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Identification of Groundwater Potential Zones by Geophysical Surveys in Naguleru Sub-Basin, Guntur District, Andhra Pradesh, India

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ABSTRACT

Geophysical exploration using electrical resistivity surveys have been taken up as method to delineate the thickness and resistivities of different layers and identification of potential zones for groundwater development in Naguleru Sub-Basin of Guntur District, Andhra Pradesh, India. It is part of Cuddapah Basin of Peninsular India. Vertical Electrical Sounding were carried out up to 100 meters with 1/2 meter electrode spacing. The absolute resistivity values in the first layer of these formations range from 2 to 160 ohm-meters. and thickness ranges from 1.2 to 29meters, second layer ranges from 4 to 1160 ohm-meters and thickness ranges from 1.3 to 38.4 meters. The third layer commonly represents hard rock displaying the resistivity values ranging from 7 to 1621 ohm-meters to as high as infinite. The co-efficient of anisotropy varies from 1 to 2.59 and the spatial distribution of anisotropy values correlate with the water table fluctuation data. Groundwater potential zones have been demarcated by using interpreted geophysical analysis.

Introduction

Groundwater potentialities of a region are controlled by the climate, topography, and lithological formations and recharge pattern. Ground water in hard rock areas is available only from the weathered and fractured zones of rocks. Thus knowledge on weathered and fractured zones is essential which can be obtained through an integrated study using geological and geophysical methods. Thus, prospecting for ground water in hard rock areas boils down to a search for the thickest portions of the weathered and fractured zone. Several factors viz. rainfall, geology, topography, runoff, effluent and influent streams, soil cover and vegetation control the availability of the ground water in an area. Collection of such hydrological information of an area, basin or sub-basin is most important to prepare a scientifically sound plan from ground water exploration and its subsequent economic development. The water-bearing properties of crystalline rocks have been considered to be dependent on the extent of weathering and occurrence of joints, fractures and faults. Geological and structural factors play a dominant role in degree and depth of weathering and also in localization and movement of ground water. It is well known fact that the values of resistivity of any formation depend on various factors such as porosity, permeability, lithology, salinity and oil, gas or water saturation. Resistivity increases with lesser degree of saturation.

Hard rock areas are hither to know to yield limited quantities of ground water by virtue of its mode of origin and absence of inter-granular porosity. Hence, the identification of structurally favourable zones of ground water viz., lineaments, faults, fractures and joints has gained much importance and momentum in the development of ground water potential of hard rock areas. Hard rock areas are known to yield limited quantities of groundwater by virtue of its mode of origin and absence of inter-granular porosity (Sree Devi, 2001). Hence the identification of structurally favourable zones or groundwater viz. Lineaments, faults, fractures and joints has gained much importance in the development of groundwater potential of hard rock area. Electrical resistivity method has proved successful for groundwater prospecting in different geological formations (Todd, 1959).

Study Area

The study area Naguleru sub-basin of Krishna River, is situated in the Palnad basin, on the western part of the Guntur District of Andhra Pradesh state of India as shown in Figure.1. It is located in between the north latitudes of $16^{0}14'29"$ and $16^{0}43'05"$ and the east longitudes of $79^{0}35'24"$ and $79^{0}50'43"$ and it falls in SOI Toposheet Nos.56 P/10, P/11, P/12, P/14 and P/15 on 1:50,000 scale. The areal extent of the study area is 572 sq.km., of which 201.09 sq km area is covered by forests and hills.

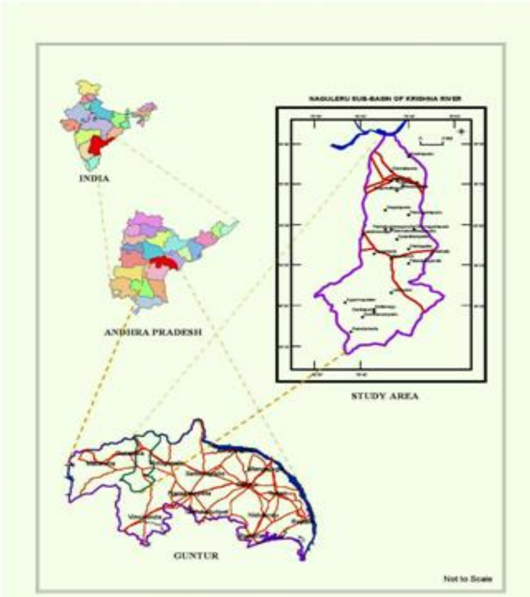

Fig. 1 Location Map of the Study Area

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Geology

The study area generally comes under Cuddapah Super Group, particularly Kurnool group (Table 1). The northern portion of the study area from centre mainly consists of Nargi lime stones except at northern part where a patch of Banaganapalli conglomerates and quartzites is vividly observed. The southern portion is mostly occupied byCumbhum shales/phyllites. The other minor formations include Cumbhum dolomite/limestone, Cumbhum quartzites, Koilakuntla limestones, Banaganapalli conglomerate/quartzite. The Koilakuntla limestone is triangle in shape is underlined as basement is Cumbhum quartzite as the basement.

Physiography and Climate

The sub-basin is physiographically divided into two parts, i.e., 1) the non-command area (southern part) and 2) the command area (northern part). Hill ranges surround the southern part from a perfect sub-basin, (small habitation). Within this sub-basin some isolated hills are observed. These hills are having steep to medium slopes. In command area also some isolated hills are observed. On the periphery of Krishna River, steep sided gorges are also observed. Thus the topography is highly undulating having high to moderate slopes in the foothill zones and moderate low to gentle slopes in middle zones of the study area. The physiography of study area includes mountains and plateaus. The area covers 572 sq kms. covering and adjoining the major areas. The study area receives an annual rainfall of 853 mm and receives maximum rainfall in September and October months. It is very hot in summer and the heat is very muggy in Rentachintala where maximum temperature of the state is generally recorded. It enjoys tropical climate.

Methodology

Geoelectrical soundings using the Schlumberzer's configuration (Figure. 2) were carried out at 50 points in the basin for delineation of ground water zones. The locations of sounding points are shown in the Figure .3. The maximum length of current electrode separation (AB) was kept 100 m. VES curves were initially interpreted using the master curves of Orellana and Mooney (1966).

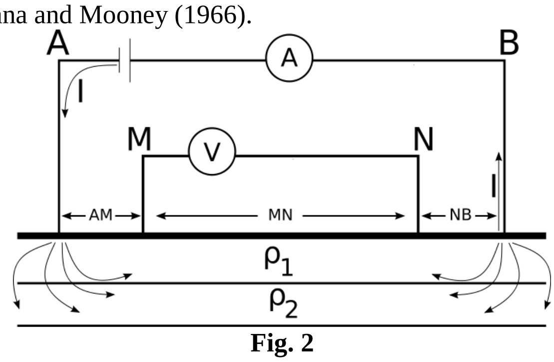


Fig. 2

The sounding data were interpreted by using the Curve Matching Method (Bhattacharya and Patra, 1968) and the graphs for 4 layers prepared by Rijkswaterstaat of the Netherlands (1975). The data were interpreted qualitatively and quantitatively.

The apparent resistivity data has been plotted on log-log graph with modules of the length of 62.5 mm and are represented in the Figure.4. These field curves have been interpreted quantitatively with the help of available two or three layer master curves (Orellana and Mooney, 1966; Rijkswaterstaat, 1975). In a few curves the terminal branch of the curve is not raising linearly at an angle of 45^0 indicating infinite resistivity of the bed rock due to insufficient data available.

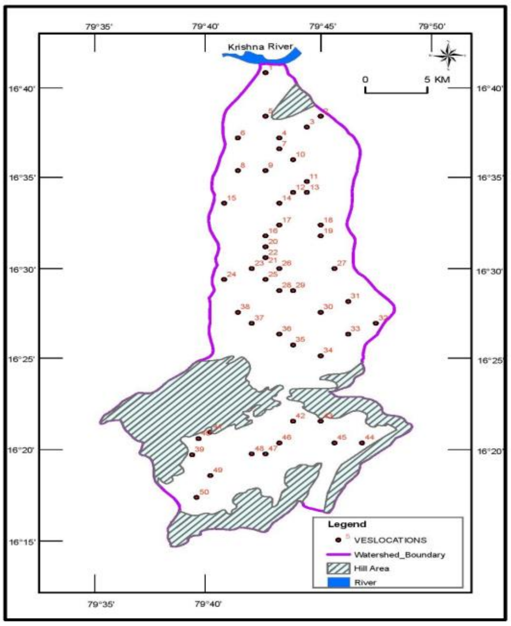
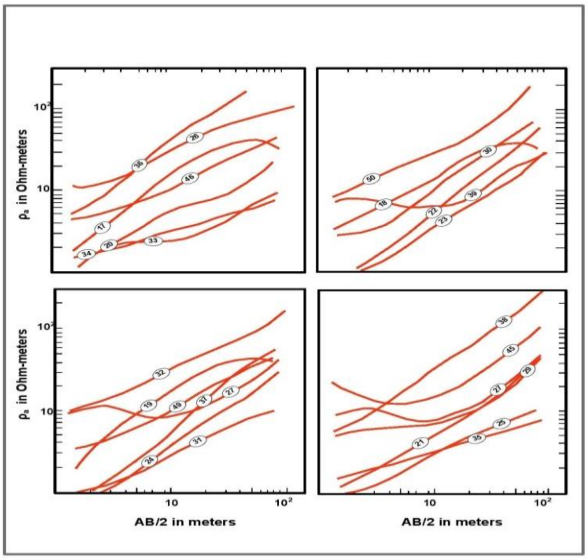


Fig. 3 VES Location Map of the Study Area



Field curves of Vertical Electrical soundings

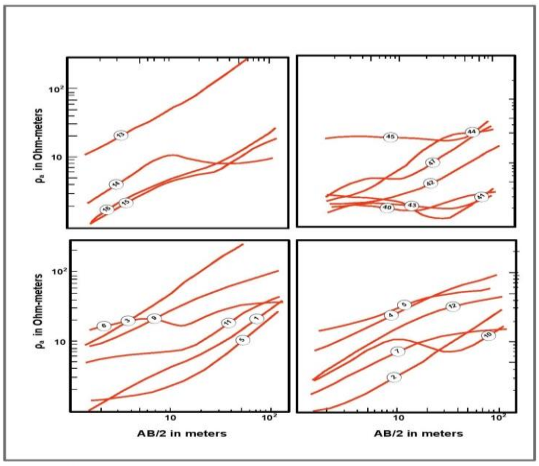


Fig.4. Field curves of Vertical Electrical soundings

Table 1. Geological Succession of the study area

Age	Group	Sub-Group	Rock Type
Upper Jurassic	Upper Gondwana	Vemavaram Budawada	Shales, Sandstones
	Unconformity		
Pre-Cambrian	Kurnool(Palnadu Series)	Nandyal Koilkuntla Panyam Owk	Shales Lime Stones Quartzites Shales
	Narjee Banaganapalli	---	Lime Stones Shales Quartzites Shales, Sand Stones
	Unconformity		
Pre-Cambrian	Nallamalai Upper Cuddapah (Super Group)	Srisailam Cumbum	Quartzites Shales, Phyllites Slates with intercalated Quartzites Lime Stones.
	Unconformity		
Archean	Basement Complex	---	Granite Gneisses Charnockites Basic Dykes Amphibolites Khondalites, Schist

Results and Discussion

A total of 50 vertical electrical soundings (VES) carried out covering the entire area of the sub-basin. The groundwater levels in the area varies from 8m to 64m below ground surface. The paper presents the results of VES carried out at 50 locations (Fig.3). The layers are described by resistivity 'ρ' and thickness 'h'. The other parameters can be obtained from these two fundamental properties. The total transverse resistance (Y) can be derived from the relation

$$T=\sum_{i=1}^{n} h_i \rho_i$$

Where h_i and ρ_i are the thickness and resistivity of the i^{th} layer within the saturated surface and 'n' is the number of layers having distinct resistivity contrasts. Geophysical resistivity surveys using VES have been taken up to i) detect and delineate various subsurface layers ii) decipher and demarcate groundwater potential zones (Fig.5) .

Resistivity and Thickness of the layers

Resistivity of resistivity values in the first layer of these formations range from 2 to 160 ohm-meters and thickness ranges from 1.2 to 29meters, second layer ranges from 4 to 1160 ohm-meters and thickness ranges from 1.3 to 38.4 meters (Table.1). This is treated as weathered layer. The low resistivity of second layer is due to abundance of clay. The third layer commonly represents hard rock displaying the resistivity values ranging from 7 to 1621 ohm-meters to as high as infinite. Very low resistivities are due to geological formations and climatological conditions. The high resistivities are noticed in areas of massive limestones.

Dar Zarrouk Parameters

Dar Zarrouk parameters (Maillet, 1947), such as transverse unit resistance (Tr) and longitudinal unit conductance (S) play a significant role in the interpretation of sounding data (Table 3).

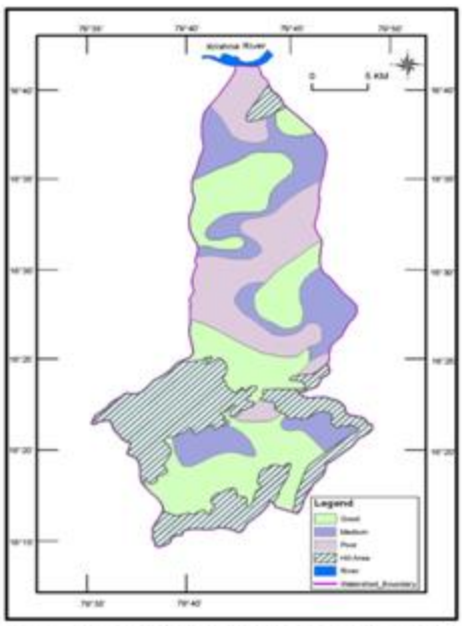


Fig.5. Ground Water Potential Map of the Study Area

Longitudinal Unit Conductance

In the present study area longitudinal unit conductance values vary from 0.04 to 3.16 mhos (Table 4). Variations in longitudinal unit conductance from one VES point to the other have been used in a qualitative sense to indicate changes in the total thickness of low resistivity materials (Henriet, 1975, Worthington, 1977, Galin, 1977). Large values are indicative of deeper basement and small values of shallow basement. Major portions of the study area poses 0.04 to 0.9 mhos as longitudinal conductance values and are more prevalent on the most of the area except northeastern northwestern and south eastern as small patches where values are rather higher shown in the Figure.6.

Table 2. Results of Vertical Electrical Soundings

VES No.	Type	$\rho1$	h1	$\rho2$	h2	$\rho3$	h3	$\rho4$	h4	$\rho5$	h5	H
1	A	2	1.7	12	24.5							26.2
2	A	3	2.8	26	28							30.8
3	A	14	2.2	126	6.2							8.4
4	A	68	1.5	370	8.5	1440						10
5	A	160	2.2	245	6.2	848						8.4
6	KA	136	1.7	258	3.9	152	9.2	1495				5.6
7	KA	96	1.7	145	1.6	64	7	220	22.4	1249		32.7
8	A	3	2	4	10							12
9	A	11	1.8	93	16	170						17.8
10	KA	4	1.6	29	5.1	69	42	654				48.7
11	A	46	1.6	72	8.9	535	3.2	807				13.7
12	A	2	1.5	56	13	554						14.5
13	A	10	1.6	108	16							17.6
14	KA	23	1.6	398	7.7	69	41	122				50.3
15	A	10	1.7	97	29.5	492						31.2
16	A	10	1.6	106	38.4							40
17	K	26	1.8	895	22.3	226	6.9					31
18	K	17	1.5	739	27	316	9.5					38
19	K	28	1.7	1160	18.4	319	9.6					29.7
20	A	9	1.5	97	26.2	1515						27.7
21	A	9	1.2	150	20.5							21.7
22	A	8	2.2	210	11.5							13.7
23	A	9	2.3	310	32.5							34.8
24	A	7	2.1	321	31							33.1
25	A	118	3.2	829	11.1	1161						14.3
26	A	95	29	578	15.2	1220						44.2
27	KH	96	1.4	143	1.8	59	11.2	2455				14..4
28	KH	82	1.7	138	1.4	58	8.5	2629				11.6
29	A	50	1.6	75	14	259						15.6
30	A	3	1.8	36	9.2							11
31	AA	92	2.6	949	116	182	10.0					28.6
32	AA	8	2.2	34	4.3	135	56.4					62.9
33	A	158	2.1	298	18.1	1621						20.2
34	AA	160	3	245	4.9	949	28	1740				35.9
35	AA	159	2.8	249	5.5	680	25.1	820				33.4
36	A	9	2.3	258	21.6							23.9
37	A	15	2.3	510	11.3							13.6
38	A	5	2	230	20							22
39	KH	30	2.2	105	5	55	7	548				14.2
40	KH	18	1.8	32	1.5	18	13.5	139				16.8
41	QH	35	2	33	5.1	14	28.2	536				35.3
42	A	26	2	31	6.1	86	10.1	466				18.2
43	KH	22	1.8	26	7.8	18	39.7	355				49.3
44	A	4	2.1	15	11.5	154						13.6
45	KH	22	2.5	27	3.7	21	32.5	322				38.7
46	A	4	3.1	29	6.3	59						9.4
47	KH	5	1.6	15	1.3	7	6.4	225				9.3
48	H	20	1.4	7	6.2	97						7.6
49	A	5	2.6	23	8.2	290						10.8
50	A	13	2.3	29	13.5							15.8

Table 3. Analysis of Resistivity Sounding Field Curves

S.No.	Type of Curve	Vertical Sounding
1	A type	1, 2, 3, 4, 5, 8, 9, 11, 12, 13, 15, 16, 20, 21, 22, 23, 24, 25, 26, 29, 30, 33, 36, 37, 38, 42, 44, 46, 49 and 50
2	KH Type	27, 28, 39, 40, 43, 45 and 47
3	KA type	6, 7, 10, and 14
4	AA Type	31, 32, 34 and 35
5	K Type	17, 18 and 19
6	H Type	48
7	QH Type	41

Table 4. Dar Zarrouk Parameters of the study area

VES No.	Longitudinal Conductance (Mhos)	Transverse Resistance Ohm-m^2	Aquifer Anisotropy
1	2.9	297.4	1.12
2	2	736.4	1.24
3	0.2	812	1.51
4	0.04	3247	1.13
5	0.03	1871	0.89
6	0.08	2635.8	2.59
7	0.23	5771.2	1.11
8	3.16	46	1.00
9	0.33	1507.8	1.25
10	1.18	3052.3	1.51
11	0.16	2426.4	2.06
12	0.98	731	1.84
13	0.30	1744	1.29
14	0.68	5930.4	1.26
15	0.47	2878.5	1.17
16	0.52	4086.4	1.15
17	0.12	21564.7	1.64
18	0.15	22980.5	1.54
19	0.10	24882.4	1.67
20	0.43	2554.9	1.19
21	0.26	3085.8	1.30
22	0.32	2432.6	2.03
23	0.36	10095.7	1.73
24	0.39	9965.7	1.88
25	0.04	9579.5	1.87
26	0.33	11540.6	1.39
27	0.21	1052.6	1.06
28	0.17	825.6	1.02
29	0.21	1130	0.98
30	0.85	336.6	1.53
31	0.05	24913.2	1.23
32	0.81	7777.8	1.26
33	0.07	5725.6	0.99
34	0.06	28252.5	1.14
35	0.07	18882.7	1.08
36	0.33	5593.5	1.77
37	0.17	5797.5	2.30
38	0.48	4610	2.13
39	0.24	976	1.07
40	0.89	323.4	1.01
41	2.22	633.1	1.06
42	0.38	1109.7	1.12
43	2.58	957	1.00
44	1.29	180.9	1.12
45	1.79	837.4	1.00
46	0.99	195.1	1.47
47	1.32	72.3	1.05
48	0.95	71.4	1.08
49	0.87	201.6	1.22
50	0.64	421.4	1.03

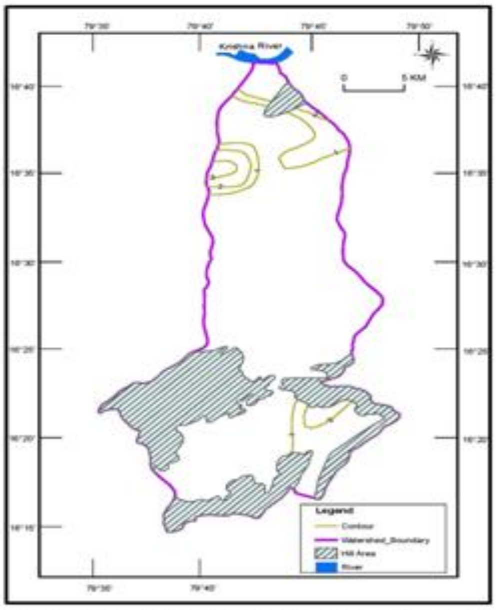


Fig. 6 . Longitudinal Conductance of the Study Area

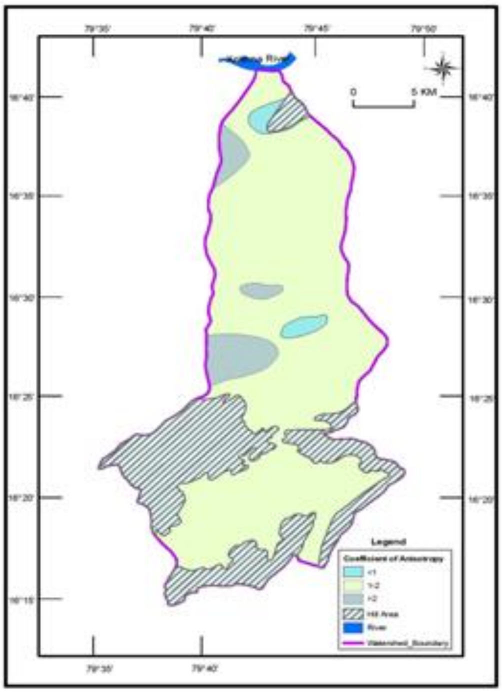


Fig. 7 . Aquifer Anisotrophy of the Study Area

Transverse Unit Resistance

Transverse unit resistance values ranges from 46 ohm-meters^2 to 28252.5 ohm-meters^2. Major portions of the study area experiences less than 10,000 ohm-meter^2.

Coefficient of Anisotropy

This coefficient is usually greater than 1 but does not exceed 2 (Zohdy et. al, 1974). As the hardness and compaction of rocks increase the coefficient of anisotropy also increases (Keller and Frischknecht, 1966) and hence such areas can be associated with low porosity or permeability. It can be used as measure of finding out the extent of anisotropy prevailing in an area of interest. In the present study the coefficient of anisotropy varies from 1 to 2.59 and shown the spatial variation of the anisotropy values in the Table.3. The Figure.7 shows major portions of the study area characterized with low anisotropy value (<2).

The areas having lowest water table fluctuation is associated with low anisotropy values and the area having highest water fluctuation is associated with higher anisotropy values. Hence it can be considered that the area around 55% is characterized by high porosity and permeability where as areas around 45% are characterized with low porosity and permeability.

Conclusions

The geophysical surveys in the study area have brought out the general distribution of various aquifers and subsurface aquifers zones. Basing the apparent resistivity contour maps obtained from the quantitative interpretation, the map of the ground water potential zones of the basin has been prepared and presented in the Figure 5. As for the map the study area has been divided into three categories, namely poor, medium and good zones. The poor zone is observed at north southern central and southern portion of the study area as patches. Medium zones are present northern eastern and southeastern and southwestern portions of the study area. Good zones are present northeast northwest and eastern portion of the study area. It can be concluded map of ground water potential zones obtained from qualitative interpretations is considered to be in good agreement with the ground water potential zones obtained from quantitative interpretations.

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