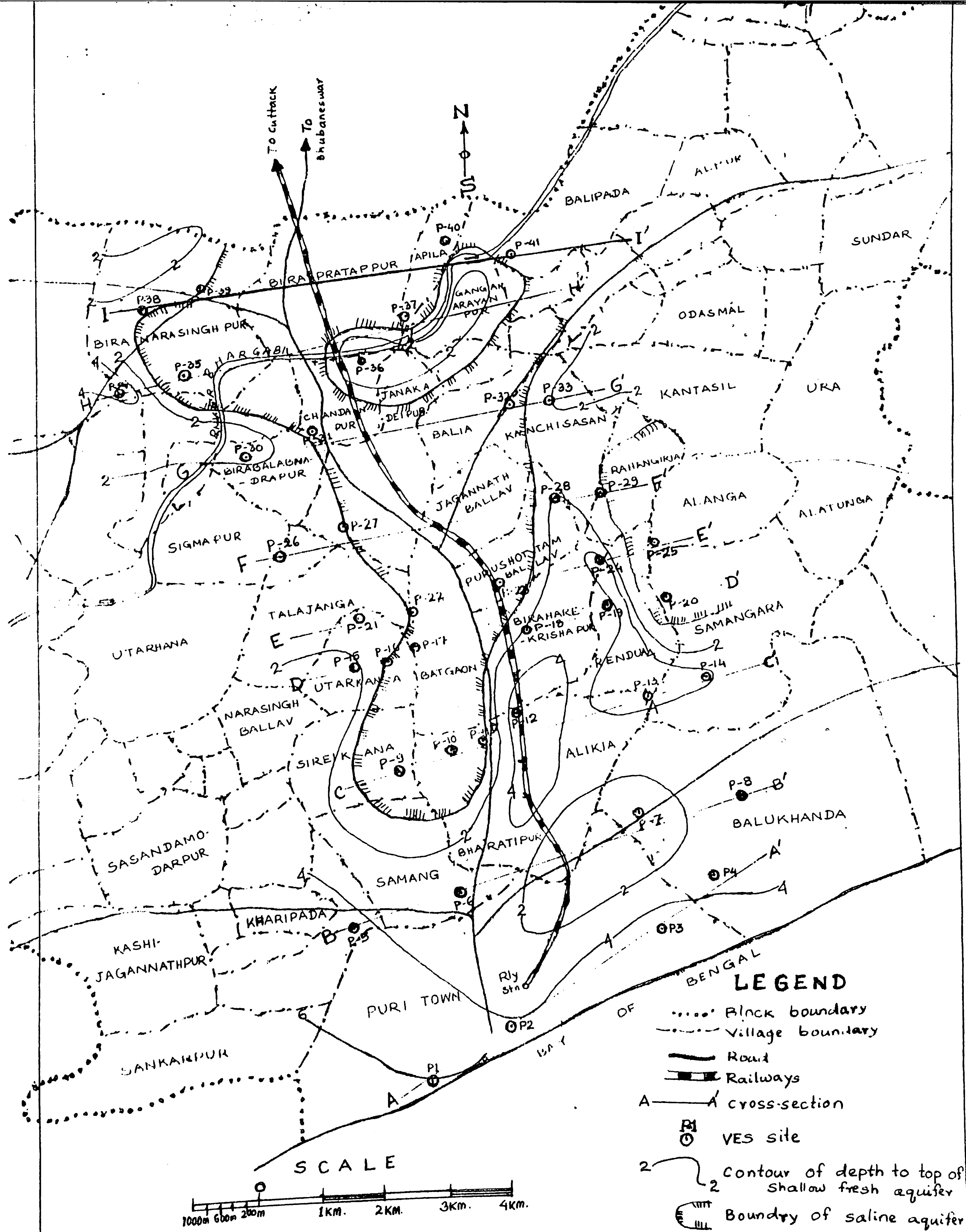


Fig 5·7 Contours showing depth to top of shallow fresh aquifer

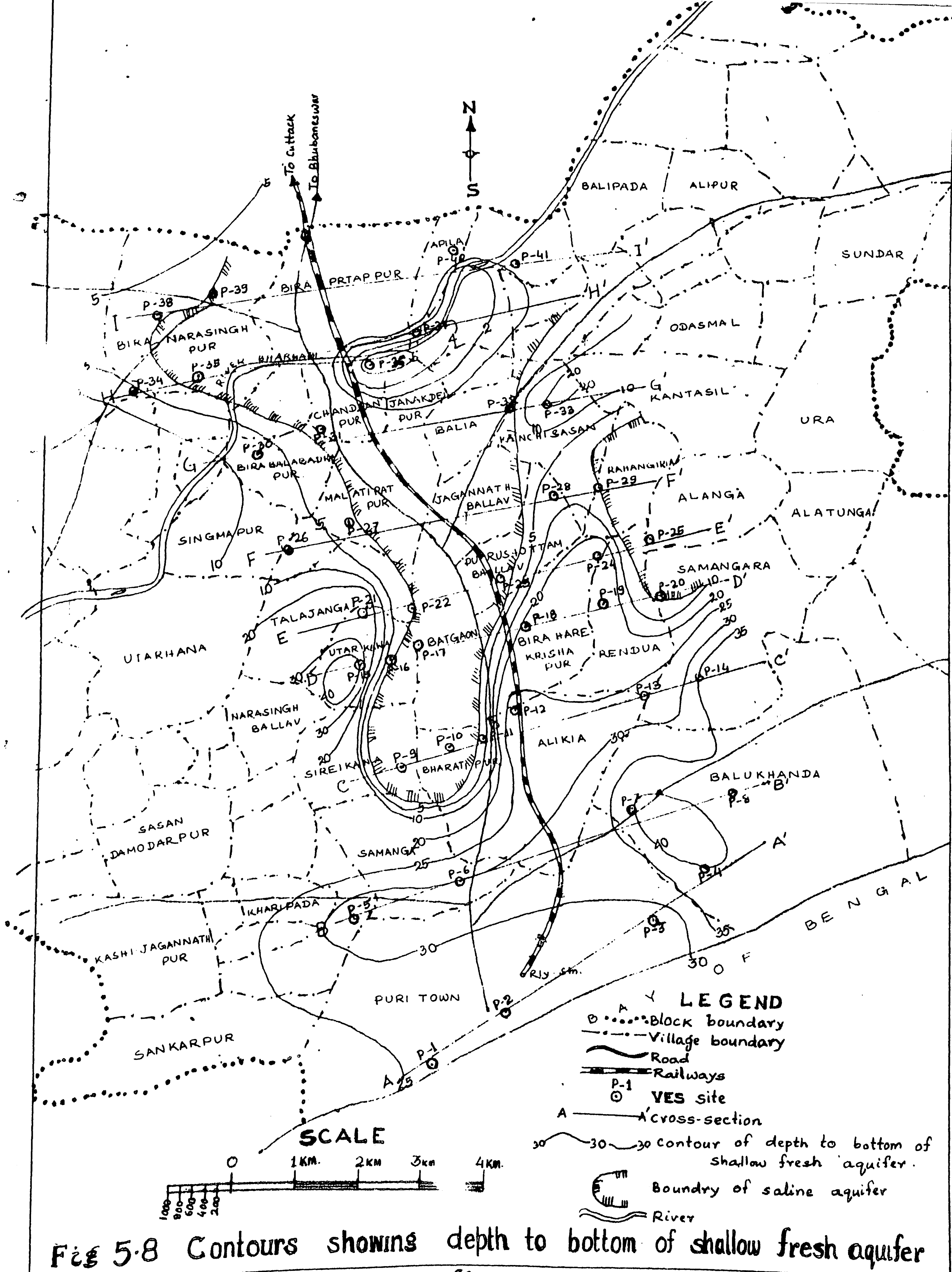


Fig 5·8 Contours showing depth to bottom of shallow fresh aquifer and is presented in Fig 5.9. The sandy surface layer may facilitate the direct recharge to shallow aquifer from the rains and surface water. The clayey top surface layer may acclerate the run-off and the drainage density would be finer in such areas.

5.8 Protecting Capacity of Overburden

The capacity of overburden the layer(s) occurring above the water table, to protect the aquifer from chemical and bacterial pollutants entering into groundwater with percolating waters called protecting capacity. The protecting capacity has also been evaluated from the layer parameters obtained from VES results(Table 5.2). After plotting the qualitative estimates of protecting capacity graded as weak, average, good and very good the pockets characterised with each type have been demarcated within the profile zone investigated and are shown in Fig 5.9 . .

It is seen that south of Taljanga and 2-3 km wide zone along the coast are characterised by \`weak' protecting capacity. The \`average' protecting capacity of overburden has been found only in very small patches around Gadhiapatna, Mangalahat (South-West of Samanga lake) and south-east of Biraharekrishnapur. Surface layer with \`good' protecting capacity occupies central part of profile zone. The northern and south-central parts of Puri Sadar block is associated with \`very good' protecting capacity of the overburden.

5.9 Water Quality

The water quality reports of handpump water of Puri Sadar block are given in Table 5.4. Since this water is used for

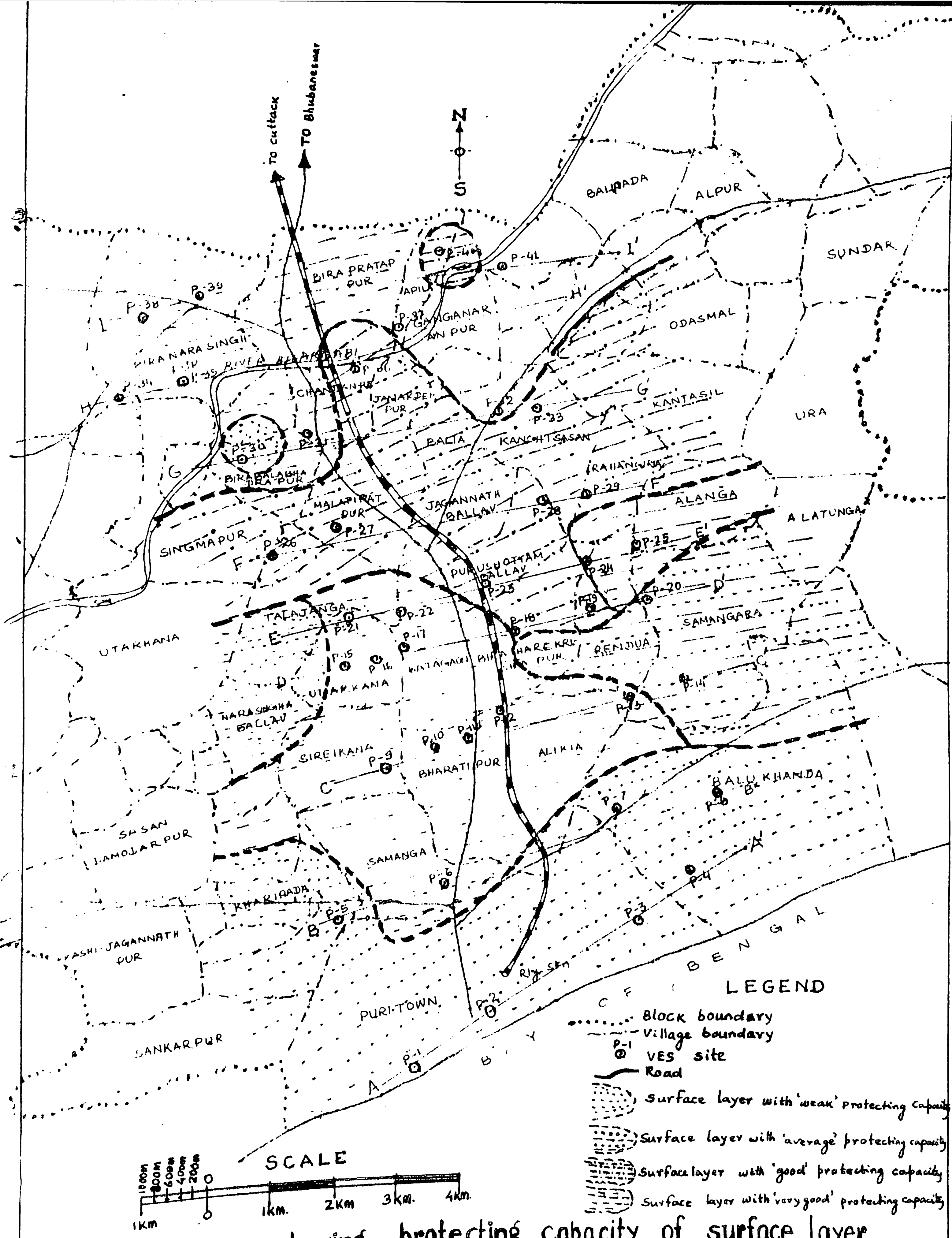


Fig 5.9 Map showing protecting capacity of surface layer

Table 5.4 Water quality report.

Sl. No.	Location	Total depth of drilling (m)	Position of Screen (m)	Test report	
				Chloride (mg/l)	Iron (mg/l)
1	Janakadeipur	110	160-166	100.0	0.60
2	Talajanga	120	115-117	130.0	0.50
3	Balia	20	16-20	360.0	1.00
4	Batagaon	20	12-16	330.0	0.80
5	Gadhiapatna	160	148-152	170.0	4.30
6	Singhmapur	160	154-158	90.0	0.20
7	Jagannath Ballav	130	121-125	130.0	1.60
8	Alasana	130	119-123	160.0	0.65
9	Birakishore Pur	160	153-157	140.0	0.30
10	Sundar	20	18-20	2640.0	1.50
11	Bagha	20	6-14	160.0	6.0
12	Garhamrugasira	50	48-50	10600.0	10.0
13	Gopinath Pur	20	14-17	750.0	1.40
14	Rendua	35	31-33	540.0	0.10
15	Ura-1	150	140-144	90.0	1.80
16	Sasan Damodar Pur	160	148-152	1320.0	1.80
17	Jagannath Bidyadhar Pur	20	14-18	130.0	2.8
18	Balipada	140	135-139	530.0	0.20
19	Uttaraswarpada	120	116-120	310.0	0.40
20	Ura-2	140	129-133	60.0	0.10
21	Beladal	140	136-140	30.0	1.0
22	Balukhanda	TW	TW	40.1	1.50
23	Samangara	TW	TW	40.0	1.30
24	Odasamal	TW	TW	60.0	0.30

drinking purpose, only chloride and iron content are given. In Table 5.4 column (1) represent sl. no, clolumn (2) location, cloumn (3) total depth of drilling in meter, column (4) position of screen, column (5) and (6) the chloride and iron content in (mg/l) respectively. In almost all the villages given in Table 5.4 the handpump water is suitable for drinking purpose.

CHAPTER-VI

SUMMARY AND CONCLUSION

CHAPTER VI

SUMMARY AND CONCLUSION

A geophysical method of groundwater exploration i.e. vertical electrical sounding(VES) was deployed in a profile zone of Puri Sadar block for assessment of good quality groundwater.Puri Sadar block has triple problem of water logging, salinity and sand dunes. The VES was done at 41 points spreading over an area of 60 km^2 stretching from sea coast in south to boundary of Puri Sadar block in north with 5 km width. 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 and recommendations are made:

i) A correlation has been established between the electrical resistivity values and lithological units, their water bearing characteristics and quality of formation water. 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 21-80 ohm.m or slightly higher and correlated with sand saturated with fresh water (moderate to granular aquifer).

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 and 5.2. These results have been analysed and discussed for (a) individual sites by type curves, (b) different sections by geoelectrical-hydrogeological cross sections, (c) whole area of the profile zone by maps showing demarcation of fresh-saline aquifers and depth to fresh aquifer contours and nature of surface layers.

iii) The type curves presented illustrate the setting with (a) top dry coastal sand, fresh aquifer and clays; (b) all saline from top to 50 m depth; (c) brackish zone sandwiched between saline zones; and (d) thin shallow aquifer overlying clays. They can be used for deciphering similar situations in other parts of coastal tract.

iv) The cross sections exhibit clearly the subsurface picture down to 50 m depth below ground level and have brought out disposition of fresh-saline and brackish aquifers and clay layers. The northern and central part of the study area is covered by saline water zone. The southern part has shallow fresh aquifers going down to a maximum depth of 40 m. The aquifer is also indicated to be granular is these parts.

v) The area demarcation of shallow fresh and saline aquifers has been done. The saline aquifers are occuring in major northern part of Puri Sadar block upto south of Samanga lake. In the eastern part, also the saline water zone is encountered around Rahangiria and Rendua. The shallow fresh aquifers are encountered towards western, east central and southern parts of Puri Sadar block. Considering the overall distribution of fresh and saline water areas, about 65% of the profile zone is found associated with shallow fresh aquifers and rest area with saline or brackish water.

vi) The depth to the top of fresh aquifer is estimated to range between 2 to 6 m below ground level in general, coinciding with the water table. Statistically the depth to top of fresh aquifer ranges 2-6 m in 21 sites (51%), 10-15 m in 1 site (2.5%), 15-20 m in 1 site(2.5%) and at greater than 50 m depth in 18 sites (44%) out of 41 VES Sites (100%).

vii) The thickness of shallow fresh aquifer varies from less than 5.0 m to more than 40 m. The analysis has shown that out of 41 VES sites (100%), the thickness of fresh aquifer is more than 40 m in 1 site (2.5%), 30 to 40 m in 3 sites (7.5%), 20 to 30 m in 9 sites (22.%), 10 to 20 m in 4 sites (10%), 5 to 10 m in 3 sites (7.5%) and less than 5 m in 3 sites (7.5%). In 18 sites (43%) there is absence of any shallow fresh aquifer.

viii) The shallow fresh aquifer is indicated to be granular in southern parts of the profile zone. However, in the major central parts the shallow aquifer may have clay intercalations.

ix) The resistivity profiling has been useful in demarcating precisely the boundary between fresh and saline aquifers and fresh and brackish water zones at Mangarajpur of Puri Sadar block.

x) The surface layer is found to be sandy in southern parts of profile zone, west of Samanga lake and along the coast in Puri Sadar block. This sandy surface layer covering about 25% of the profile zone may facilitate the direct recharge to shallow aquifer from the rains and surface waters. The clay surface layer covers the northern and central part. The clayey top layer may enhance the runoff from the area. In the rest area the top layer is clayey with some sand content.

xi) The protecting capacity is found to be `good' to `very good' in about 70 % area of the profile zone covering major part of the profile zone except the southern part. The statistical analysis show that out of 41 VES sites (100%), the protecting capacity is weak at 7 sites (17%), average at 5 sites (12%), good at 10 sites (24%) and very good at 19 sites (47%). This implies that although the shallow aquifers in these areas are well protected against contaminations expected to enter into aquifer with direct recharge but since the recharge areas are found to be else where and would mostly be associated with sandy surface layers having `weak' to `average' protecting capacity, the risk of contamination (both chemical and bacterial) entering into the aquifer remains. It is recommended that water quality of these shallow fresh aquifers may be tested for irrigation purpose from a network of observation wells evenly distributed over the area.

xii) The shallow vertical electrical sounding(VES) thus have enabled delineation of shallow fresh aquifers and determination of its depth, thickness, areal extent and nature; delineation of clay beds; assessment of the salinity of formation water qualitatively; and determination of the nature of surface layer and assessment of it's 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. They should form essential components of the methodology to be employed for the exploration of groundwater resources.

xiii) Although the detailed recommendations for the types of irrigation structures (dugwell, borewell, ponds etc.) to be constructed; capacity and horse power of water lifting device (diesel pump, electric pump etc.) to be adopted at different sites based on the results of shallow VES are not given at this stage. It is recommended that few of the observation bore holes are to be drilled at different sites and pump test should be done to assess the discharge of the aquifer and area that can be irrigated by that well. Since the water supply system at Puri town and Baliguali gramapanchayat solely depends upon groundwater, it can be recommended that if borewells will be drilled in these areas, then they can meet the irrigation requirements of the crops.

xiv) The water logging problems in rainy seasons in Sara lake and Samanga lake area can be avoided if excess water will properly recharged into sub-surface. This is possible if filter point wells will be installed and water will be drawn in Rabi season for raising crop which will substantially lower the groundwater table, thus increasing the recharge capacity of the area.

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APPENDICES

APPENDIX - I

COVERAGE OF THE STUDY AREA

Sl. No.	Gram panchayat	Revenue villages
	SAMANGAPAT	
1.	Samanga	1. Khadipada
		2. Rebatiramana
		3. Kashi Jagannathpur
		4. Sankarpur
		5. Samanga
2.	Sasana Damodarpur	1. Sasan Damodarpur
		2. Karpur Harichandanpur
		3. Gadhiapatana
		4. Narsinghaballabha
		5. Uttarakana
		6. Sireikana
		7. Krupasindhu Harichandanpur
3.	Balabhadrapur	1. Balabhadrapur
		2. Singhmapur
4.	Kerandipur	1. Nuagaon
5.	Malatipatapur	1. Malatipatapur
		2. Talajangha
6.	Gopinathpur	1. Gopinathpur
		2. Bharatipur
		3. Kadalibadipatana
		4. Atharanalapatana
		5. Sireikanapatana
		6. Chakrabartipatana

Sl. No.	Gram Panchayat	Revenue village
	SARAPAT	
1.	Baliguali	1. Ura
		2. Alanga
		3. Alatunga
		4. Samangara
		5. Beladala
		6. Rohitakhanda
		7. Mohinipur
		8. Balukhanda (Gopalpur)
2.	Biraharekrishnapur	1. Rendua
		2. Utareswarapada
3.	Chalisbatia	1. Paniorali
		2. Odasamala
		3. Kantasila
4.	Gadamrugasira	1. Bagha
		2. Alaba
		3. Sundar
5.	Raigorada	1. Naiguan
		2. Raigorada
		3. Sanua
		4. Barana
		5. Akupada

APPENDIX - II

PROBLEMATIC AREA IN THE STUDY AREA

(in hectares)

Sl. No.	Name of Gram-panchyat	Total cultivated area	Area under water logging	Area under salinity	Area under sand dunes	Problem area	Total	Remarks
1.	Gopinathpur	236	200	-	-	200	436	Samangapat
2.	Keranipur	408	100	-	-	100	508	Samangapat
3.	Bira Harekrishnapur	600	300	200	-	500	1100	Samangapat and Sarapat
4.	Malatipatapur	304	100	-	-	100	404	Samangapat
5.	Balabhadrapur	650	150	10	-	160	775	Samangapat
6.	Samanga	954	250	50	-	300	1254	Samangapat
7.	Sasandamodarpur	774	150	-	5	155	929	Samangapat
8.	Baliguali	1565	700	84	1600	2384	3949	Sarapat
9.	Chalisbatia	308	100	20	-	120	428	Sarapat
10.	Gadamrugasira	218	100	10	30	140	358	Sarapat
11.	Raigorada	321	50	20	-	70	391	Sarapat
	Total	6303	2200	394	1635	4229	10532	