Application of Geophysical Techniques in Artificial Recharge to Ground Water

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Investigations/Studies Required

- Topographical surveys
- Hydrometeorological Studies
  - In-situ precipitation, rainfall pattern, evaporation losses and climatologically features etc.
- Hydrological Studies
  - Runoff pattern, drainage pattern etc.
- Soil Infiltration Studies
- Geochemical Studies
- Hydrogeological Studies
- Geophysical Investigations
- Engineering Design and Construction
- **?**

Please remember this 8 words

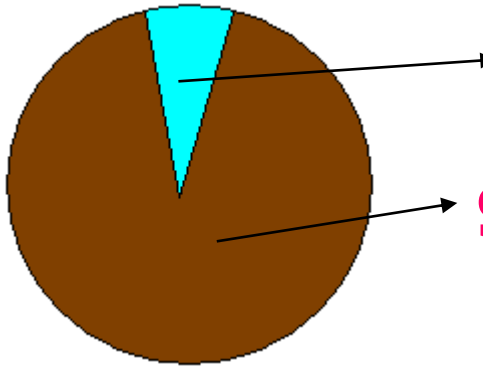
If fail to Plan, you plan to fail”

Types of rocks

Three Types

1. Igneous rock
2. Sedimentary rock
3. Metamorphic rock

Total water on earth



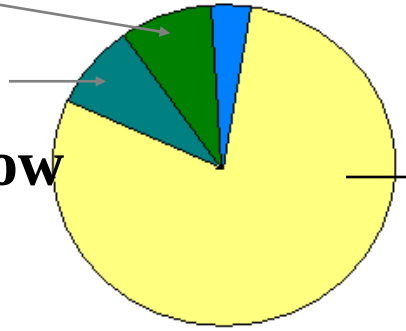
3% (37.5 mill. Cu.Kms) Fresh Water

97% (1320 mill. Cu. Kms.) (Saline Water)

Distribution of fresh water on earth

11% (ground water up to 800m)

11% (ground water below 800m)

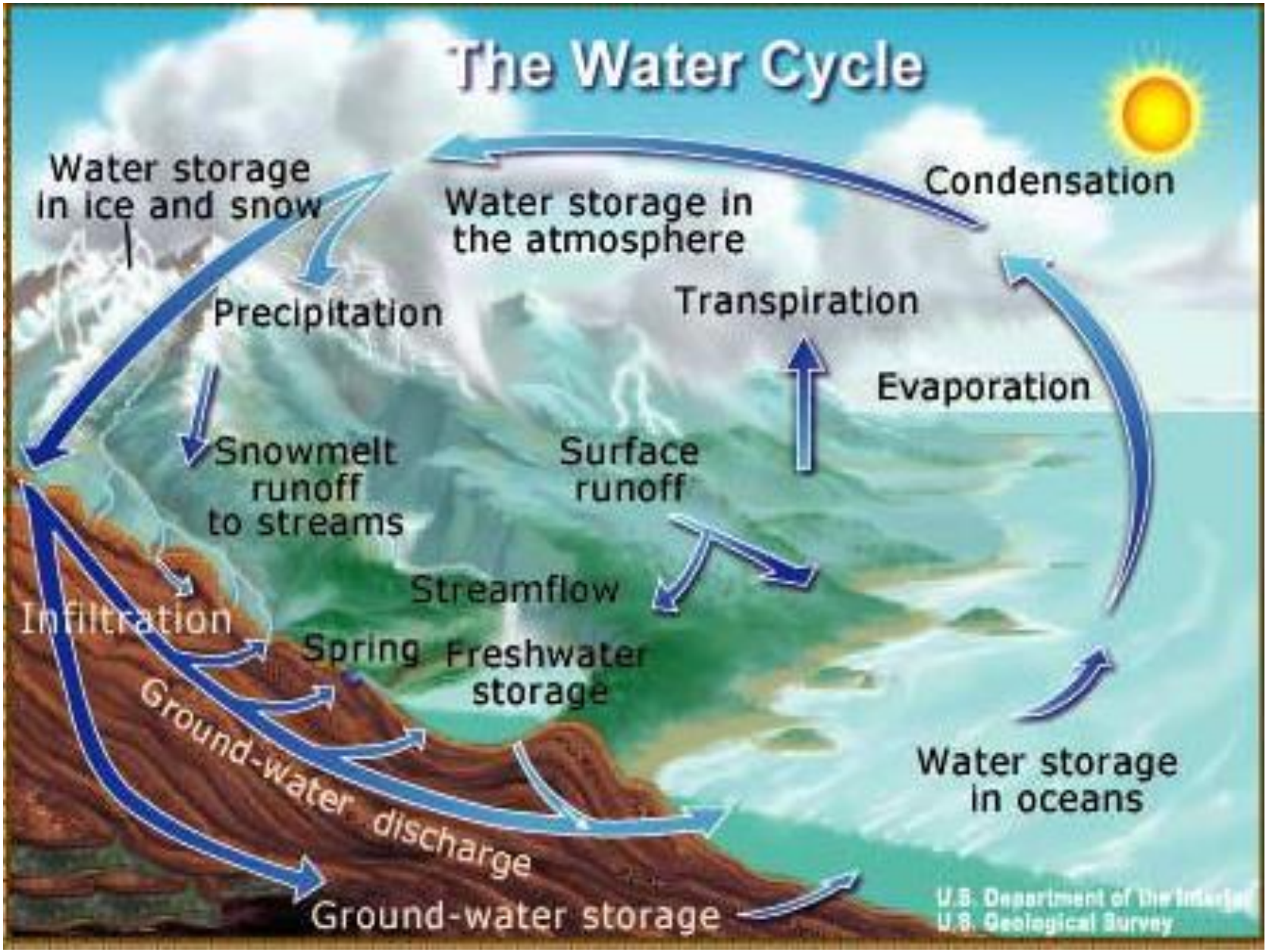


1% (in lakes, rivers and streams)

77%(in glacier & ice caps)

11% of the total fresh water on earth (up to 800 m depth) is available for extraction

Water: Where does it come from ?



Hydrogeology

(*hydro*- meaning water, and *-geology* meaning the study of the Earth) is the area of geology that deals with the distribution and movement of groundwater in the soil and rocks of the Earth's crusts, (commonly in aquifers).

What is Ground water ?

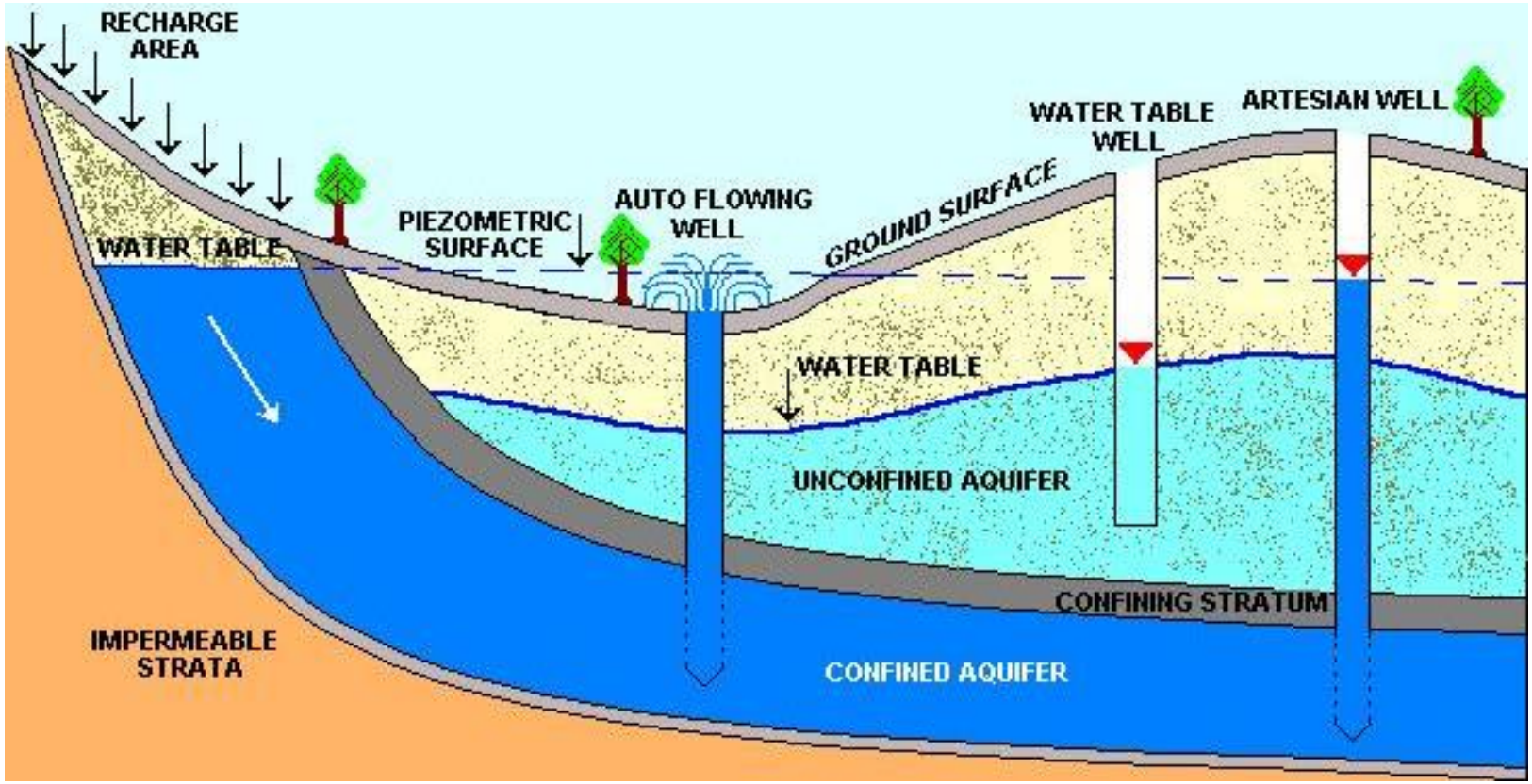
All subsurface water that fills the pores, fractures, and other spaces in rock strata below the Water Table(in the saturated zone of geologic formations).

- **Aquifer:** **A saturated permeable geological unit that is permeable enough to yield economic quantities of water to wells. (Sand)**
- **Aquitard:** **A geological unit that is permeable enough to transmit water in significant quantities when viewed over large areas and long periods, but its permeability is not sufficient to justify production wells being placed in it.(Arenacious Shale & Clay)**
- **Aquiclude:** **A geological unit which can only store water but can't transmit significant amount.(Shale & Clay)**
- **Aquifuge:** **A geological unit with no interconnected pores and hence can neither absorb nor transmit water(Massive Granite/Marble/Basalt)**

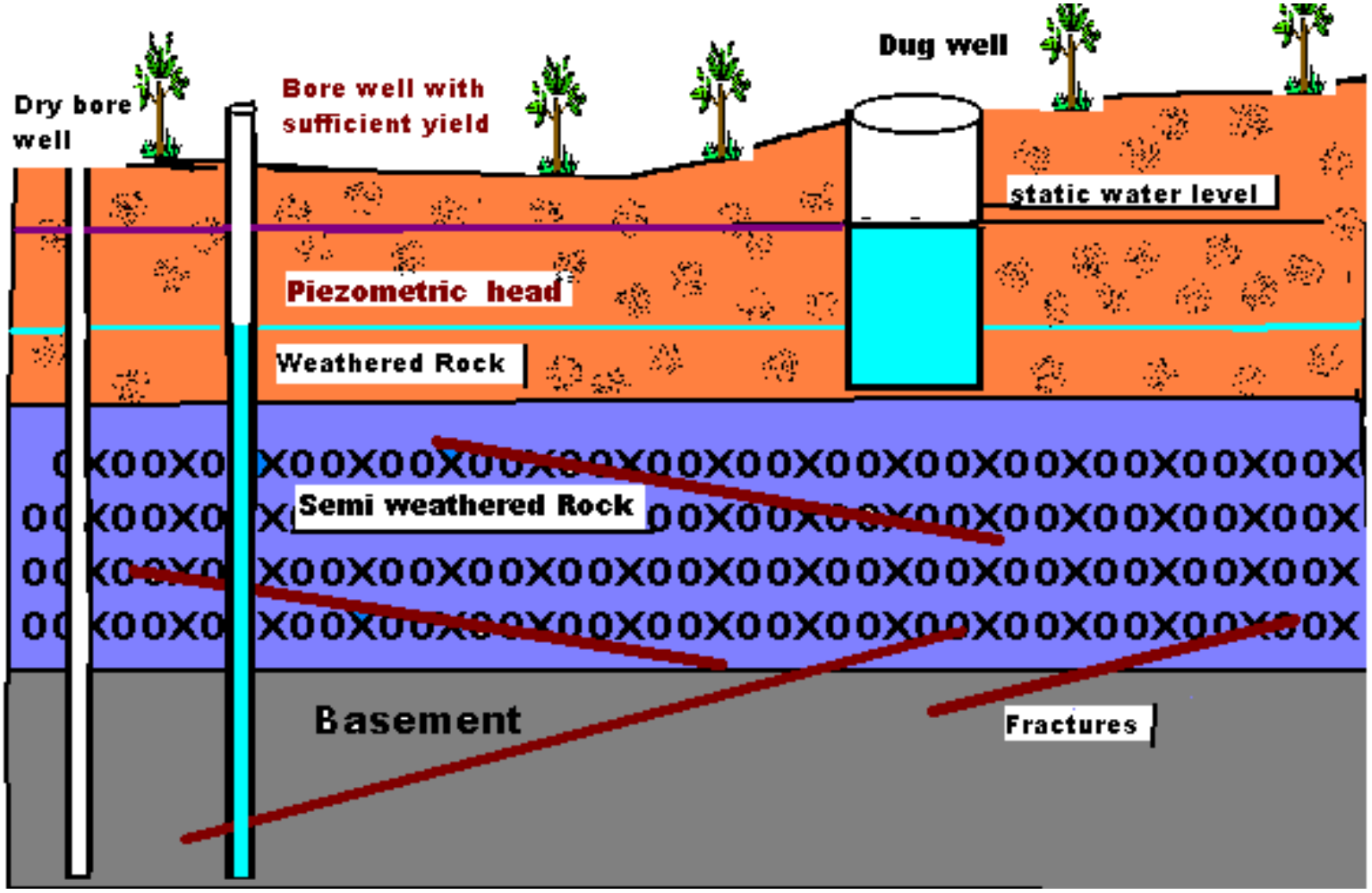
In Surface Geophysical Survey we can consider the formation are of two types depending their compactness

1. **Hard Formation &**
2. **Soft formation**

Aquifers in Alluvium Formation



Occurrence of Ground Water in Hard Formation



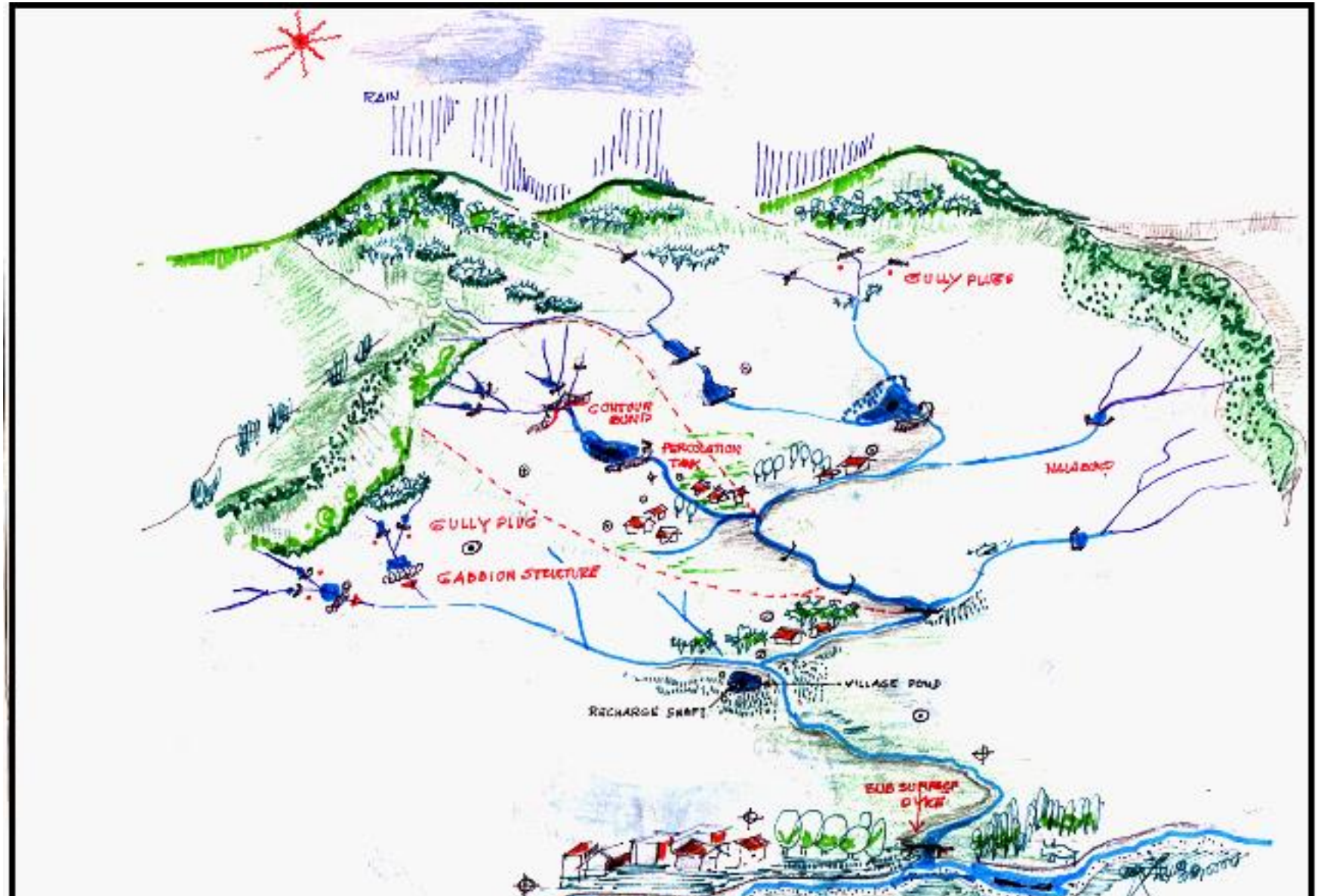
What is Geophysics ?

Measurements of earth's physical parameters at the earth surface.

Objectives of Geophysical Surveys

- The prime objective of geophysical survey is to unravel the hidden sub-surface hydrogeological conditions to save money and time.
- The other major objectives include
  - Delineation of sub-surface water bearing horizons.
  - Identification of fractured zones in hard rock areas.
  - Estimation of overburden thickness and delineation of bed rock topography.
  - Mapping of aquifer geometry.
  - Delineation of fresh/saline groundwater interface.
  - **Identification of suitable areas/locations for artificial recharge of groundwater.**

Artificial Recharge Structure



Information's Required to select site, zone or area for artificial recharge

- Lithologic variations, thickness, depth and lateral extent of the vadose zone and the aquifers
- Water level / Peizometric head
- Obstacles and direction of groundwater movement
- Groundwater quality and hydrogeologic parameters

Geophysical Objectives in Different Terrain for AR

Hard Rocks: in the weathered zone and fracture zones or maintain water level in it through constraining the movement of groundwater

Limestones : in solution channels or cavities after identifying their location and path of recharge

Alluvium: in near surface sandy soil, sand zone, flood plain, stream bed, sand dunes, . Also in confined aquifers through injection wells

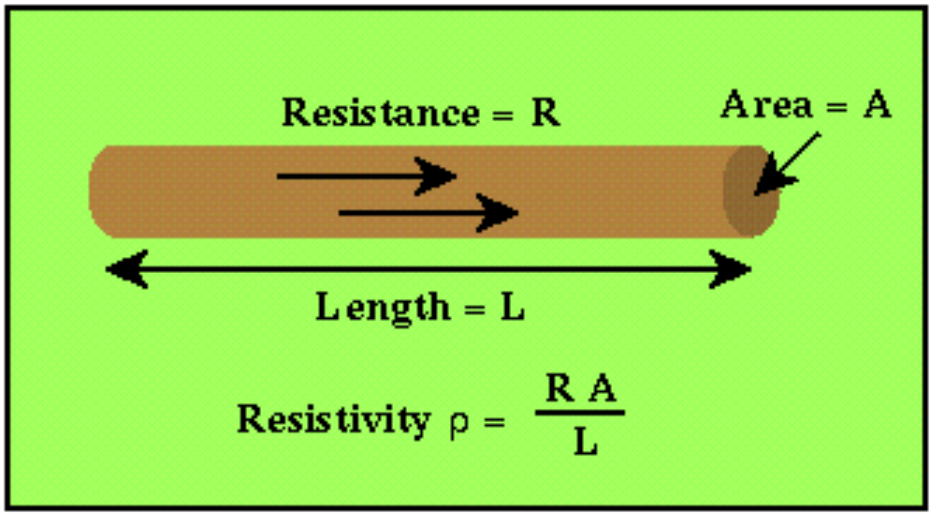
Urban areas: in open areas/porous pavement/parking place

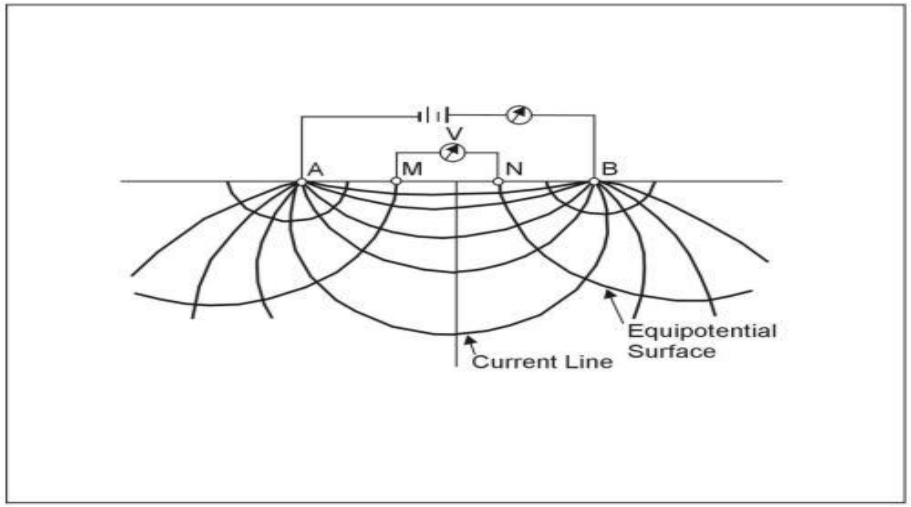
Electrical Resistivity Surveys

- Started by American Scientist *SCHLUMBERGER* during year 1912 -1914
- It is based on Ohm's Law (V=IR)
- Resistivity of a material is defined as the resistance un ohm between opposite faces of a unit cube (l=1 m, A= $1m^2$) of the material
- If the measurement is made over a semi – infinite space of homogeneous and isotropic material, then it will be a true resistivity
- If medium is inhomogeneous or anisotropic then it will be a apparent resistivity

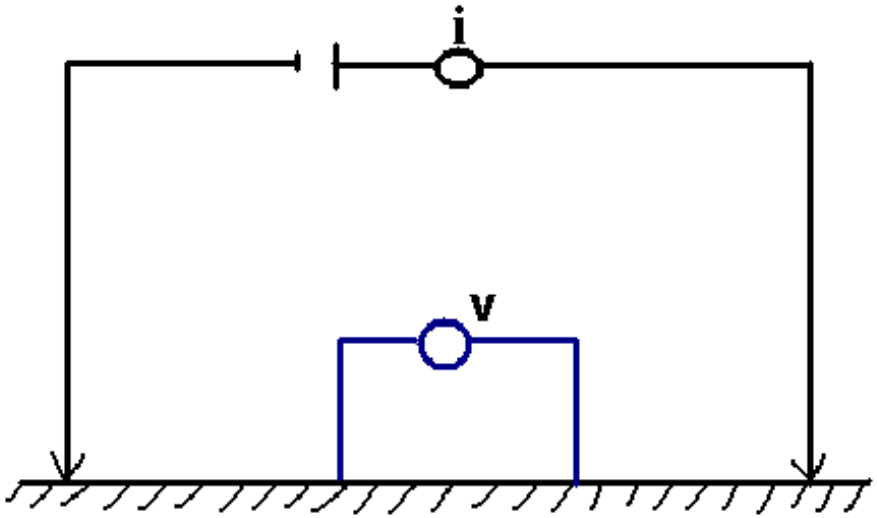
Electrical Resistivity Methods

Principle – Ohm's Law





In simplest form of resistivity method, a known amount of electric current is sent into the ground through a pair of electrodes and potentials developed due to current within the ground are measured across another pair of electrodes on the ground.



$$\rho = K\frac{\Delta V}{i}$$

Advantages of Electrical Resistivity Survey

- ✓ **Relatively direct and simple response to the groundwater conditions**
- ✓ **Low cost of survey**
- ✓ **Easy field data interpretation procedures**

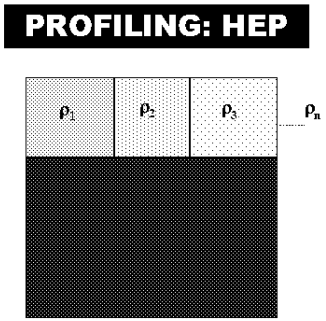
APPLICATION OF GEOPHYSICAL TECHNIQUES IN GROUND WATER EXPLORATION

- **Narrow down the target area.**
- **Pinpoint the probable site for ground water exploration.**
- **Comparative picture of the sub-surface litho environment.**
- **Identification of brackish/fresh ground water interface.**
- **Direction of ground water flow under natural/artificial recharge processes.**

Types of Electrical Resistivity Survey

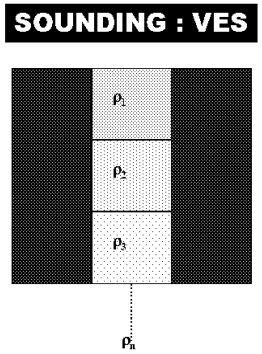
Horizontal Electrical Profiling (HEP)

It measures lateral variations in earth resistivity

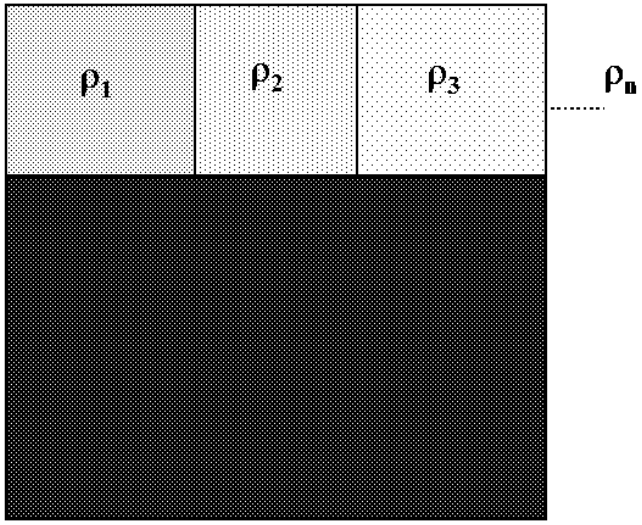


Vertical Electrical Sounding (VES)

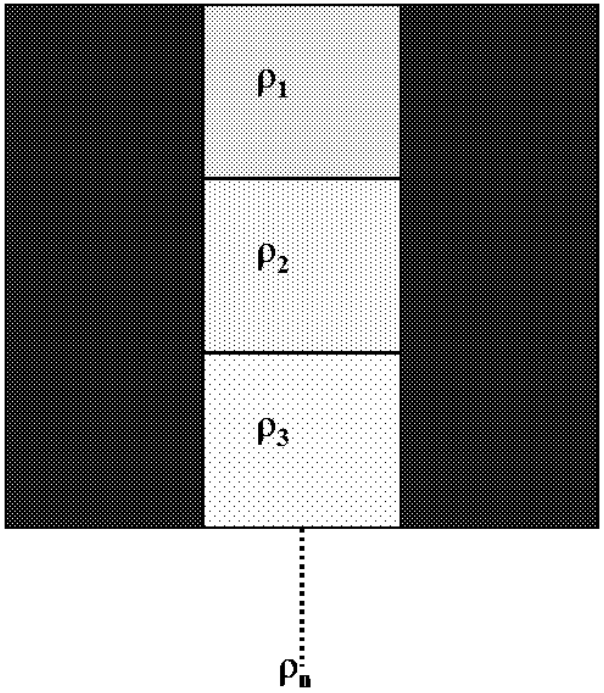
It measures resistivity variations with depth



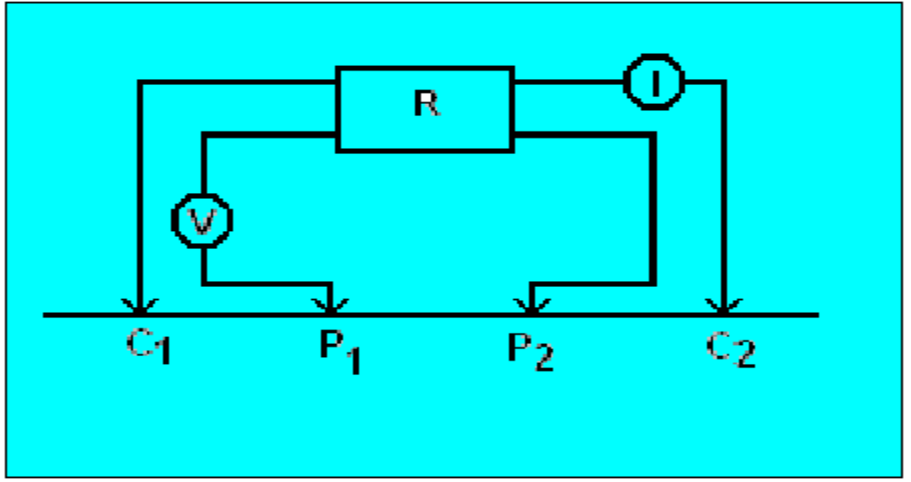
PROFILING: HEP



SOUNDING : VES



1. Wenner Configuration:



The formula for measuring the electrical Resistivity (apparent) is:

$\rho_a = 2 \pi a R$,

where a = Distance between two successive electrodes

R = V/I (V= Voltage, I = Current)

The unit for measuring apparent Resistivity is ohm-metres. In this method all 4 electrodes are moved constantly after each reading and the depth of penetration is about 1/3 of the total electrode separation , (C1-C2).

The Wenner array itself has got three variations, depending the change of positions of electrodes. These are,

α - **Wenner, where the electrode positions are C1, P1, P2, C2. This is also called normal Wenner array.**

β - **Wenner, where the electrode positions are C1, C2, P1, P2.**

γ - **Wenner, where the electrode positions are C1, P1, C2, P2.**

Surface Geophysical Survey

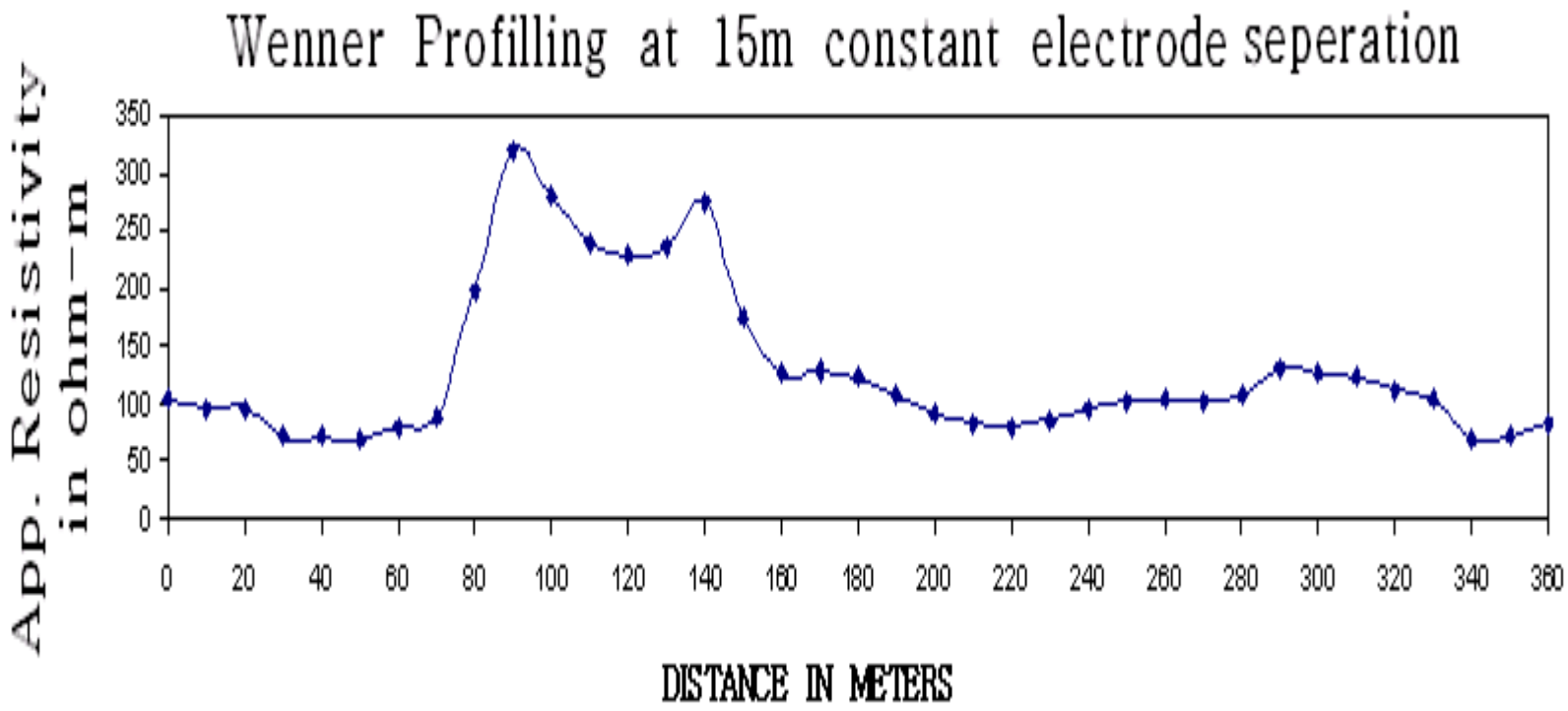
Wenner Profilling

Rajiv Gandhi National Ground Water Training Institute, Raipur

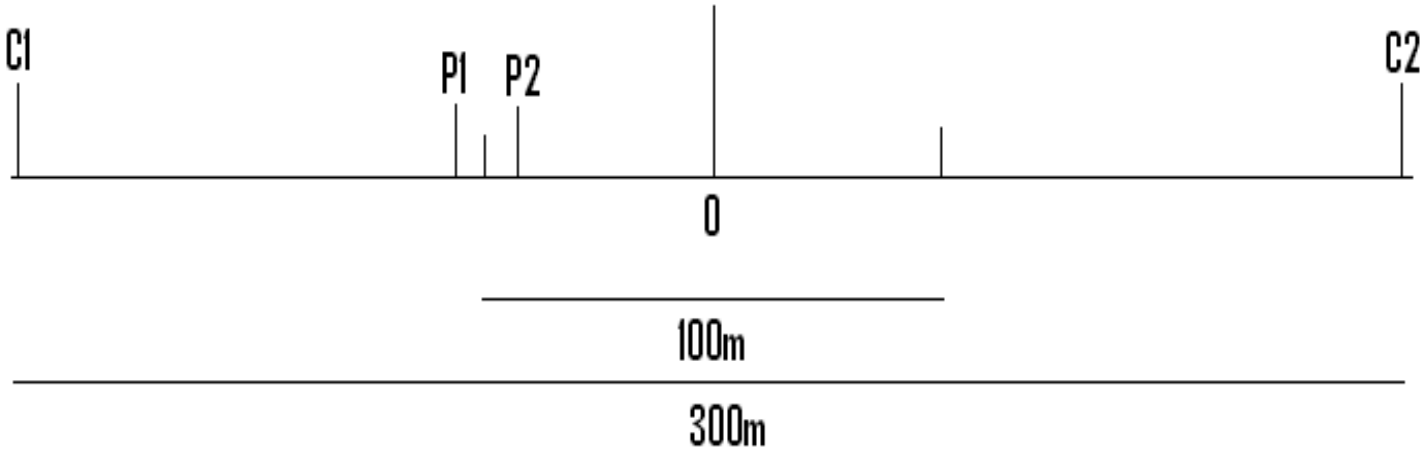
Government of India, Ministry of Water Resources,
River Development & Ganga Rejuvenation

Village :	Geophysicist :		Village :	Geophysicist :	
Block :	Profilling No:		Block :	Profilling No:	
District :	Direction:		District :	Direction:	
Date:			Date:		

Station	K	R	App. Rest.	Station	K	R	App. Rest.
1				1			
2				2			
3				3			
4				4			
5				5			
6				6			
7				7			
8				8			
9				9			
10				10			
11				11			
12				12			
13				13			
14				14			
15				15			
16				16			
17				17			
18				18			
19				19			
20				20			
21				21			
22				22			
23				23			
24				24			
25				25			
26				26			
27				27			
28				28			
29				29			
30				30			


Wenner Profilling at 15m constant electrode seperation
App. Resistivity in ohm-m
350
300
250
200
150
100
50
0
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
320
340
360
DISTANCE IN METERS

Layout of Gradient Resistivity Profiling(GRP)



Gradient Resistivity Profiling(GRP

Formula

$$\rho_a = \frac{\pi}{2l} \times \frac{L^2(1 - x^2/L^2)^2}{1 + x^2/L^2} \times \frac{\Delta V}{I} = K\frac{\Delta V}{I} = K \times R$$

P_a = Apparent Resistivity

2L = Distance between two current electrode

2l = Distance between potential electrodes

X = Distance between the Centre of the current electrodes to the centre of the potential electrodes

R = Resistance of the formation

Surface Geophysical Survey

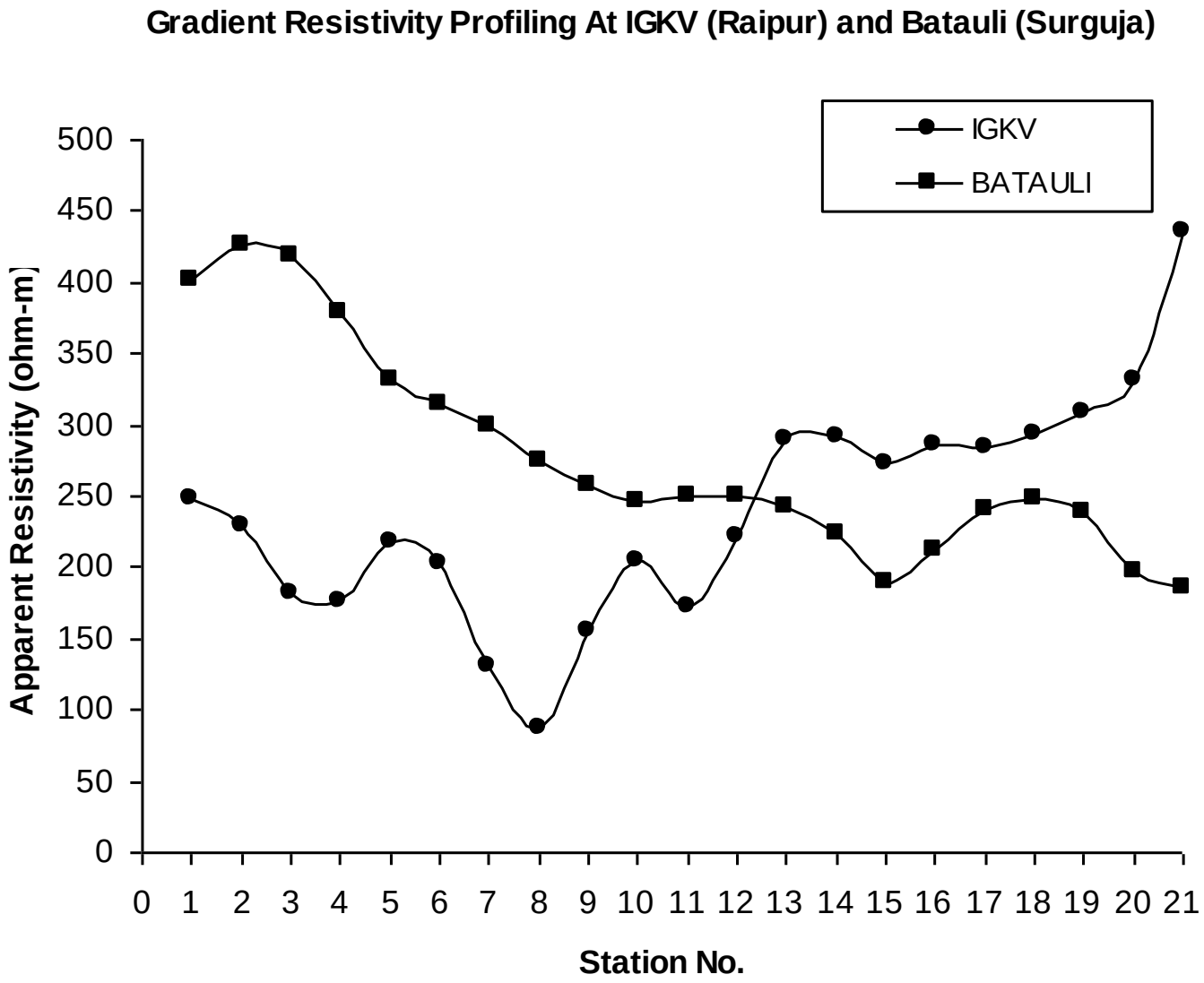
Gradient Resistivity Profiling(GRP)

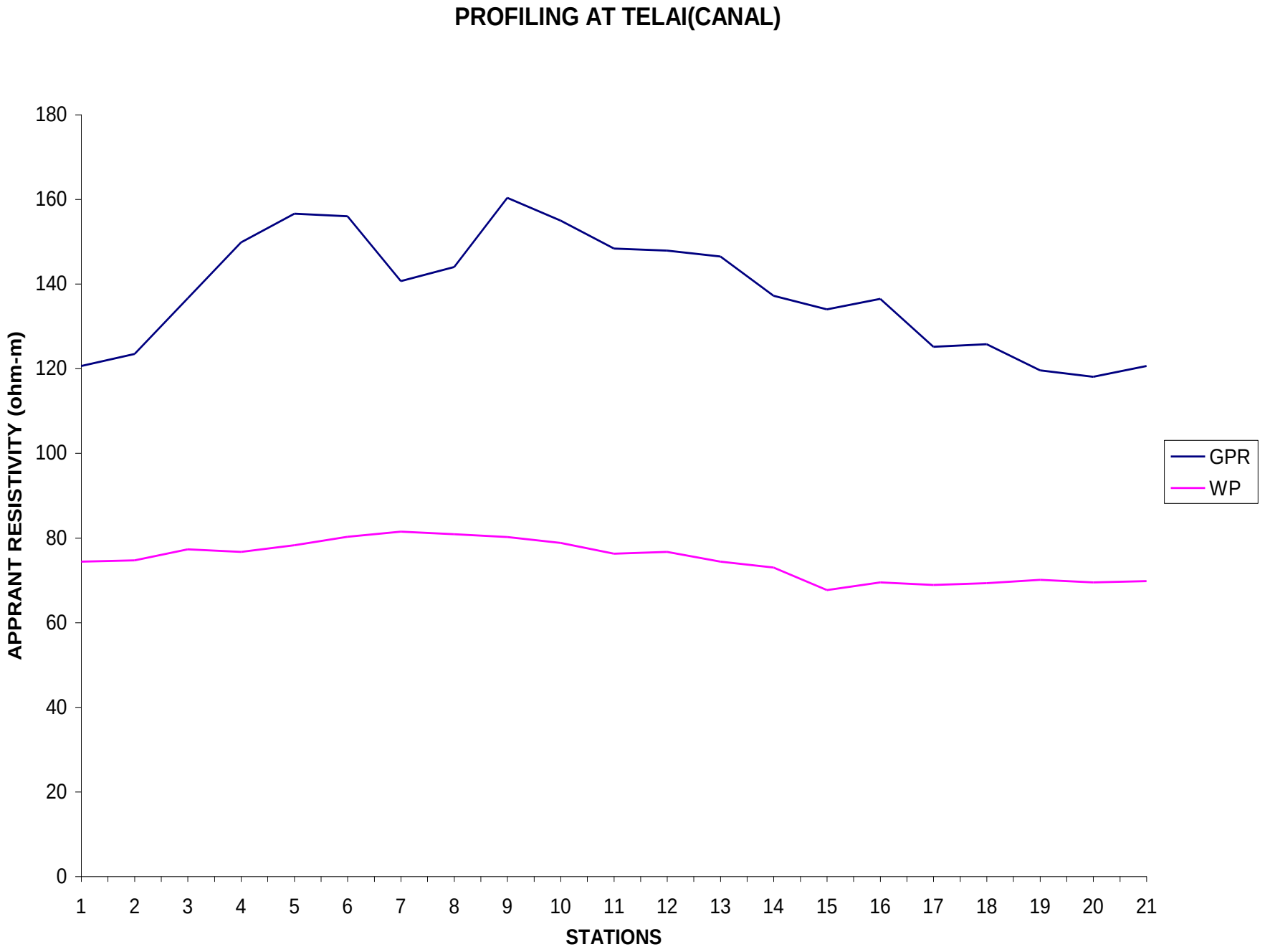
Rajiv Gandhi National Ground Water Training Institute, Raipur

Government of India, Ministry of Water Resources, River Development & Ganga Rejuvenation

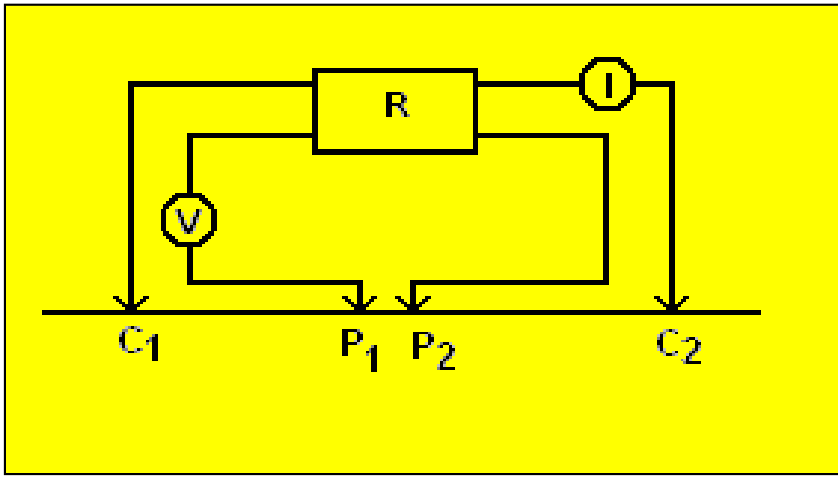
Village :	**Geophysicist :**	**Village :**	**Geophysicist :**
Block :	**Profiling No:**	**Block :**	**Profiling No:**
District :	**Direction:**	**District :**	**Direction**
Date:		**Date:**	
K for AB=300, MN=10m& Stn. interval=5m		**K for AB=300, MN=10m& Stn. interval=5m**	

Station	K	R	App. Rest.	Station	K	R	App. Rest.
1	5026.88			1	5026.88		
2	5370.53			2	5370.53		
3	5694.48			3	5694.48		
4	5993.93			4	5993.93		
5	6264.27			5	6264.27		
6	6501.19			6	6501.19		
7	6700.81			7	6700.81		
8	6859.78			8	6859.78		
9	6975.35			9	6975.35		
10	7045.52			10	7045.52		
11	7069.05			11	7069.05		
12	7045.52			12	7045.52		
13	6975.35			13	6975.35		
14	6859.78			14	6859.78		
15	6700.81			15	6700.81		
16	6501.19			16	6501.19		
17	6264.27			17	6264.27		
18	5993.93			18	5993.93		
19	5694.48			19	5694.48		
20	5370.53			20	5370.53		
21	5026.88			21	5026.88		


Gradient Resistivity Profiling At IGKV (Raipur) and Batauli (Surguja)
IGKV
BATAULI
Apparent Resistivity (ohm-m)
500
450
400
350
300
250
200
150
100
50
0
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21
Station No.


PROFILING AT TELAI(CANAL)
APPRANT RESISTIVITY (ohm-m)
180
160
140
120
100
80
60
40
20
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
STATIONS
GPR
WP

2. Schlumberger Configuration:



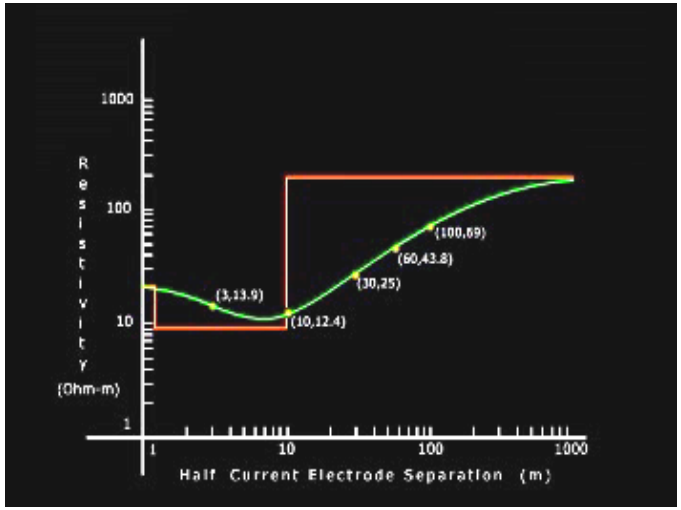
The formula for measuring the electrical resistivity (apparent) is

$$\rho_a = \pi R \frac{[(AB/2)^2 - (MN/2)^2]}{MN}$$

Where AB/2 = Half current electrode separation

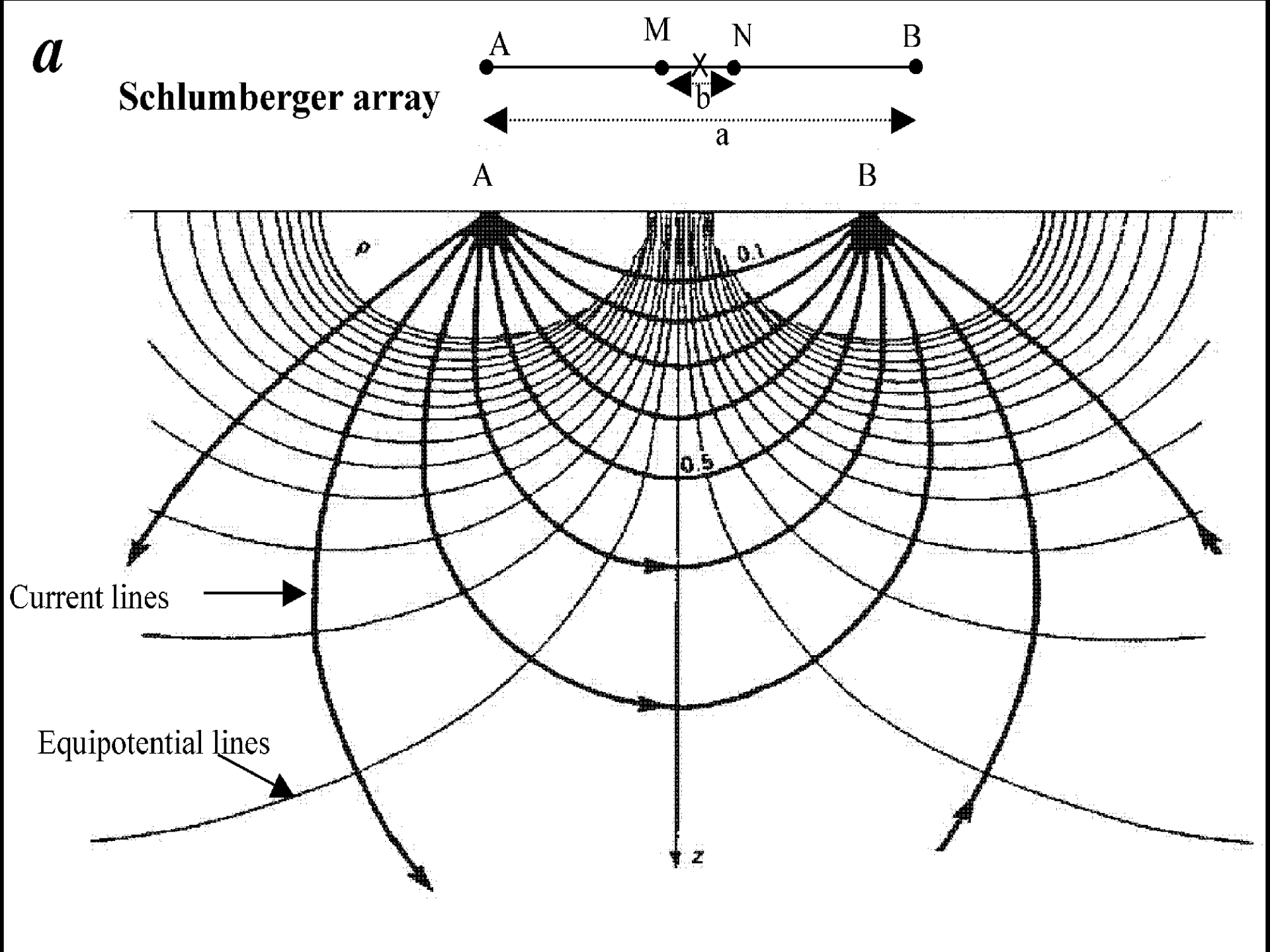
MN/2 = Half potential electrode separation

R = V/ I (V= Voltage) (I= Current)



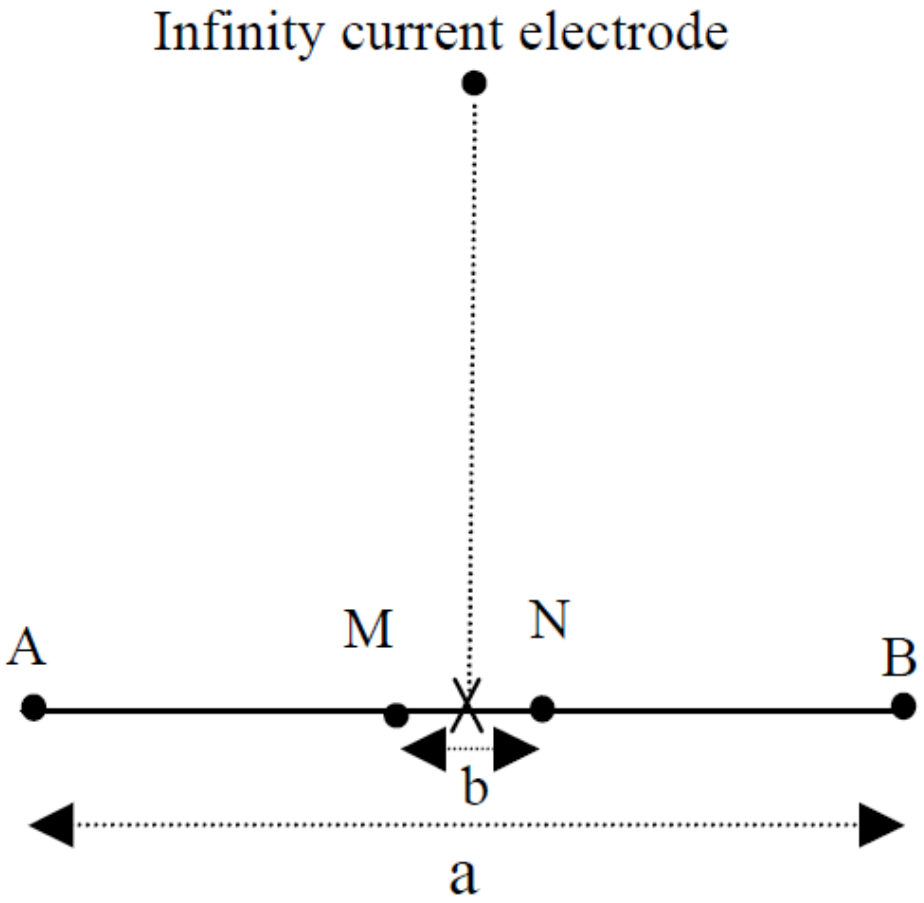
a

Schlumberger array



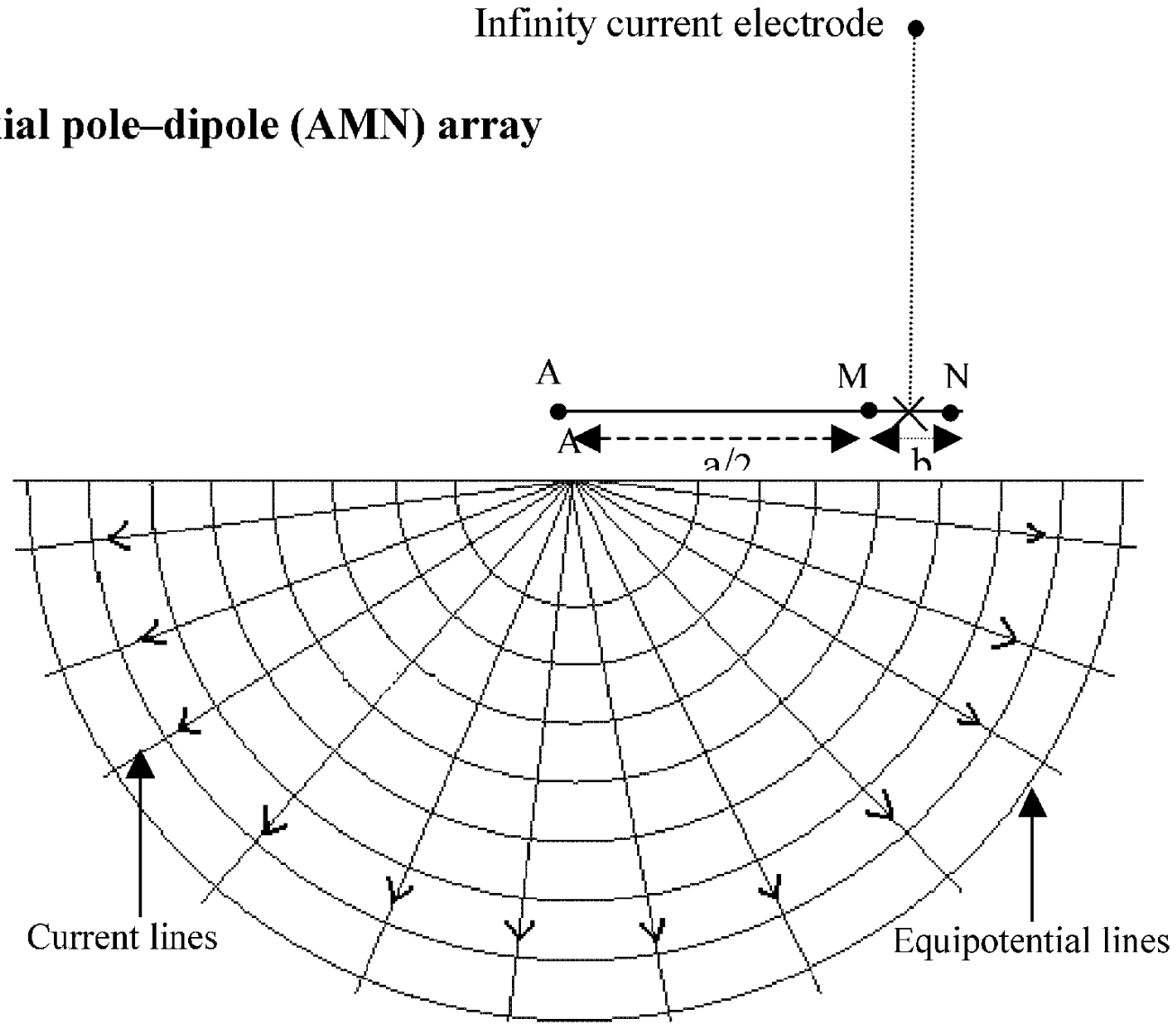
Surface Geophysical Survey					
Vertical Electrical Sounding (VES)					
Rajiv Gandhi National Ground Water Training & Research Institute, Raipur					
Government of India, Ministry of Water Resources, River Development & Ganga Rejuvenation					
Village :			Geophysicist :		Date :
Block :					VES No. :
District :			Survey No. :		VES Direction :
S.No.	AB/2 (m)	MN/2 (m)	Geometrical Factor (K)	Resistance (ohm)	Apparent Resistivity (ohm-m)
1	2	0.4	15.09		
2	3	0.4	34.73		
3	4.5	0.4	78.92		
4	6	0.4	140.80		
5	8	0.4	250.80		
6	10	0.4	392.22		
7	10	2	75.43		
8	12	0.4	565.08		
9	15	2	173.64		
10	20	2	311.14		
11	25	2	487.92		
12	30	2	703.99		
13	30	5	275.00		
14	35	5	377.14		
15	40	5	494.99		
16	45	5	628.56		
17	50	5	777.84		
18	60	5	1123.55		
19	70	5	1532.12		
20	70	10	754.27		
21	80	10	989.98		
22	90	10	1257.12		
23	100	10	1555.69		
24	120	10	2247.10		
26	150	10	3519.94		
27	200	10	6269.89		
28	250	10	9805.54		
29	300	10	14126.89		
30	300	20	7039.87		
31	350	20	9593.40		
32	400	20	12539.77		
33	500	20	19611.07		

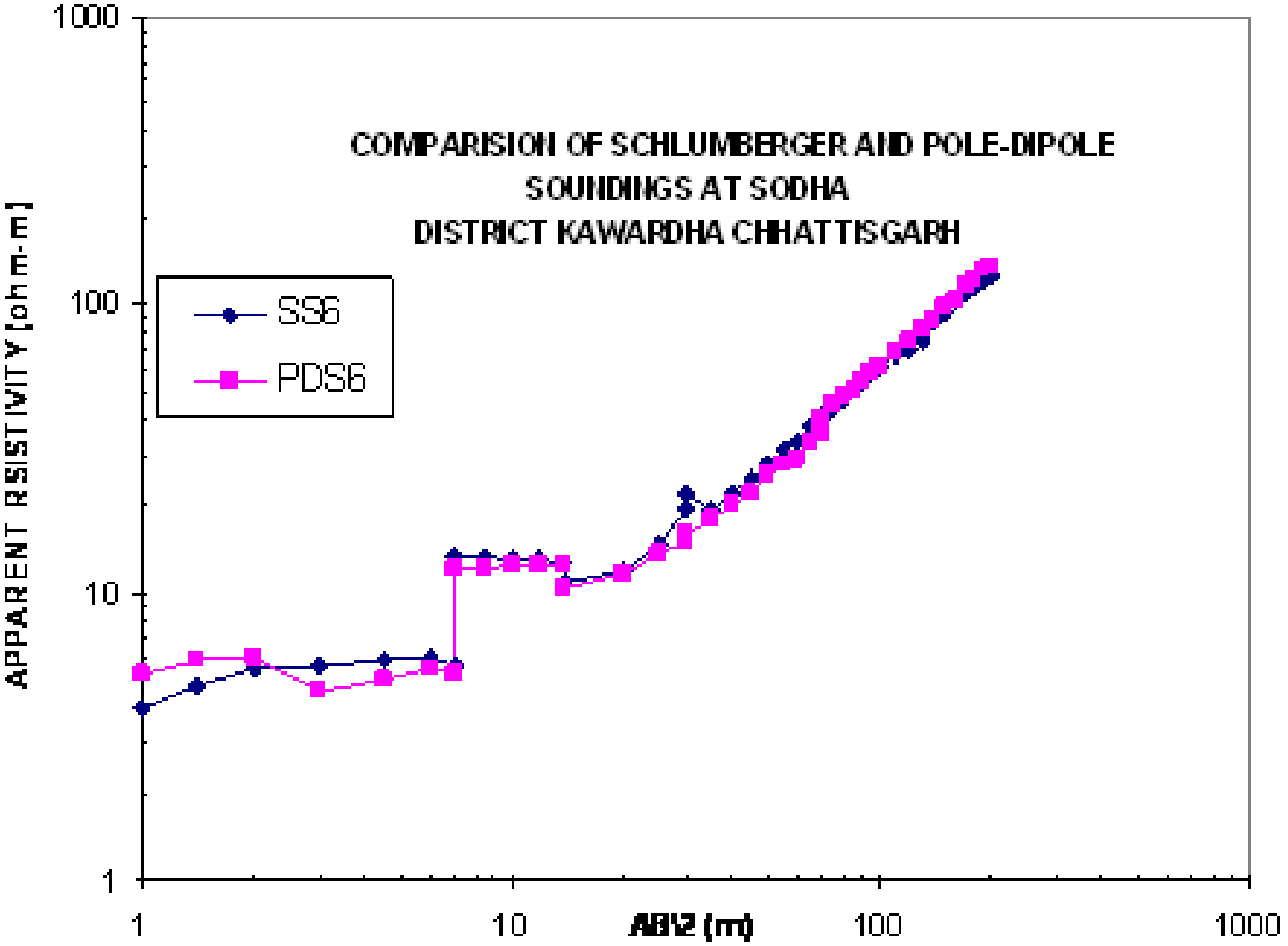
Pole-Di-Pole (Half Schlumberger Method)

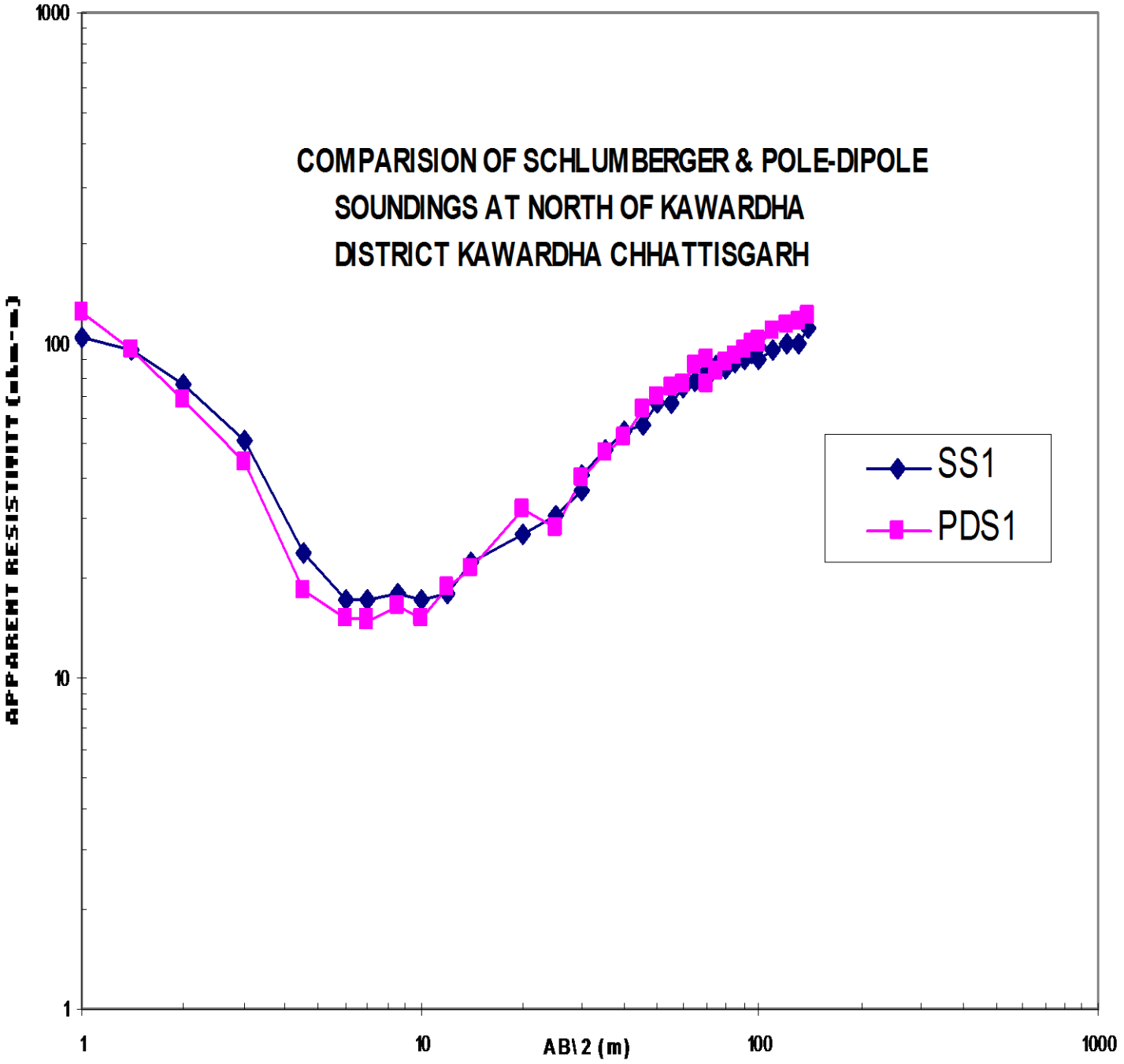


Axial pole–dipole (AMN) array

b




COMPARISION OF SCHLUMBERGER AND POLE-DIPOLE
SOUNDINGS AT SODHA
DISTRICT KAWARDHA CHHATTISGARH
SS6
PDS6
APPARENT RESISTIVITY [ohm-m]
1000
100
10
1
1
10
100
1000
AB/2 (m)


COMPARISION OF SCHLUMBERGER & POLE-DIPOLE
SOUNDINGS AT NORTH OF KAWARDHA
DISTRICT KAWARDHA CHHATTISGARH
APPARENT RESISTIVITY (ohm-m)
1000
100
10
1
1
10
100
1000
AB\2 (m)
SS1
PDS1

Interpretation of VES Data

- Plot of apparent Resistivity values for different electrode separation on Logarithmic scale
- Interpretation through curve matching techniques
- Interpretation through Computer Software
  - Forward modeling
  - Inverse modeling

Interpretation can be done by two methods

1. **Manual Data Interpretation**
2. **Computerised Data Interpretation**

Interpretation of VES Data

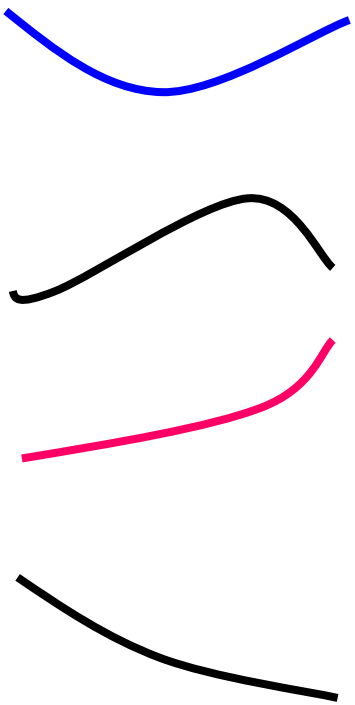
Interpretation can be done by two methods

1. Manual Data Interpretation

2. Computerised Data Interpretation

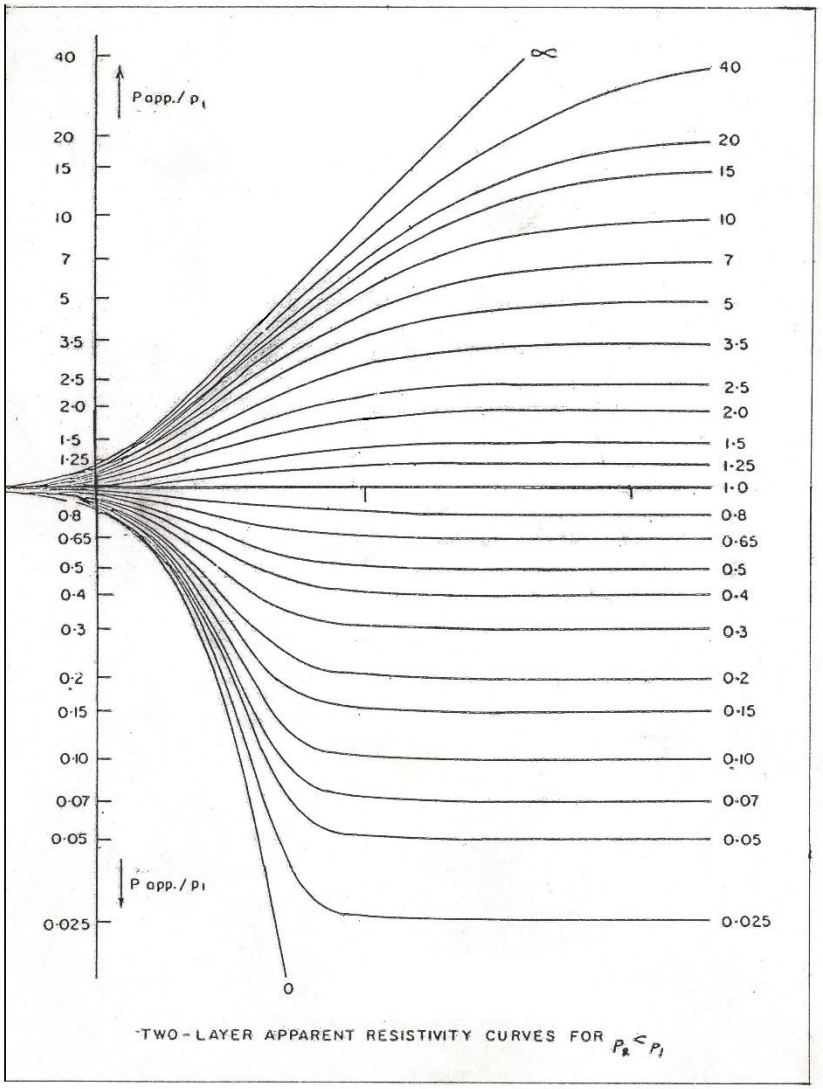
Type of VES curves

- H – type ($\rho_1>\rho_2<\rho_3$)
- K - type ($\rho_1<\rho_2>\rho_3$)
- A - type ($\rho_1<\rho_2<\rho_3$)
- Q - type ($\rho_1>\rho_2>\rho_3$)

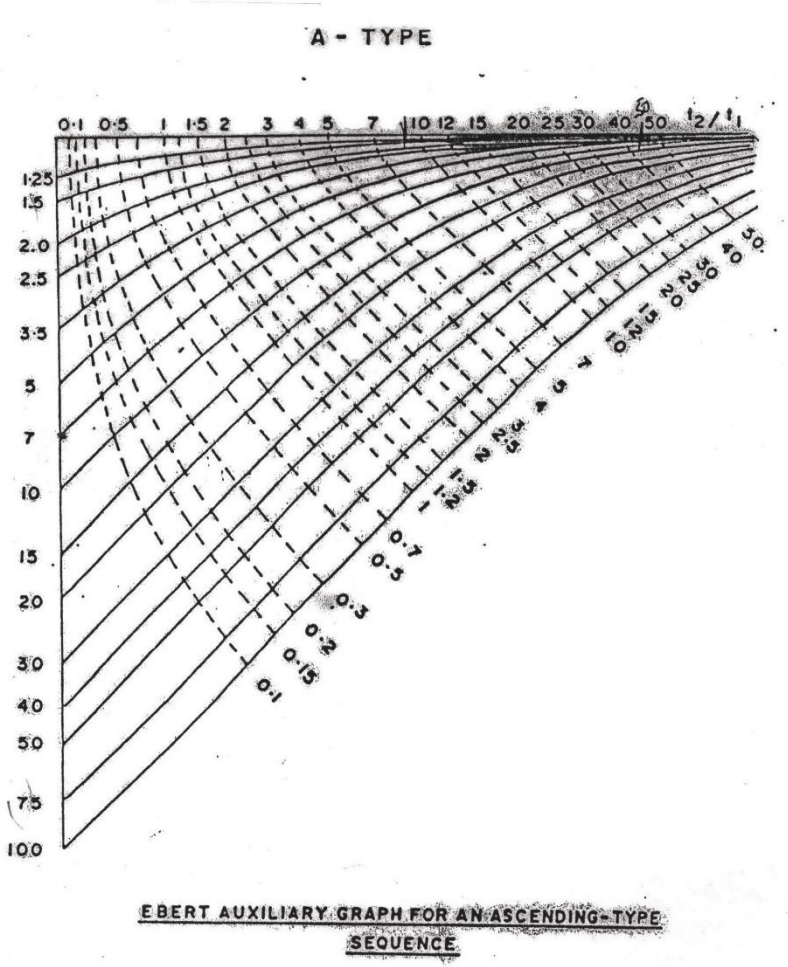


Two Layer Master Curve

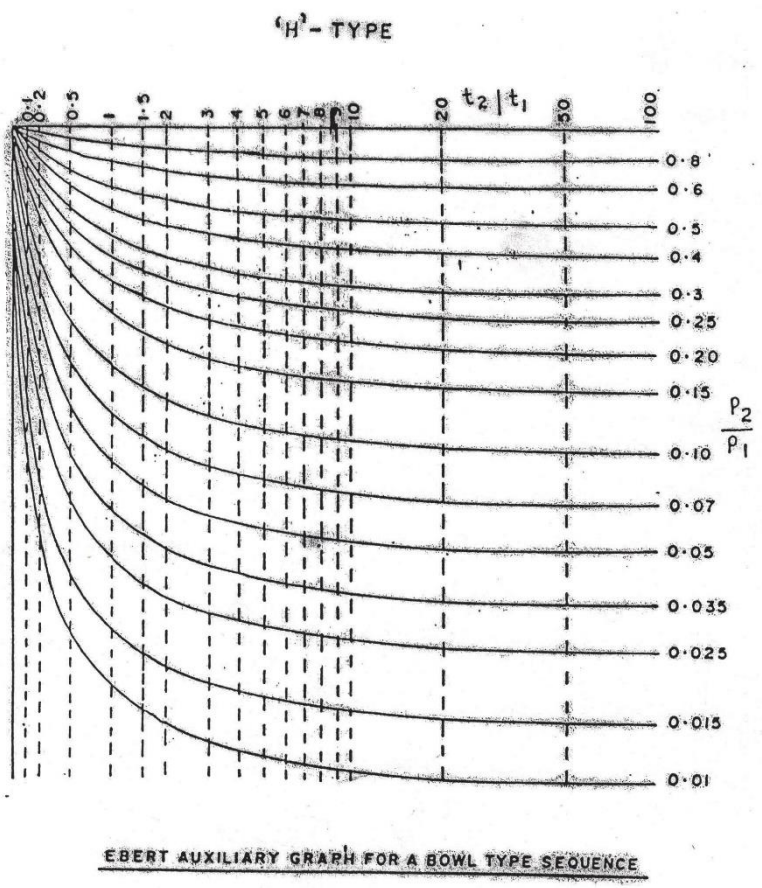
Multilayer problem is reduced to the simple two layer case with four charts of auxiliary curves.



Auxiliary Curve

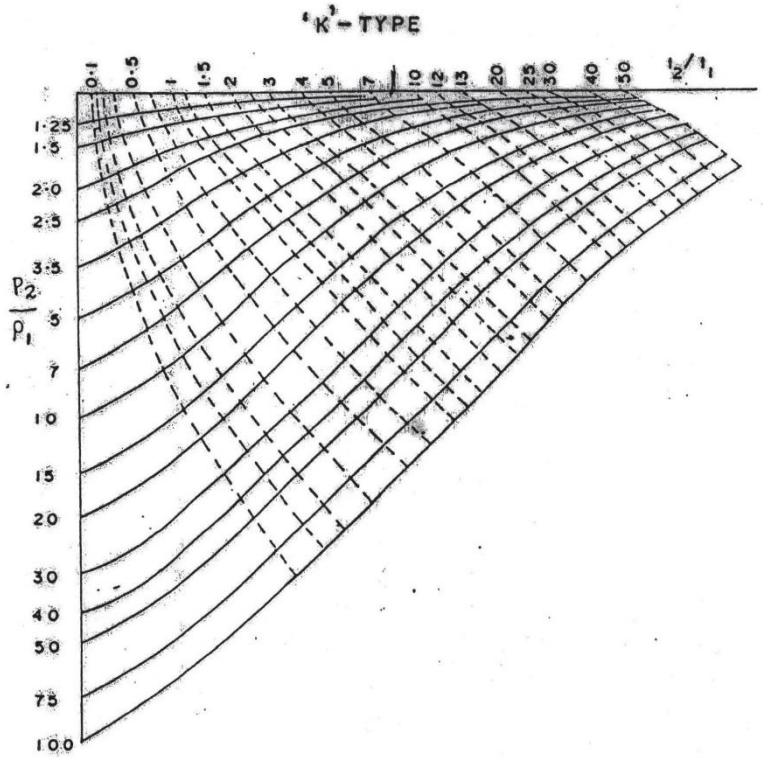


EBERT AUXILIARY GRAPH FOR AN ASCENDING-TYPE SEQUENCE

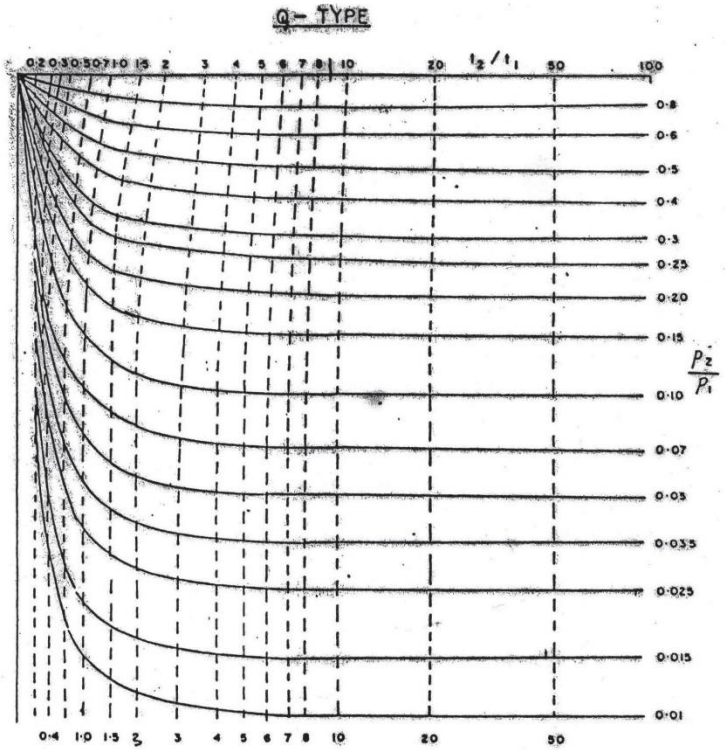


EBERT AUXILIARY GRAPH FOR A BOWL TYPE SEQUENCE

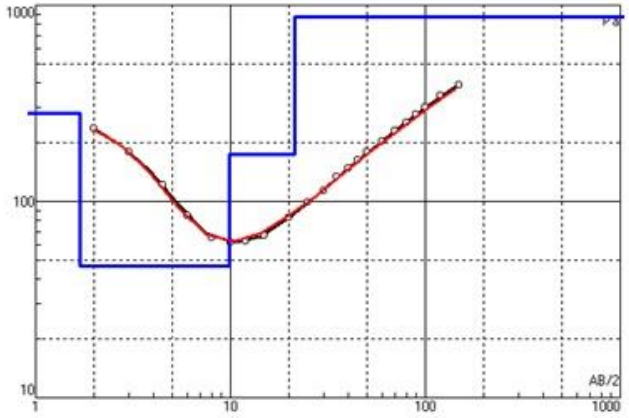
Auxiliary Curve



EBERT AUXILIARY GRAPH FOR A BELL TYPE SEQUENCE

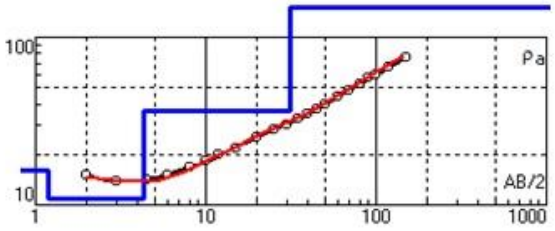


EBERT AUXILIARY GRAPH FOR A DESCENDING TYPE SEQUENCE



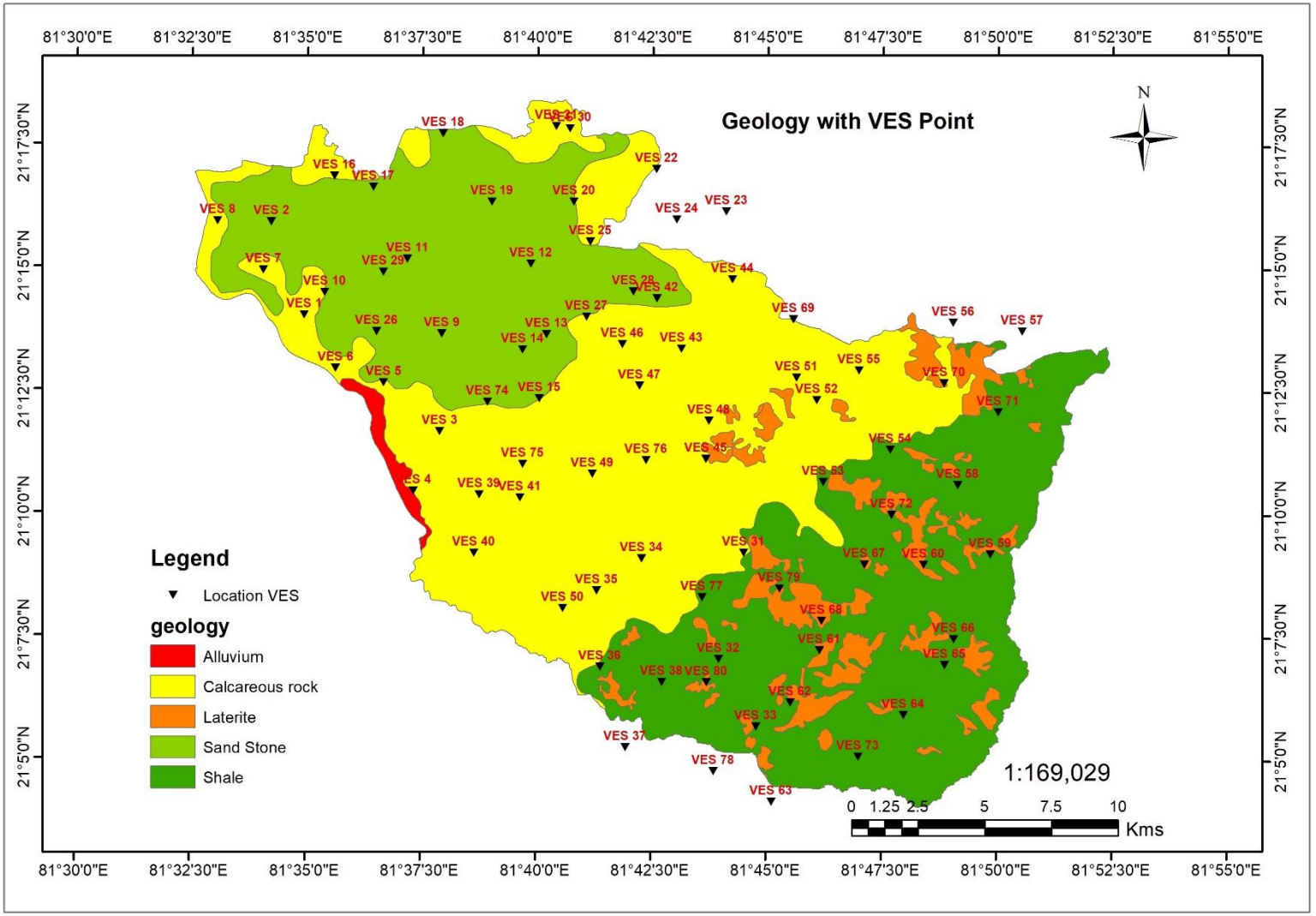
N	ρ	h	d
1	280	1.7	1.7
2	47	8.1	9.8
3	174	11.5	21.3
4	870		

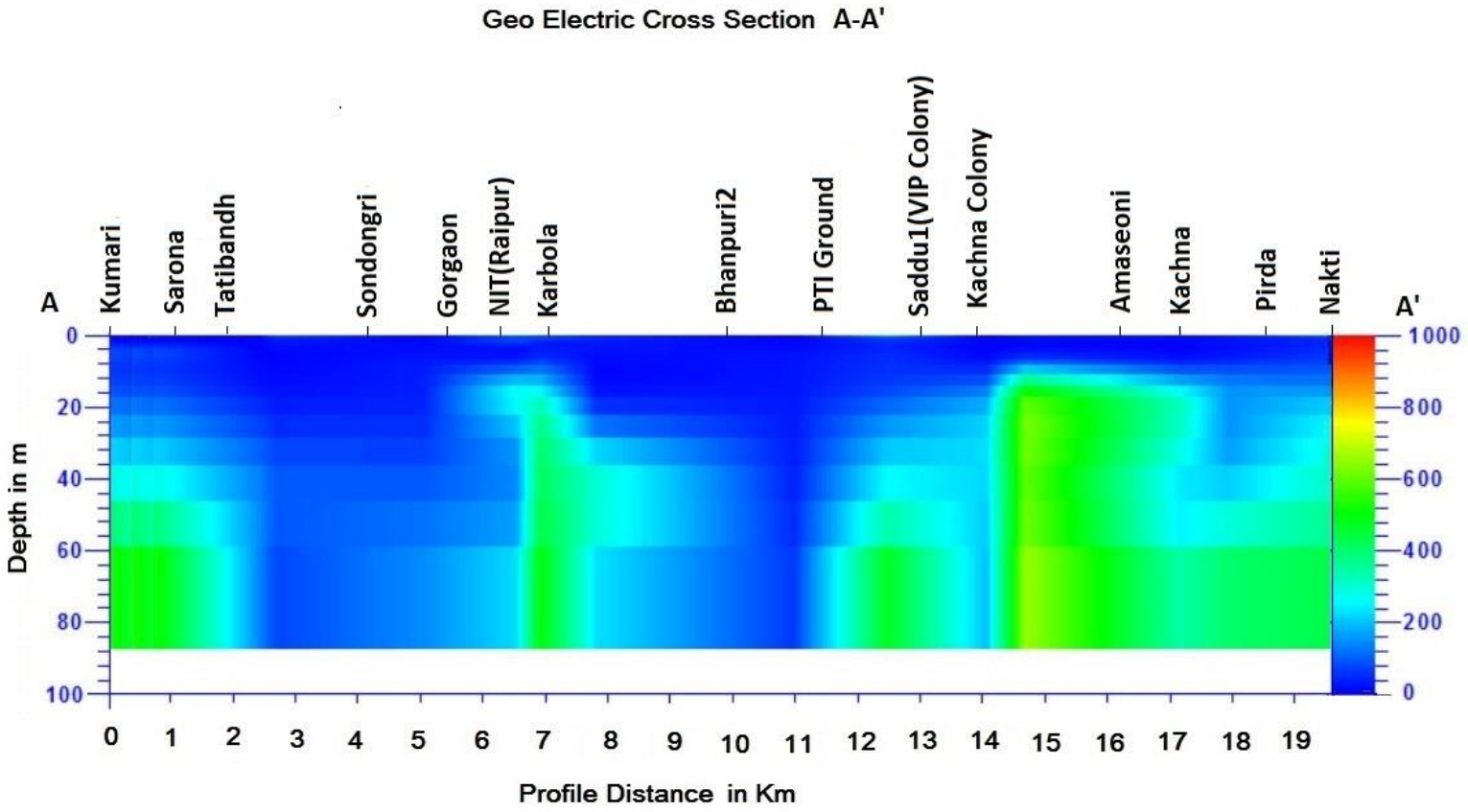
Field Curves and Interpreted Results of VES- 15 (Kamal Vihar)

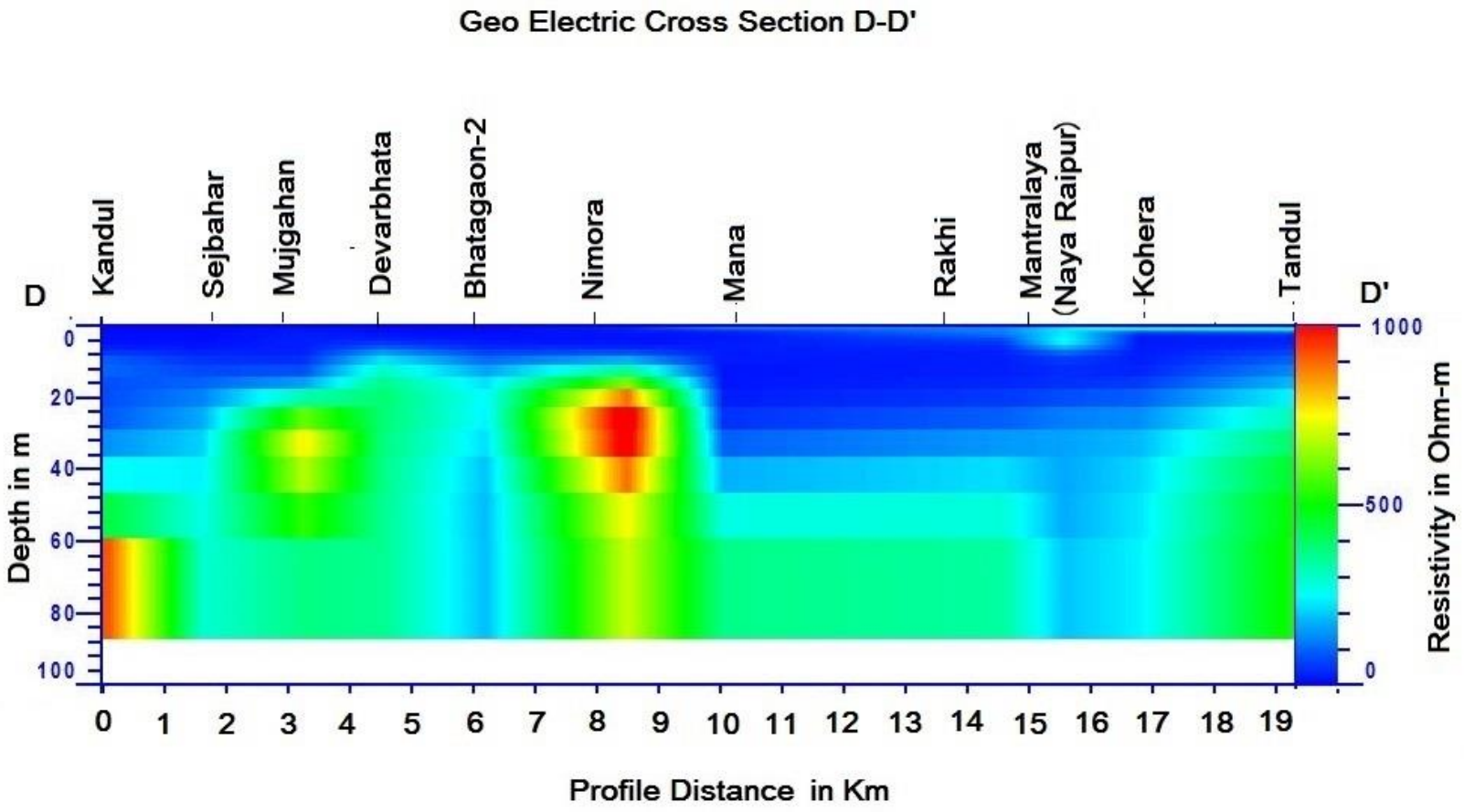


N	ρ	h	d
1	16	1.2	1.2
2	11	3.1	4.3
3	36	27	31.3
4	150		

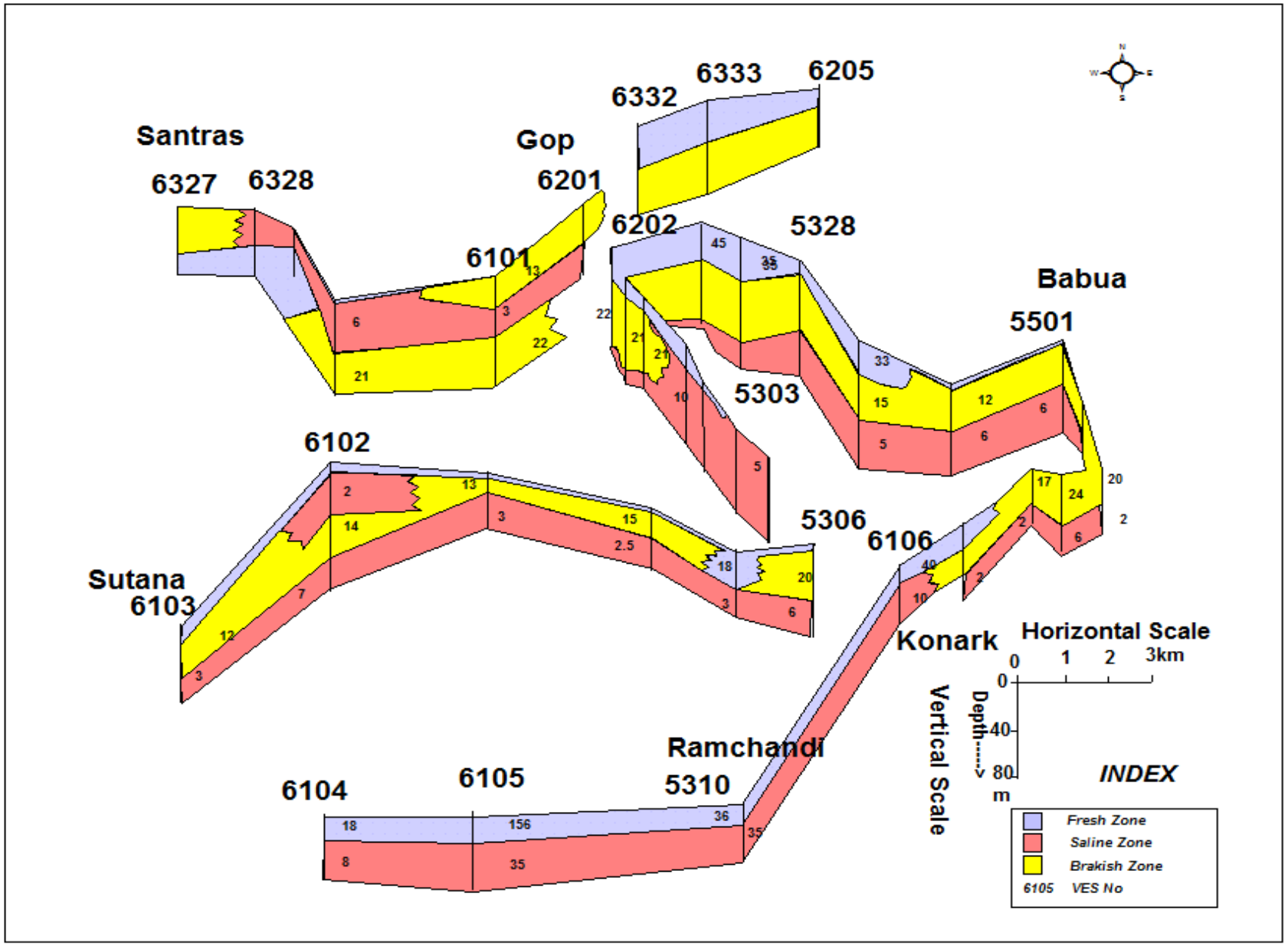
Field Curves and Interpreted Results of VES- 16 (Sondongri)


Geology with VES Point
N
81°30'0"E
81°32'30"E
81°35'0"E
81°37'30"E
81°40'0"E
81°42'30"E
81°45'0"E
81°47'30"E
81°50'0"E
81°52'30"E
81°55'0"E
21°17'30"N
21°15'0"N
21°12'30"N
21°10'0"N
21°7'30"N
21°5'0"N
Legend
Location VES
geology
Alluvium
Calcareous rock
Laterite
Sand Stone
Shale
1:169,029
0 1.25 2.5 5 7.5 10
Kms

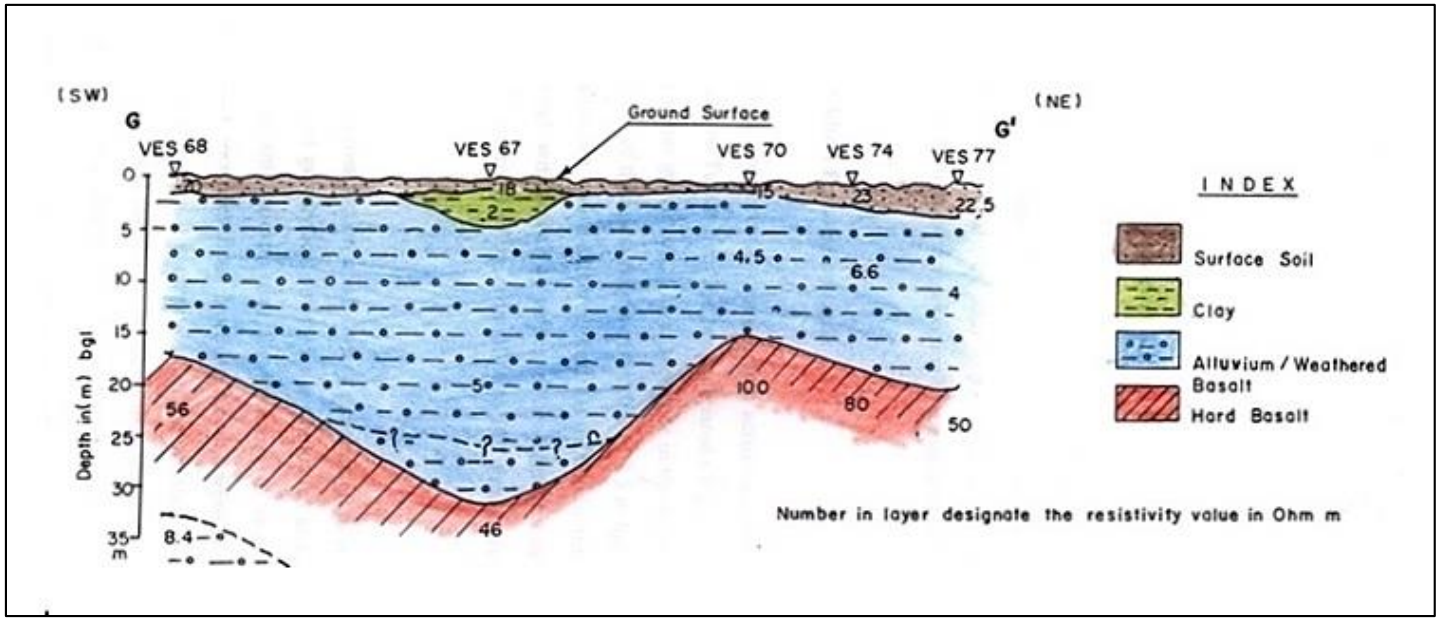

Geo Electric Cross Section A-A'
A
Kumari
Sarona
Tatibandh
Sondongri
Gorgaon
NIT(Raipur)
Karbola
Bhanpuri2
PTI Ground
Saddu1(VIP Colony)
Kachna Colony
Amaseoni
Kachna
Pirda
Nakti
A'
Depth in m
0
20
40
60
80
100
1000
800
600
400
200
0
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19
Profile Distance in Km


Geo Electric Cross Section D-D'
D
D'
Kandul
Sejbahar
Mujgahan
Devarbhata
Bhatagaon-2
Nimora
Mana
Rakhi
Mantralaya (Naya Raipur)
Kohera
Tandul
Depth in m
0
20
40
60
80
100
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19
Profile Distance in Km
1000
500
0
Resistivity in Ohm-m

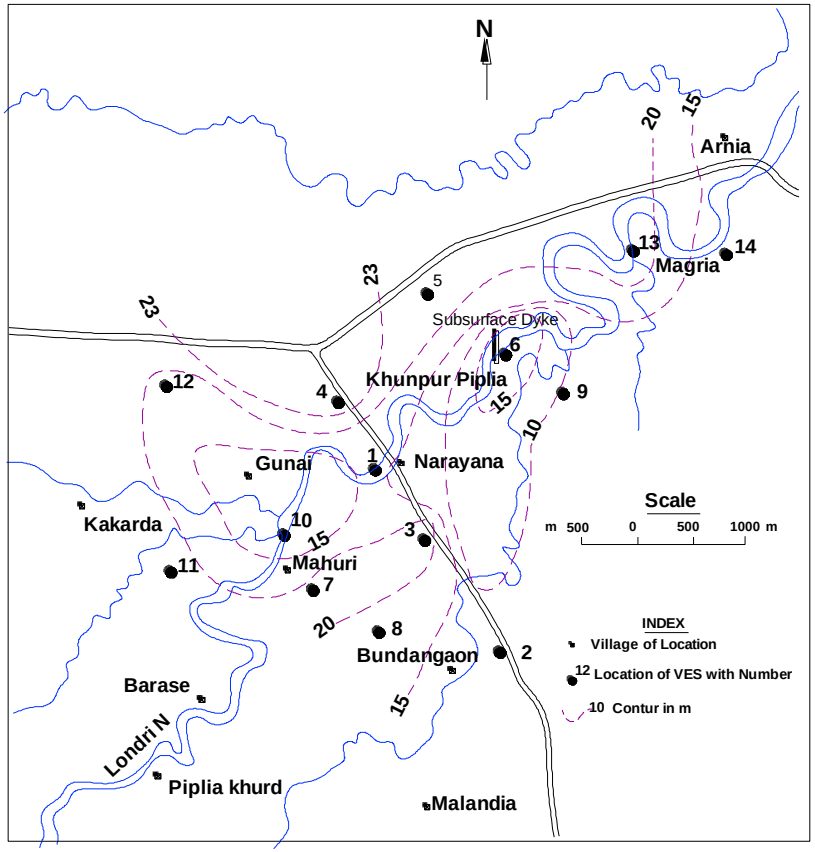
Map showing Fresh/Saline/Brakish zones between Gop and Konark, interpreted from VES

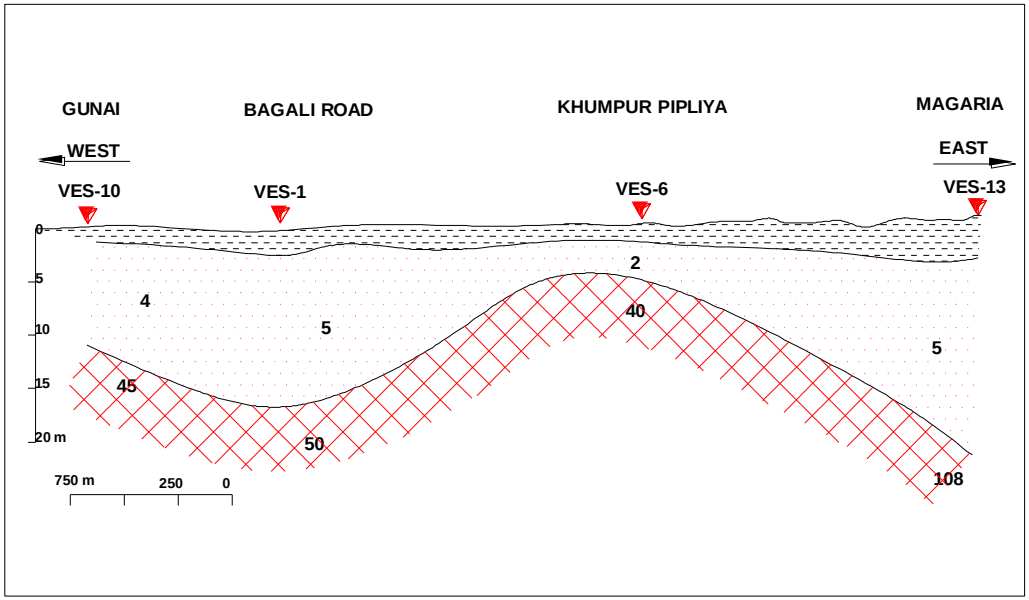


Geo-electrical Cross Section along Percolation Dam of Sikheri , District- Mandasoure (MP)



Londhri River bed, Dewas district (MP)





Any doubt?

Thank You