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Evaluation of Dar Zarrouk Parameters in Hard Rock Terrain in Parts of Nuthankal Mandal, Suryapet District, Telangana, India.

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***ABSTRACT**: Dar Zarrouk parameters are of great importance in to delineate the groundwater potentiality. In total 131 Vertical Electrical Soundings (VES) are carried out adopting Schlumberger electrode array conducted with maximum electrode spacing of 200m. The data was acquired using DDR-3 Resistivity meter and processed using with IPI2WIN, GeoSoft and Arc GIS softwares. The parameters are evaluated in this work include Longitudinal Conductance (S_c), Transverse Resistance (T_r), Coefficient of Electrical Anisotropy (λ), Resistivity for the formation (ρ_m), Reflection Coefficient (R_c) and Resistivity Contract (F_c). Results obtained represent, that the study area revealed four subsurface geoelectrical layers, where in the top soil layer is of variable resistivity values between 2 Ωm to 1143 Ωm whose maximum thickness is 0.26 m to 9 m. The highly weathered, second layer resistivity value varying from 2 Ωm to 2578 Ωm, thickness is 0.2 m to 78 m. Resistivity of the aquifer is divided in to two parts, Western and Eastern part because of the dyke of the formation act as a barrier in central part the area. The Dar Zarrouk parameters evaluated showed that the study where as good groundwater potentials with values of Reflection Coefficient ranging from -0.9 to 0.7, Resistivity Contrast values ranges from 0 to 20472, while that of Coefficient of Anisotropy ranged from 1 to 3.82.*

***KEYWORDS:** Aquifer, Aquifer Protective Capacity, Dar Zarrouk Parameters, Resistivity.*

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I. INTRODUCTION

Groundwater is one of most valuable natural resource, which supports agriculture economic development and ecological diversity. In the recent past groundwater as become very important throughout worldwide with attention for proper monitoring, conservation as well as exploration of groundwater resources have become essential (Madan et al, 2009). Nuthankal mandal of Suryapet district Telangana state is predominantly covered by Archaean/Precambrian rocks, comprising granite, biotite, schist and metabasalt. These formations were subjected to tectonism and schist facieses metamorphism. Based on mineral composition, they were further classified as alkali feldspar granite, migmatite granites gneisses and granodiorite. All these rock formations are traversed by N-S, NW-SE trending basic (dolerite) dyke. Hard rock aquifers are generally occupy the first tens of meters below ground surface (Detay et al., 1989). The hydrogeological characteristics (e.g. hydraulic conductivity and storage) of the weathered mantle and underlying bedrock derive primarily from the geomorphologic processes of deep withering and stripping (Taylor and Howard, 2000). Granites reveal greatest permeability in the range 2400 to 6000 liters per hour (Davis and Dewist, 1966) when they are in the partially decomposed state. Maillet (1947) termed the Dar Zarrouk (D-Z) parameters namely, Tr is the resistance normal to the face and Sc is the conductance parallel to the face for a unit cross section area, which plays an important role in resistivity soundings. D-Z parameters are sufficient for computing the distribution of surface potential and hence an electrical resistivity (honrient, 1976). The application of these parameters are discussed (Satya kumar, 1979; prakasha Rao, 1983; singh et al., 2004) in different groundwater characteristics and geological conditions

Study Area: The study area selected for ground geophysical survey is in and around the Nuthankal mdandal, Suryapet district, Teangana, India form part of the Dharwar Craton of Southern Inidan shield. The present area is lying between 17.289N to 17.389N latitudes and 79.627E and 79.732E longitudes and forms part of survey of India Toposheets of N56O/11 or E44N11.The topography of the study area can be treated as undulating with a gradual relief towards NE, NW. The maximum elevation observed is 220 m and minimum elevation is 164 m with respect to mean seal level. The area in general gently slopes from NW to SE toward the tettevagu region.

II. GEOLOGY AND DRAINAGE OF THE STUDY AREA

Study area formation of rock formed with magmatic condition. The study area is with crystalline granite rock of Archaen age encompassing grey with medium to coarse grained texture cover. These rocks are having with dotted patches of amphibolites, Biotite schist and Metabasalt of the same age. Proterozoic to Archaean age acid intrusivs with pegmatite, quartz reefs/veins and migmatites are noticed. Further recent alluvium occurs either side the stream (tattevagu region). It also consist the area topographically contains upper undulations, because of weathered eroded material. Thus the geological framework defines a complex heterogeneous aquifer system cussing variations in hydraulic conductivity in with pronounced with lateral variations. The generalized geological succession (Geological Map of 56O/11) of the area is as follows (Figure 1).

In the field investigations, strike directions of joints are measured from the exposures. The most prominent joints are N-S, NE-SW, NW-SE and E-W with multiplicity and Mural Joints. The density of the joints in rocks varies from 1 to 4 in most of the area, reaching up to a maximum of 8 per sq. meter in certain places of the area. The fracturing and jointing are found to extend to depths beyond 10 to 20 meters as revealed in dry wells and bore wells of the area. Further the study area joints are almost vertical and horizontal. These horizontal joints connect to the vertical joints, providing continuous channels for groundwater movement. The study area drainage pattern is dendritic in nature with high drainage density, consisting of huge exposed and scattered boulders in the North-western direction. The area is marked by number of gullies and stream lets and the terrain appears to be undulating.

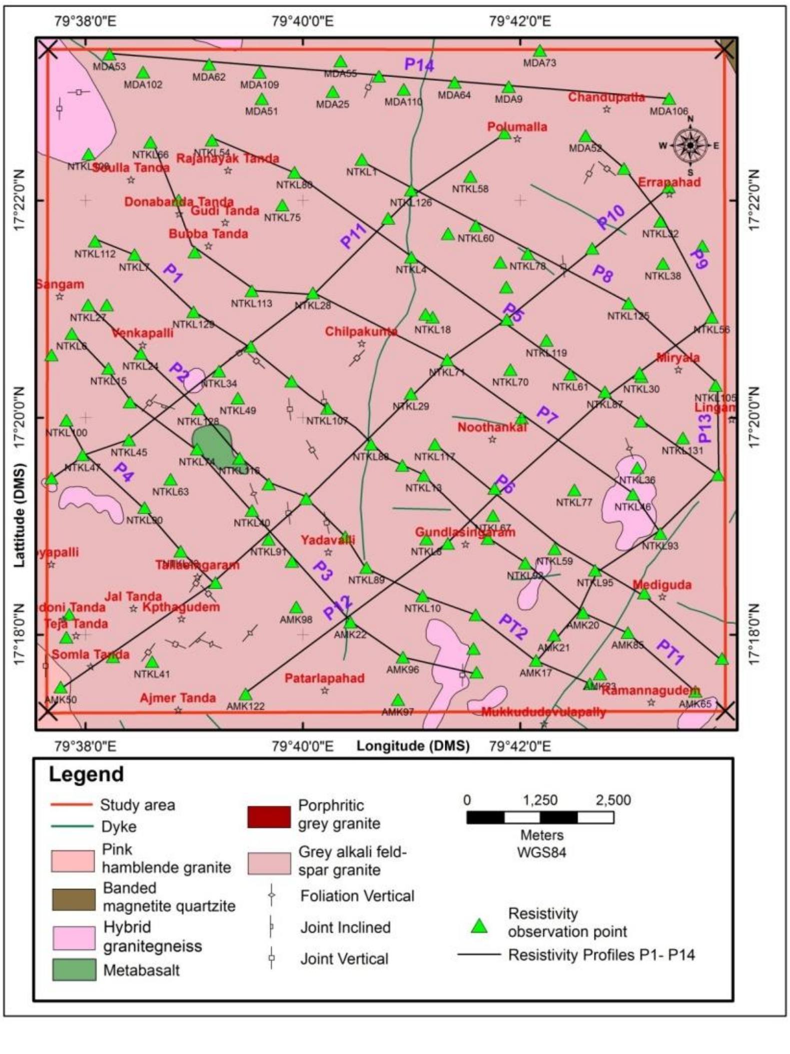

Figure 1. Geology of Study Area

III. MATERIALS AND METHOD

In the study area, covering 14 villages at total of 131 soundings (Figure 3) are carried out using DDR-3 Instrument, IGIS, Hyderabad. This instrument comprises two distinct chambers and are kept in a single box: (1) current reading unit (G-Unit) and (2) resistance / the potential reading unit (P-Unit).

The Schlumberger configuration has been used to measure the resistivity of the ground. In the former, the gradient of potential is measured which is uniform at the centre over one-third distance of the current electrodes, whereas in the latter the potential is measured. Consequently, the anomaly in schlumberger is smoothed off and the minor distortions and the local inhomogeties. The high resolution between local and deeper effects, by increasing the ratio of current and potential electrode separation as in schlumberger has been emphasized by UNZ (1963). For the Schlumberger array used in this work (Figure 2) reading of resistance R of the volume of earth material within the electrical space of the electrode configuration. The product of geometric factor K and R was then made to obtain the apparent resistivity (ρ_a) of the said earth material using equations 1 and 2. Figure 2 shows the Schlumberger Array of Vertical Electrical Sounding used in this work. Field operations are easier and less time-consuming.

$$K = \pi \left[\frac{\left(\frac{AB}{2}\right)^2 - \left(\frac{MN}{2}\right)^2}{MN}\right] \quad \text{-----------------} \ (1)$$

$$\rho_a = \pi \left[\frac{\left(\frac{AB}{2}\right)^2 - \left(\frac{MN}{2}\right)^2}{MN}\right] R \quad \text{----------------} \ (2)$$

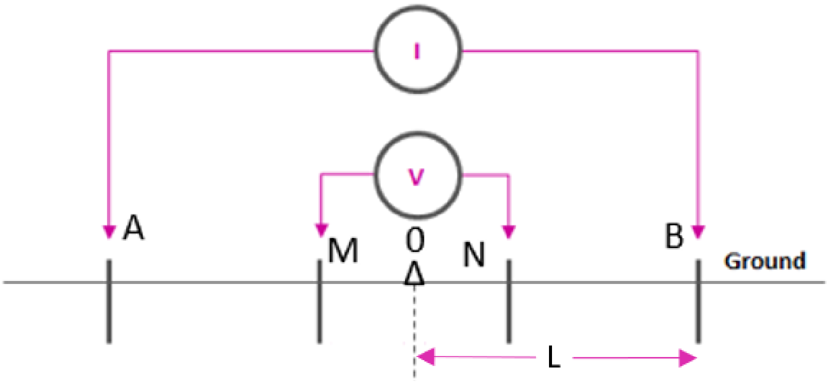

Figure 2. Schlumberger Array of Vertical Electrical Sounding

AB = Current Electrodes
MN = Voltage Electrodes
I = Electric Current (Ampere)
V = Potential Difference

IV. ANALYSIS OF VES DATA

The study area result of vertical electrical sounding curves represents the area with three layers, where in A and H types are more prominent. The A type is the most foremost curve type with predominantly curve of 38% similarly, H type 14%, with 4 -layers AA, AK, HA, HK, KH and QH type having percentage curves 10%, 1%, 21%, 5%, 13% and 1% respectively. It is observed that the dominant type of curves is the A type followed by the HK type. Sporadically, wherever fracture and multilayer zones present four layers. Quantitative interpretation of VES data are performed using curve matching method and inversion IPI2WIN software analysis aims at obtaining the electrical configuration of the subsurface and containing generation and examination of geoelectric section, resistivity contour maps, depth contour maps and contour maps of longitudinal conductance, transverse resistance, anisotropy and formation resistivity. From the study area electrical VES data various components for quantitative analysis are evaluated and as discus as under.

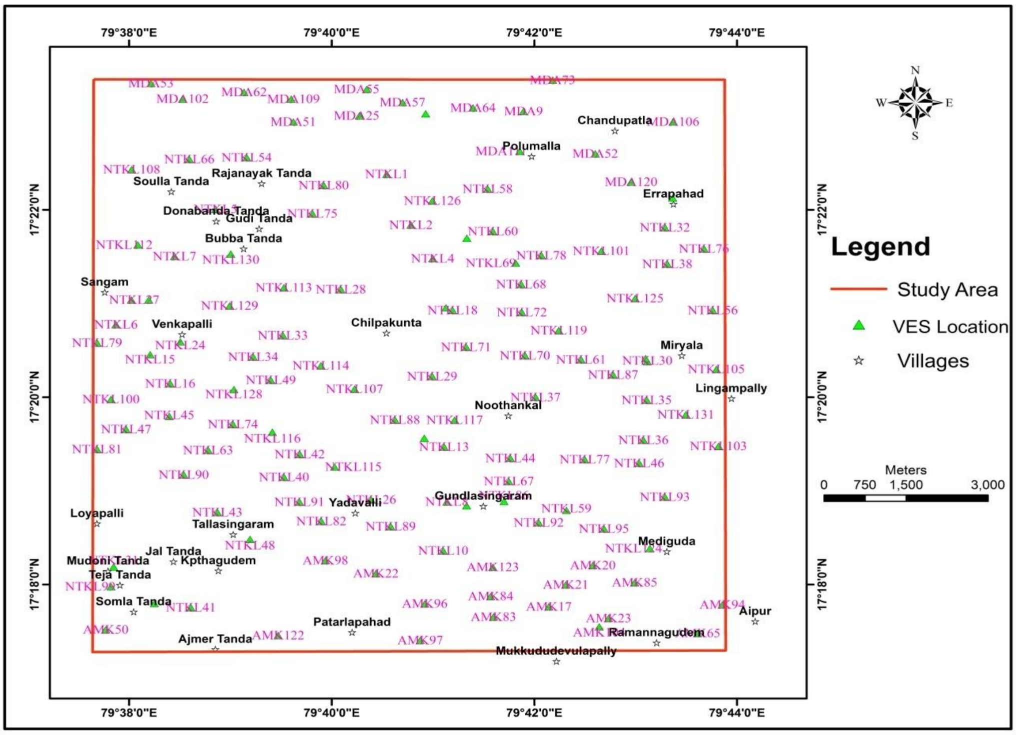

Figure 3. Locations of VES points in study area

DAR-ZARROUK (D-Z) PARAMETERS

Maillet (1947) termed the Dar Zarrouk (D-Z) parameters viz; Tr is the resistance normal to the face and Sc is the conductance parallel to the face for a unit cross section area, which plays an important role in resistivity soundings. D-Z parameters are sufficient for computing the distribution of surface potential and hence an electrical resistivity graph was given (honrient, 1976). The relevant graphical procedures are discussed by (kalenov, 1957; kuentz, 1966; keller et al., 1966) the application of these parameters are discussed (Satya kumar, 1979; prakasha Rao, 1983; singh et al., 2004) in different groundwater characteristics and geological conditions. Vertical electrical soundings (VES) using schlumberger configuration have been conducted at 131 locations in the study area with maximum electrode spacing of 200 m. A geoelectrical layer is described by two fundamental parameters: its resistivity ρ_i and its thickness h_i here the subscript i indicated the location of the layer in the section. Other parameters are derived from its resistivity and thickness.

These are:

(i) Longitudinal unit conductance (S_c)

If current passes collateral to the geoelectrical boundaries, the current flow is effected by the parameter which is called Longitudinal Conductance. The greater values of 'S' infer the high thickness of overlaying layers above the basement, it means the basement is at greater depths. If the minor values of 'S' obtained, it indicates the basement is shallow depth and the overlaying layers thickness is less (Glain, 1979, Worthington, 1977).

$$S_c = \frac{h_1}{\rho_1} + \frac{h_2}{\rho_2} + \frac{h_3}{\rho_3} + \ldots\ldots\ldots + \frac{h_n}{\rho_n} = \sum_{i=1}^{n} \frac{h_i}{\rho_i} \qquad (3)$$

(ii) Transverse unit resistance (T_r)

If current passes normal to the boundaries of layers, the parameter transverse resistance becomes conspicuous. The greater values of 'T' infer the high thickness of high resistive media. (Zohdy et al. 1974; 1989).

$$T_r = \rho_1 h_1 + \rho_2 h_{2+} \rho_3 h_{3+}\ldots\ldots\ldots\ldots\ldots \rho_n h_n = \sum_{i=1}^{n} h_i \rho_i \qquad (4)$$

(iii) The average longitudinal resistivity

$$\rho_L = \frac{H}{Sc} \qquad (5)$$

(iv) The average transverse resistivity

$$\rho_t = \frac{Tr}{H} \qquad (6)$$

(v) Anisotropy (λ)

ρ_t is always greater than ρ_L. Therefore, the entire section will thus be anisotropic with regard to electrical resistivity. The coefficient of electrical anisotropy is defined as

$$\lambda = \frac{\sqrt{(Tr * Sc)}}{H} = \sqrt{\frac{\rho_t}{\rho_L}} \qquad (7)$$

Where λ is real and greater than 1.

A mean value of resistivity for the formation (ρ_m) can be defined as

$$\rho_m = \sqrt{\rho_t \rho_L} \qquad (8)$$

The reflection coefficient (R_c) and resistivity contrast (F_c) of the fresh basement rock of the study area was calculated using the method of Oladunjoye and Jekayinfra (2015)

$$R_c = \frac{\rho_n - \rho_{n-1}}{\rho_n + \rho_{n-1}} \qquad (9)$$

And

$$F_c = \frac{\rho_n}{\rho_{n-1}} \qquad (10)$$

Where ρ_n is the layer resistivity of the n^{th} layer and ρ_{n-1} is the layer resistivity overlying the nth layer.

The above parameters were used for delineating the sub-surface groundwater zones in the study region and to determine the aquifer protective capacity. Henriet (1976) showed that the combination of layer resistivity and thickness in the D-Z parameters S (longitudinal conductance) and T (transverse resistance) may be of direct use in aquifer protection studies and for the evaluation of hydrologic properties of aquifer. The protective capacity is considered to be proportional to the longitudinal unit conductance (S) (Oladapo et al. 2004; Ayolabi 2005; Atakpo and Ayolabi 2008; Atakpo 2013). Thus, the overburden protective capacity was evaluated using the total longitudinal unit conductance (S) values (Henriet 1976; Oladapo et al. 2004; Atakpo and Ayolabi 2008; Atakpo 2013).

V. DISCUSSION

A total of 131 VES were carried out using Schlumberger configuration in the study region (figure 3). In order to characterize the aquifers, we study to delineate the depth to the aquifer and its lateral extent and to estimate the aquifer protective capacity in the area together assessing its recharge capability, contour maps for longitudinal conductance (S_c), transverse resistance (T), transverse resistivity (ρ_t), longitudinal resistivity (ρ_L),anisotropy (λ) and root mean square resistivity(ρ_m) were generated. This will aid in understanding the spatial variation of these parameters to delineate the groundwater potential zones. The evaluated D-Z parameters are presented in Table 1.

Longitudinal unit conductance (S_c)

A contour map of longitudinal unit conductance (S_c) of the study area is prepared by using the resistivity data of 131 VES soundings. The high S_c values are characteristic of low aquifer transmissivities. Variation in Sc from one VES to other has been used in quantitative sense to indicate the change in the total thickness of low resistivity materials (Zohdy, 1989; Henriet, 1975; Rajesh et al., 2002). The total longitudinal unit conductance value ranges from 0.04 to 5.81mhos of the study area. The contour map of S_c values of the study area is prepared by using the resistivity data of 131 soundings with a contour interval of 0.05 mhos (Figure 4).

Aquifer Protective Capacity

It is clearly demonstrated that based on ground water availability, zones are divided in to six types (Table 2), these are Excellent, very good, good, moderate, weak and poor region in the study area (Henriet 1976; Oladapo et al. 2004). However VES soundings are adopting the five types of aquifer protective capacity ratings. The minimum value of S_c (0.04 mho) is nearby sounding location MDA53, at North West corner of the soullatanda and maximum values of S_c (5.25 mho) is nearby sounding location at AMK20, at south east corner of the Gundlasingaram.

The VES location NTKL19, AMK21, NTKL24, NTKL108 and MDA109 are having more than 1 mhos of longitudinal conductance, indicate the good ground water region of the study area. Whereas moderate ground water regions, S_c values range from 0.20 to 0.68 mhos and minimum values of Sc is near soundings location at NTKL4, NTKL12, NTKL112, NTKL125 and maximum value of S_c is at AMK17 at north western part of Ramannagudem. Whereas weak ground water region, S_c values ranges from 0.10 to 0.19 mhos in the study area and the minimum value is at location NTKL56, NTKL71, NTKL82, NTKL92, NTKL101, NTKL119, and maximum value is at NTKL37, NTKL39, MDA51, NTKL58, NTKL87. Similarly minimum and maximum values of Sc ranges from 0.02 to 0.08 mhos located at MDA53,NTKL2 similarly in good ground water potential sounding locations NTKL6, NTKL11, NTKL14, NTKL19, AMK20, AMK21, NTKL24, NTKL30, NTKL35, NTKL46, AMK50, NTKL108 and MDA109 depths of investigation are 1.973, 80.005, 4.578, 50.465, 30.668, 21.583, 4.984, 19.618, 5.929, 4.32, 9.293, 8.86 and 8.22 m. And moderate to poor ground water potential zones depth of investigation ranges from 2.15 to 163 m respectively. Hence these soundings are considered as outliers and without any overlapping and very clearly differentiable the characters of very good, good, moderate, weak, poor (figure 5).

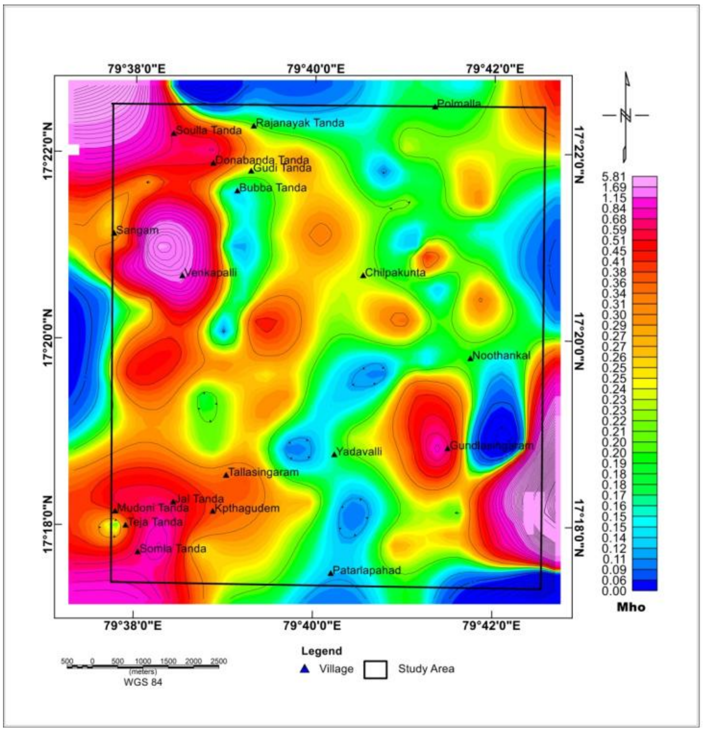

Figure 4. Contour map of Longitudinal Conductance (S_c)

Table 1: Geoelectrical layers and Dar-Zarrouk parameters in and around Nuthankalmandal.

VES	S_c *(mhos)*	T_r *(Ohm.m^2)*	*λ*	ρ_L *(Ωm)*	ρ_t *(Ωm)*	R_c	F_c	ρ_m *(Ωm)*
NTKL1	0.13	2446.39	1.86	74.77	257.79	0.99	192.8	138.83
NTKL2	0.08	2607.45	1	185.58	185.58	0.92	12.85	185.58
NTKL3	0.24	22921.22	1.03	297.54	316.57	0.99	129.78	306.9
NTKL4	0.2	580.93	1.12	48.42	61.17	1	302.15	54.42
NTKL5	0.63	145.45	1.01	15.11	15.33	1	1806.47	15.22
NTKL6	0.77	5.04	1	2.55	2.56	1	6090.58	2.55
NTKL7	0.44	551.31	1.22	28.91	43.12	1	521.95	35.31
NTKL8	0.38	30120.81	1.48	190.04	414.2	0.96	51.11	280.56
MDA9	0.26	9539.75	2.73	70.01	523.67	-0.78	0.12	191.48
NTKL10	0.25	3000.92	1.25	86.75	135.97	0.99	283.18	108.61
NTKL11	0.82	8271.33	1.03	97.54	103.39	0.98	80.76	100.42
NTKL12	0.2	954.83	1.22	57.13	84.44	1	829.64	69.45
NTKL13	0.59	202.32	1.03	17.91	19.14	1	1121.91	18.51
NTKL14	0.87	30.69	1.13	5.25	6.7	1	1412.14	5.93
NTKL15	0.36	206.72	1.01	23.93	24.26	0.84	11.24	24.1
NTKL16	0.39	6517.89	1.21	106.27	156.78	0.99	363.89	129.08
AMK17	0.68	666.5	1.16	26.92	36.4	0.99	354.75	31.31
NTKL18	0.46	4035.46	2.07	44.94	193.48	1	905.43	93.25
NTKL19	1.96	1384.19	1.03	25.76	27.43	0.71	5.88	26.58
AMK20	5.25	278.58	1.25	5.84	9.08	0.99	347.52	7.28
AMK21	1	725.35	1.25	21.67	33.61	0.99	288.36	26.99
AMK22	0.05	1983.54	3.82	50.95	745.19	0.77	7.79	194.86
AMK23	0.56	15467.12	1.78	93.7	297.16	0.53	3.23	166.86

NTKL24	1.16	35.88	1.29	4.31	7.2	1	1512.27	5.57
MDA25	0.5	583.95	1.22	28.07	41.78	1	1919.85	34.24
NTKL26	0.23	12156.08	2.6	88.26	598.88	0.99	310.19	229.91
NTKL27	0.35	2448.77	1.4	59.9	116.67	0.8	9.05	83.6
NTKL28	0.32	484.72	1.17	32.92	45.36	0.98	91.45	38.64
NTKL29	0.35	6095.12	1.62	81.55	214.19	0.82	9.87	132.16
NTKL30	0.76	750.83	1.22	25.75	38.27	1	1188.87	31.39
NTKL31	0.56	525.99	1.52	20.2	46.82	0.96	50.5	30.75
NTKL32	0.36	19.43	1.25	5.84	9.19	1	7210.13	7.33
NTKL33	0.23	622.3	1.08	47.71	55.68	0.98	93.95	51.54
NTKL34	0.15	36908.12	1.86	262.98	910.03	-0.63	0.23	489.21
NTKL35	0.75	161.94	1.86	7.92	27.31	1	729.62	14.71
NTKL36	0.22	5525.9	1.58	101.06	252.5	0.96	48.93	159.74
NTKL37	0.19	2354.47	1.04	106.95	115.25	0.93	27.9	111.02
NTKL38	0.22	598.67	1.29	40.91	67.88	1	533.13	52.7
NTKL39	0.19	781.06	1.3	48.88	82.19	-0.98	0.01	63.38
NTKL40	0.29	441.57	1.23	31.96	48.43	-0.97	0.01	39.34
NTKL41	0.25	80.89	1.04	17.17	18.6	0.99	69.91	17.87
NTKL42	0.3	380.2	1.15	31.16	40.88	0.94	35.23	35.69
NTKL43	0.21	1302.52	1.58	49.66	123.87	0.73	6.38	78.43
NTKL44	0.23	1201.03	1.42	50.6	101.7	0.97	58.24	71.73
NTKL45	0.46	21801.81	1.49	146.99	325.01	0.97	63.6	218.57
NTKL46	0.89	22.21	1.03	4.85	5.14	1	7284.68	4.99
NTKL47	0.48	346.96	1.06	25.22	28.42	0.98	104.56	26.77
NTKL48	0.39	377.17	1.02	30.75	31.86	1	1483.38	31.3
NTKL49	0.47	9850.71	1.17	124.15	170.05	1	466.04	145.3
AMK50	0.74	158.77	1.16	12.61	17.08	1	1835.71	14.67
MDA51	0.19	1449	1.02	85.66	88.52	1	862.94	87.08
MDA52	0.38	56.9	1	12.21	12.3	1	397.61	12.25
MDA53	0.04	3676.16	1.22	253.22	378.21	0.55	2.25	309.46
NTKL54	0.06	22356.38	1.7	356.78	1035.5	-0.53	0.31	607.82
MDA55	0.64	9067.34	1.74	68.41	207.97	1	401.57	119.28
NTKL56	0.1	6520.69	1.33	193.41	343.65	0.81	9.59	257.81
MDA57	0.18	415.33	1.04	46.52	50.25	1	218.5	48.35
NTKL58	0.19	203.9	1	32.88	32.93	1	1440.84	32.91
NTKL59	0.12	18429.47	1.11	349.28	429.51	1	549.59	387.32
NTKL60	0.26	183.92	1.02	26.22	27.3	0.97	37.09	26.75
NTKL61	0.13	448.51	1.28	45.68	74.33	1	1461.58	58.27
MDA62	0.18	395.54	1.02	46.27	47.86	-0.99	0	47.06
NTKL63	0.17	4105.17	1.39	111.93	216.35	0.99	66.75	155.61
MDA64	0.16	112527.57	1.71	491.57	1437.5	0.77	7.63	840.62
AMK65	0.13	531.36	1.14	55.97	72.89	1	469.63	63.87
NTKL66	0.12	5290.25	1.01	208.28	213.94	0.93	13.85	211.09
NTKL67	0.17	1438.91	1.07	85.82	99.1	0.95	19.78	92.22
NTKL68	0.12	510.6	1.02	63.55	66.48	0.99	79.86	65
NTKL69	0.31	61166.84	1.53	291.66	686.42	0.92	12.81	447.44

NTKL70	0.32	3721.22	1.15	93.94	124.62	1	523.93	108.2
NTKL71	0.1	126095.47	1.33	846.44	1503.28	0.96	44.48	1128.03
NTKL72	0.18	31105.08	1.55	265.9	640.15	0.99	132.69	412.57
MDA73	0.36	263.81	1.37	19.75	36.9	1	4633.57	26.99
NTKL74	0.31	221.47	1	26.81	26.81	1	1209.44	26.81
NTKL75	0.29	136.67	1	21.67	21.69	1	20472.95	21.68
NTKL76	0.18	2873.69	1.08	117.83	138.22	1	202.26	127.62
NTKL77	0.57	1514.28	1.02	50.93	52.49	1	201.8	51.7
NTKL78	0.18	15673.54	1.53	192.38	451.82	0.99	174.92	294.82
NTKL79	0.16	4390.37	1.08	154.52	179.79	0.99	81.63	166.67
NTKL80	0.15	8098.2	2.06	111.98	475.81	0.97	73.54	230.82
NTKL81	0.14	30928.18	1.66	285.42	785.38	0.99	114.38	473.45
NTKL82	0.1	4958.49	1.08	204.54	238.6	1	380.9	220.91
AMK83	0.18	19574.69	1.37	241.2	450.2	0.99	116.06	329.53
AMK84	0.29	298.87	1.14	28.21	36.49	0.98	61.7	32.09
AMK85	0.15	1883.98	1.03	110.29	117.68	0.99	130.69	113.92
NTKL86	0.17	2379.39	1.04	115.37	124.51	0.99	123.08	119.85
NTKL87	0.19	5096.72	1.63	100.83	268.6	0.99	300.74	164.57
NTKL88	0.07	50512.8	1.32	653.3	1141.53	0.76	4.18	863.58
NTKL89	0.18	6567.45	1.22	158.03	235.65	0.98	42.8	192.98
NTKL90	0.25	1203.97	1.19	57.82	82.35	1	668.86	69
NTKL91	0.07	50512.8	1.32	653.3	1141.53	0.76	4.18	863.58
NTKL92	0.1	6669.65	1.34	193.07	346.84	0.86	6.92	258.78
NTKL93	0.15	24474.91	1.97	205.45	797.23	0.97	77.67	404.71
AMK94	0.66	755.43	1.17	28.88	39.81	1	455.96	33.91
NTKL95	0.59	249.14	1.46	14.08	30.14	0.99	94.45	20.6
AMK96	0.27	264.55	1.03	30.11	32.03	1	1994.13	31.05
AMK97	0.17	204.89	1.06	32.5	36.65	1	3453.62	34.51
AMK98	0.27	66949.2	1.28	390.77	638.24	0.97	64.12	499.41
NTKL99	0.17	75107.32	2.44	272.93	1629.76	-0.89	0.06	666.94
NTKL100	0.22	2136.52	1.15	84.63	112.66	-0.99	0.01	97.64
NTKL101	0.1	214515.76	1.25	1146.33	1786.83	0.56	3.5	1431.18
MDA102	0.37	45023.51	1.26	279.18	441.75	0.97	64.9	351.18
NTKL103	0.64	67.35	1.01	10.17	10.28	1	202.31	10.23
AMK104	0.07	51637.4	1.34	659.8	1186.14	0.73	3.73	884.65
NTKL105	0.4	54371.63	1.05	350.33	384.68	0.92	24.58	367.1
MDA106	0.34	1013.11	1.36	40.29	74.82	0.94	17.48	54.9
NTKL107	0.17	56456.91	1.95	296.4	1122.63	0.89	8.91	576.84
NTKL108	1.44	74.58	1.17	6.14	8.42	1	4257.79	7.19
MDA109	1.65	50.88	1.11	4.99	6.19	1	884.42	5.56
MDA110	0.16	720.58	1.38	48.92	93.83	1	428.69	67.75
MDA111	0.17	64700.26	1.99	310.5	1226.08	0.88	8.21	617
NTKL112	0.2	967.56	1.01	69.61	70.42	0.99	134.83	70.01
NTKL113	0.23	484.16	1.13	40.99	52.17	0.97	36.31	46.24
NTKL114	0.23	1649.19	1.03	81.65	86.91	1	1111.32	84.24
NTKL115	0.13	33525.89	1.65	312.53	852.86	0.91	11.63	516.28

NTKL116	0.24	127.46	1.07	21.76	24.8	0.99	123.45	23.23
NTKL117	0.12	186387.16	2.11	600.18	2679.52	0.89	17.12	1268.15
NTKL118	0.12	10218.57	1.93	149.98	558.7	0.99	79.76	289.47
NTKL119	0.1	697.04	1.04	78.77	84.39	0.99	95.22	81.53
MDA120	0.18	8800.31	1.08	203.03	235.91	1	337.61	218.86
NTKL121	0.15	470.24	1.01	56.32	56.93	1	3957.83	56.63
AMK122	0.22	437.56	1.42	31.34	63.05	1	3572.44	44.45
AMK123	0.16	6361.1	1.08	182.37	212.03	0.77	4.42	196.64
NTKL124	0.24	281.78	1	34.3	34.62	1	1570.02	34.46
NTKL125	0.2	31837.71	1.13	354.31	453.59	0.99	146.42	400.89
NTKL126	0.24	152218.15	1.18	666.39	932.82	0.91	20.44	788.43
NTKL127	0.16	1049.11	2.19	36.67	175.44	1	1186.9	80.21
NTKL128	0.07	19697.11	2.96	180.69	1584.64	0.98	87.11	535.09
NTKL129	0.14	51840.7	1.18	506.04	707.26	0.99	104.18	598.25
NTKL130	0.11	248.06	1.01	45.87	47.06	1	763.21	46.46
NTKL131	0.11	1862.08	1.71	77.49	225.43	0.98	63.75	132.17

Table 2: Modified longitudinal conductance/protective capacity rating (Henriet 1976; Oladapo et al. 2004).

Longitudinal conductance (mhos)	Protective capacity rating
>10	Excellent
5–10	Very good
0.7–4.9	Good
0.2–0.69	Moderate
0.1–0.19	Weak
<0.1	Poor

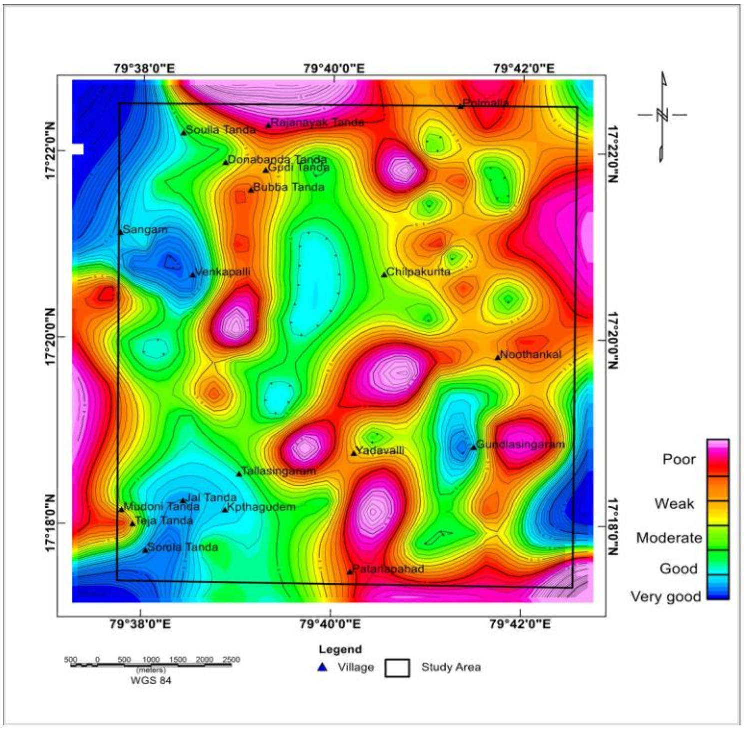

Figure 5. Contour map of Groundwater potential zones

Transverse Unit resistance (T_r)

The total transverse Unit has been used to indicate the varying thickness of high resistivity material and variations in their transverse resistance (Zohdy et al., 1974). Increasing T_r values are indicative of an increase in the thickness of the high resistivity material. The contour map of the study area is prepared by using the transverse unit resistance (T_r) values of 131 sounding with different intervals of the region (Figure 6). Again, it gives a clear picture of the regions, high resistivity zone is in the centre part due to the dyke effect. The aquifers identify their presence by attaining T_r values in the range from 14 to 214515 Ohm.m^2. The minimum value is observed at the sounding location NTKL6 near western part of Venkapally and it lies in older rock formation while the maximum value is observed near the sound location NTKL101near Errapahad.

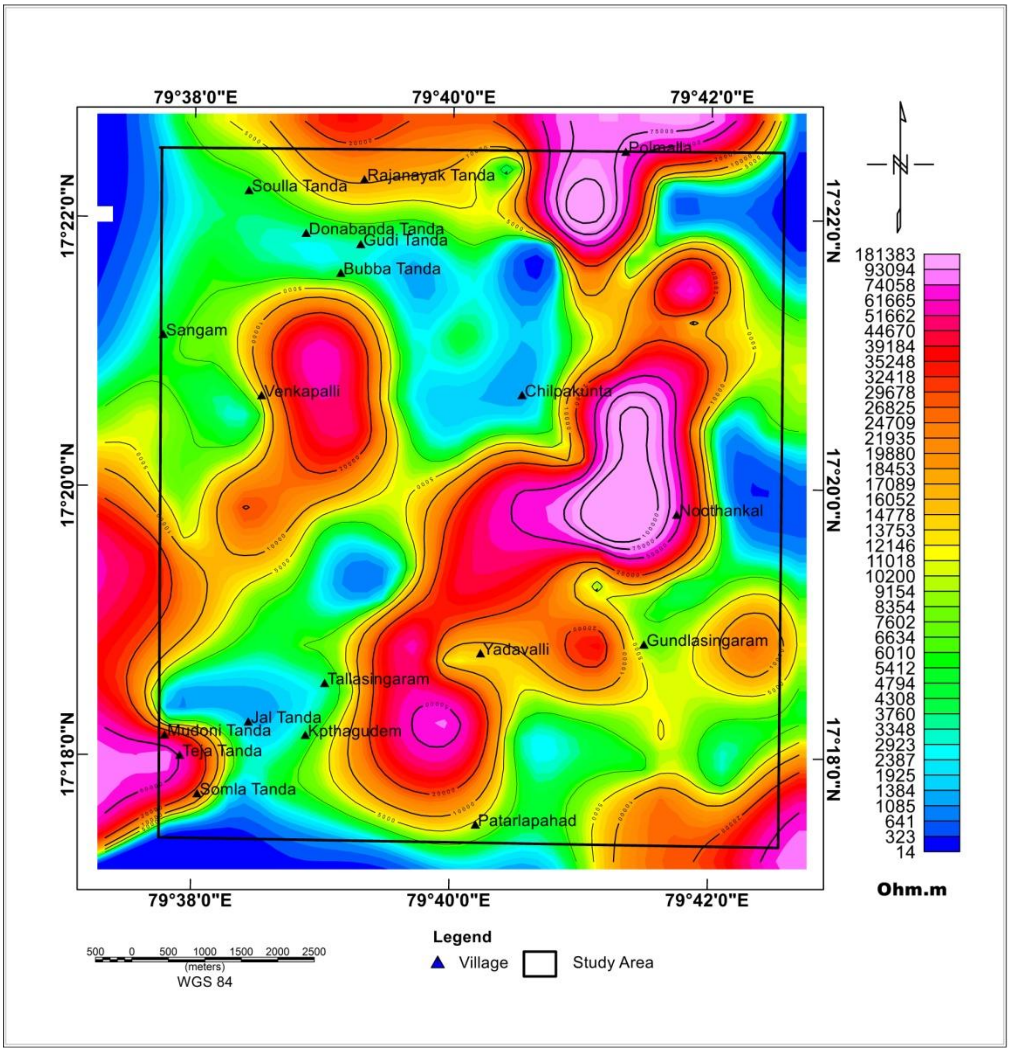

Figure 6. Contour map of Transverse resistivity (T_r)

Average Longitudinal Resistivity (ρ_L):

The Average Longitudinal Resistivity obtained from the 131 soundings and using with total depth divided by Longitudinal conductance (S_c), figure 7 displays the values from 2.55 to 1146 Ohm.m. Low values are noticed at the NTKL6 located at near to sangam village and maximum values are at the NTKL101 near the south west corner of Errapahad village.

Contour Maps of Average Transverse Resistivity (ρ_t):

The average transverse resistivity image (figure 8), displays the values from 2 to 2578 Ohm.m., same as in the image of average longitudinal resistivity (figure 7), the high and low values of (ρ_t) also noticed clearly at eastern portion of the image of transverse resistivity.

Coefficient of anisotropy (λ):
The coefficient of anisotropy (λ) is usually greater than 1.0 but does not often exceed 2.0 (Zohdy., 1974). It can be used as a measure of finding out the extent of anisotropism prevailing in an aquifer of anisotropy (Balasubramanian, 1986).

The coefficients of anisotropy greater than 2.0 are considered as those due to intrusive bodies such as dykes, sills, batholiths, and laccoliths causes by material welling from below the earth, which will normally have resistivities higher than the host rocks and therefore create an unconformity in resistivity resulting to very high values of coefficient of anisotropy. The aquifer anisotropy value ranges from 1 to 3.82 (Table 1) of the study area. The contour map of the study area prepared by using anisotropy (λ) values of 131 sounding with an interval of 0.05 is shown in the figure 9. The minimum (1.0) values of anisotropy coefficient at VES locations NTKL2, NTKL6, MDA52, NTKL58, NTKL74, NTKL75, NTKL124 and maximum value of anisotropy coefficient location near AMK22 is located at Patarlapahad. Nine VES locations are greater than anisotropy coefficient value of 2, and it is indicated the dyke of the study area.

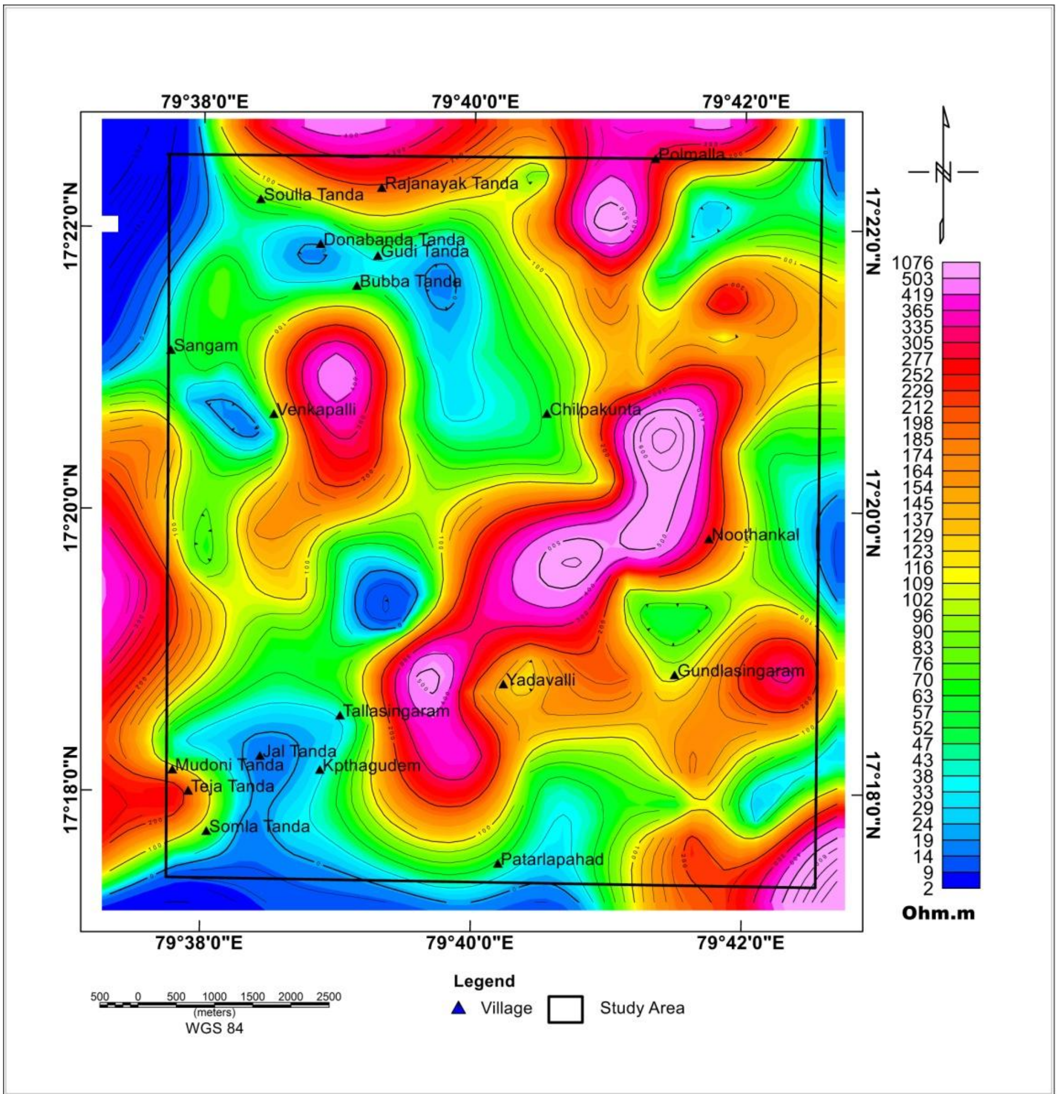

Figure 7. Contour map of Average Longitudinal Resistivity (ρ_L)

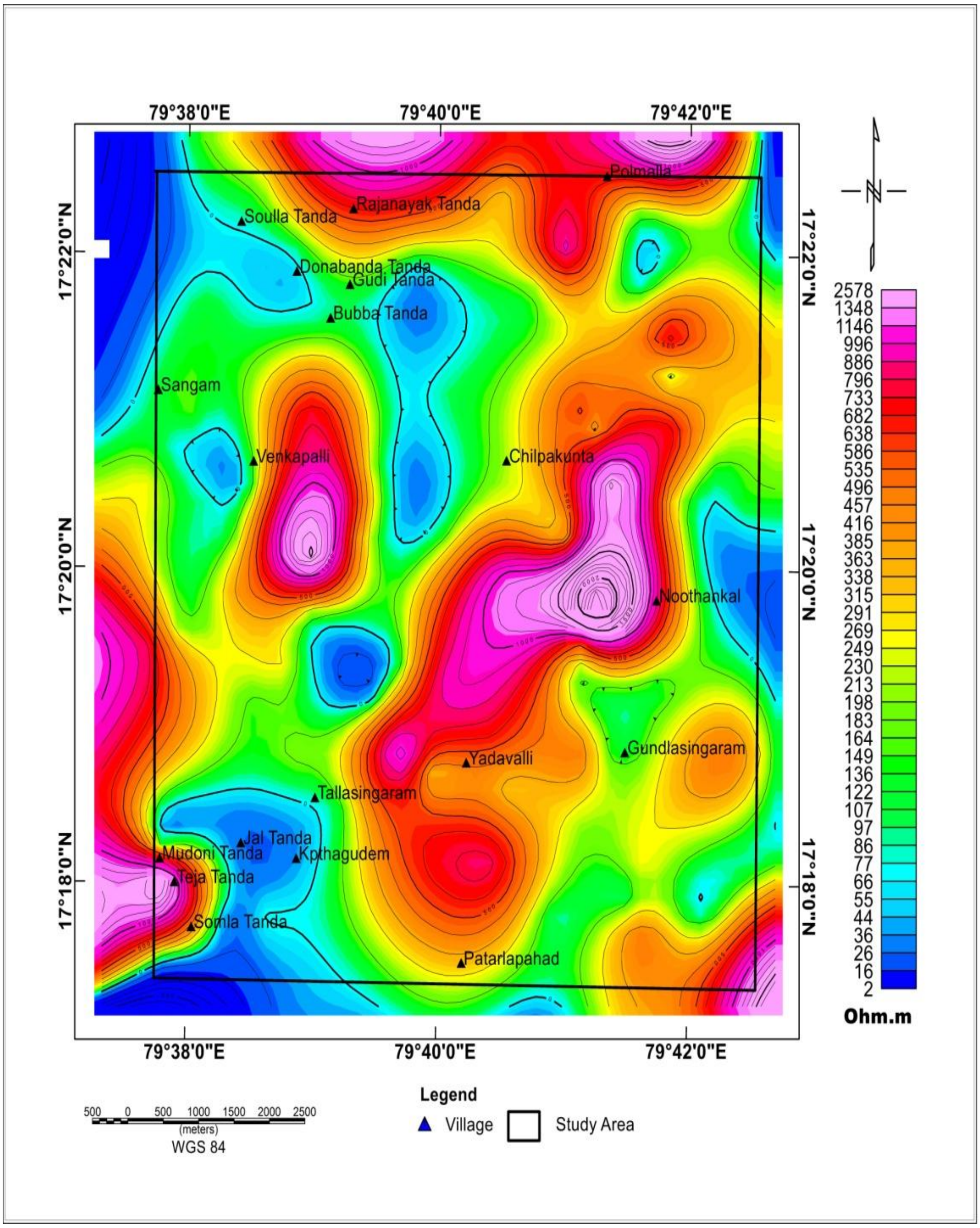

Figure 8. Contour Maps of Average Transverse Resistivity (ρ_t)

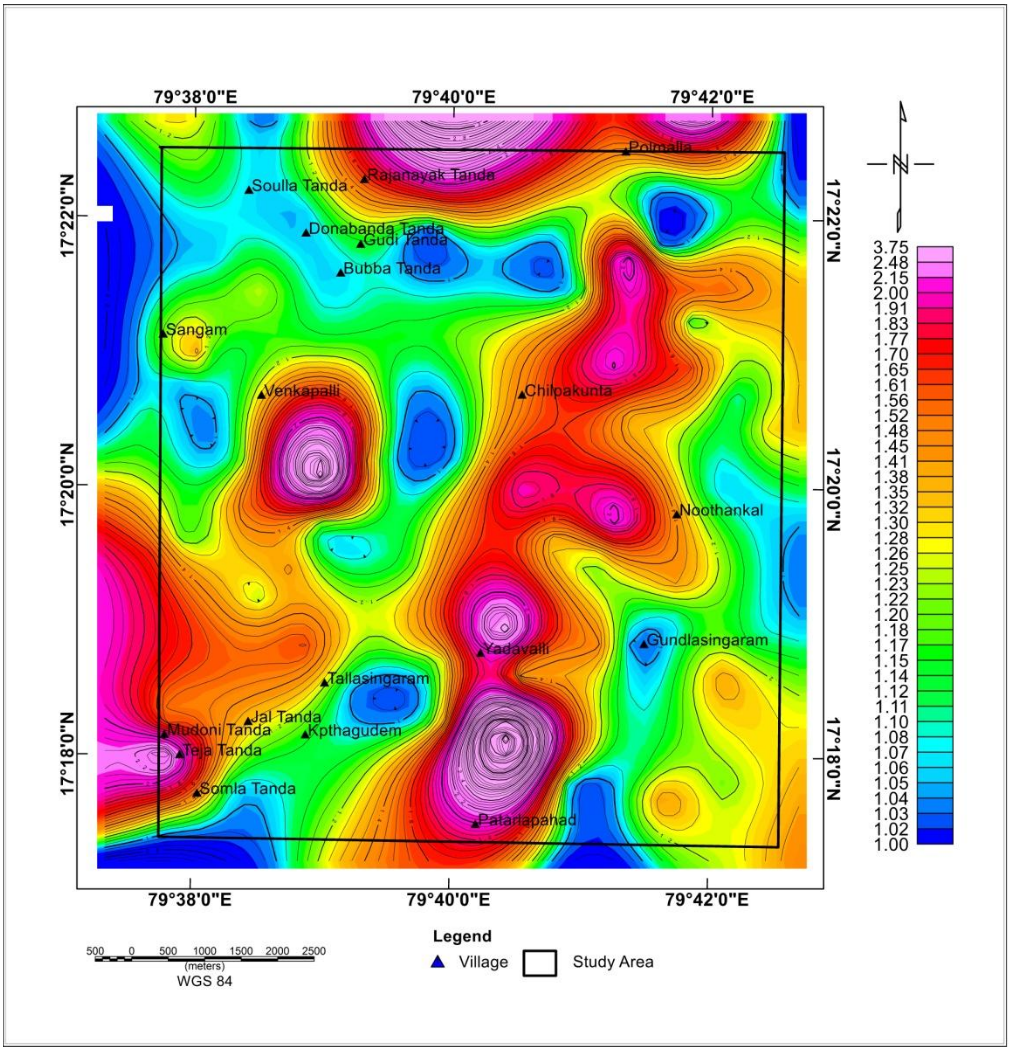

Figure 9. Coefficient of anisotropy (λ) Contour map

Reflection coefficient (R_c):

The reflection coefficient (R_c) and resistivity contrast (F_c) of the fresh basement rock of the study area was calculated (Oladunjoye and Jekayinfa 2015). It also mesure the degree of fracture together density of formation in the aquifer. The results are presented in Figure 10 where in the values ranges from -0.9 to 0.7 indicating high groundwater potentials.

Resistivity Contrast (F_c):

Low Values of resistivity contrast indicate high groundwater potentials. The values of resistivity contrast in this work ranged from 0 to 20472. This shows that the blue colour to yellow colour indicated as good to moderate and pink colour indicated low potential zones for ground waters figure 11.

Resistivity of Formation (ρ_m):

The influence of pore structure on the sample gives an indication of the resistivity formation. The resistivity formation containing hydrocarbon is usually very high (Okhue an Olorunfemi, 1991). The values of resistivity formation obtained ranged between 3 to 1257 Ohm.m figures 12. High formation resistivity near to chilpakuntla West corner to Patarlapahad North West portion, one packet of resistivity venkepally west portion, polmalla to soulla tanda and Western portion of the study area. Low formation resistivity are found along western portion and Eastern portion of the dyke formation and western part of soulla tanda to near to jal tanda.

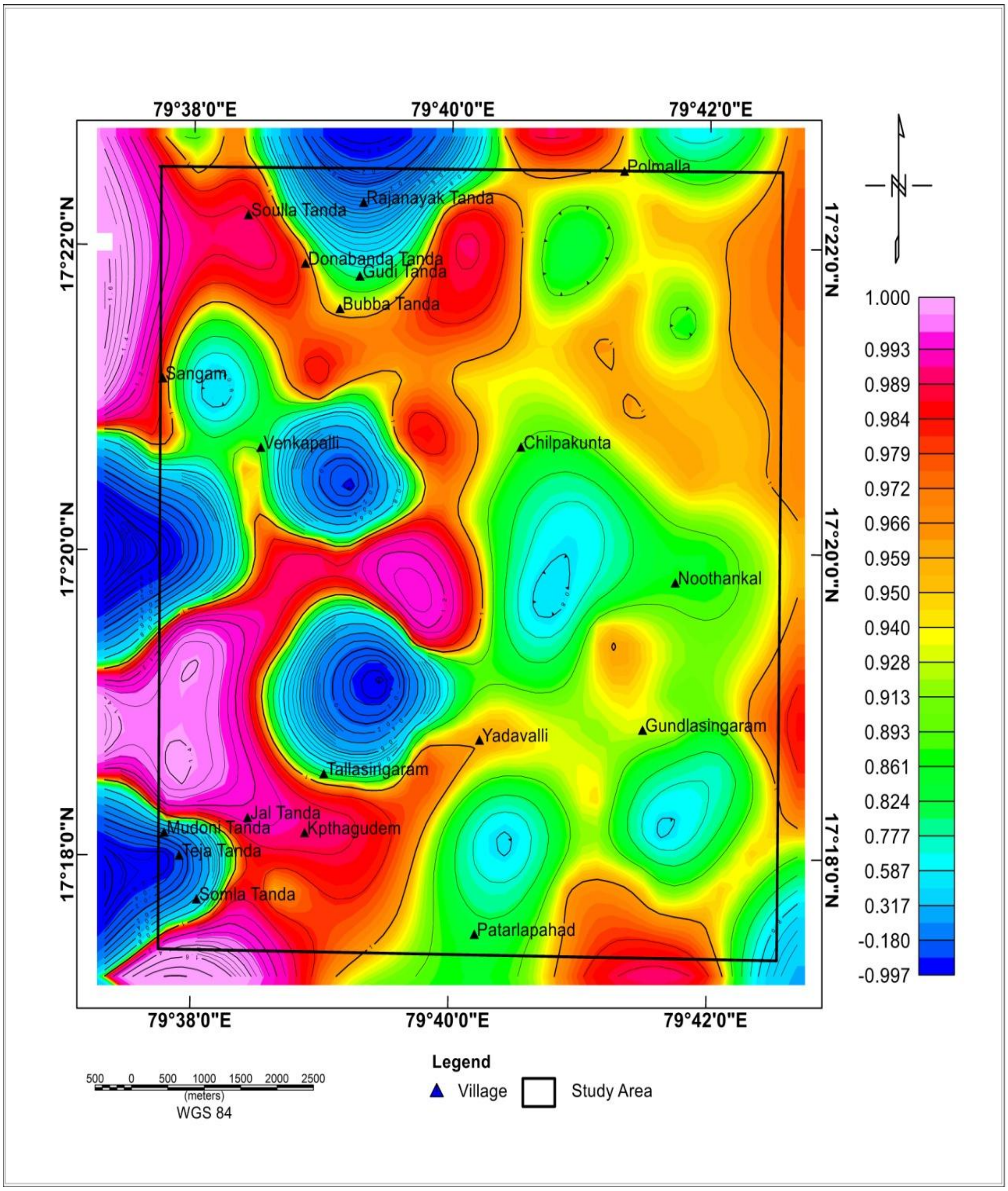

Figure 10. Contour map of Reflection coefficient (R_c)

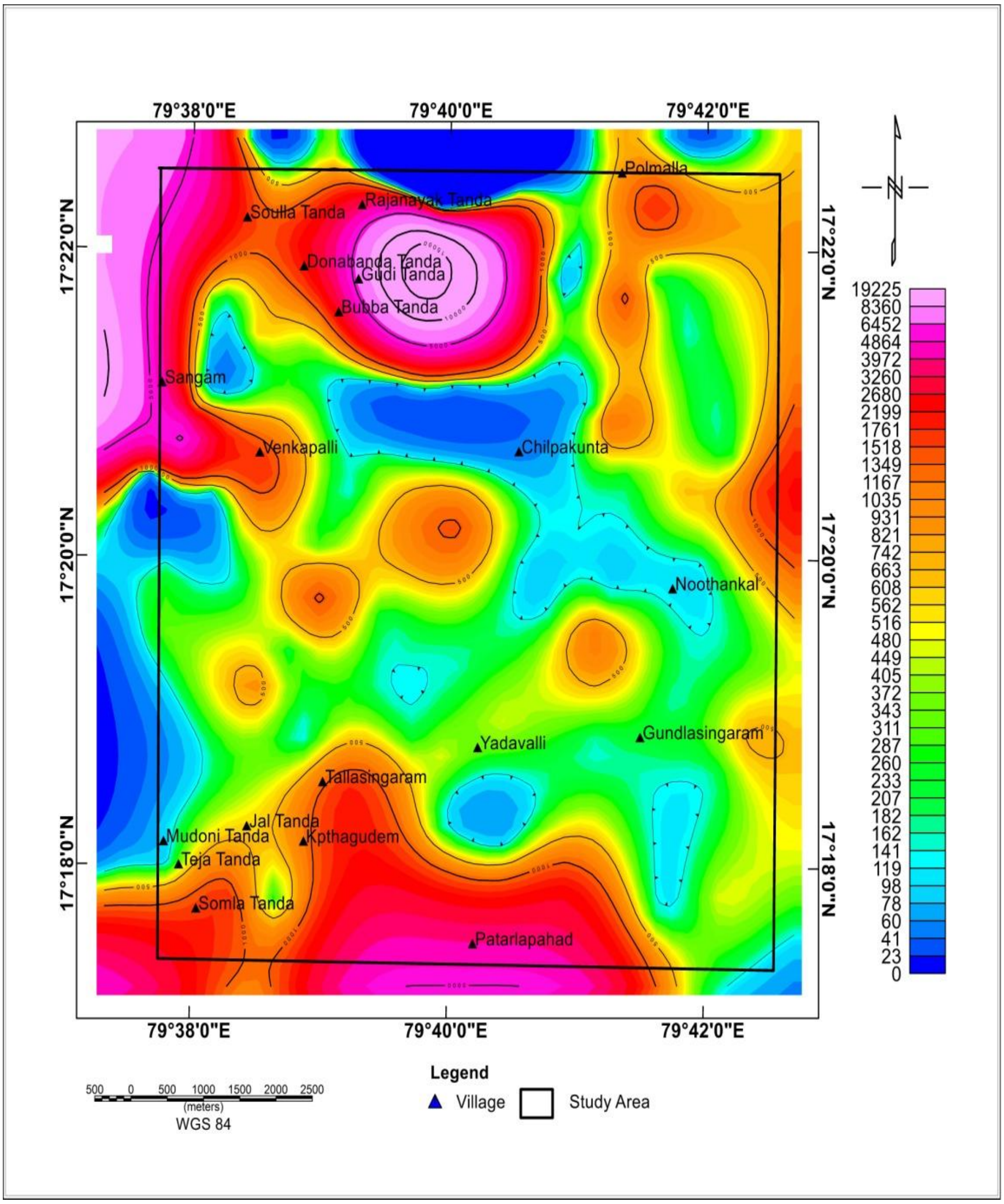

Figure 11. Contour map of Resistivity Contrast (F_c)

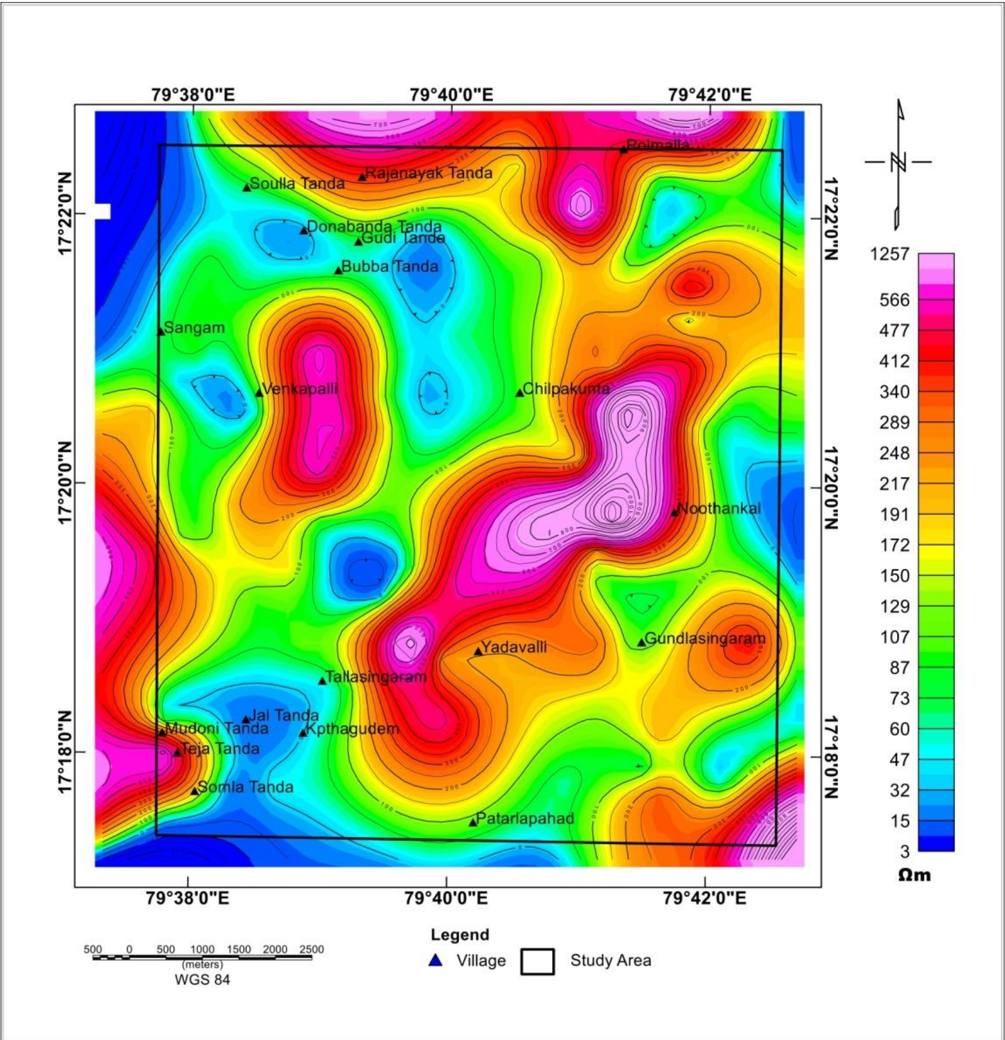

Figure 12. Contour map Resistivity of Formation (ρ_m)

VI. DISCUSSION AND CONCLUSION

Geological and geo-hydrological studies, followed by geophysical studies made easy to locate good groundwater pockets in weathered and fractured zones of the hard rock terrain in the study area. This study helps us to make possible to demarcate the good, moderate, poor groundwater zones of the area. From the analysis and studies, the behaviour of S_c, T_r, λ, R_c, F_c and ρ_m represent the very good, good, moderate, weak, and poor pockets of aquifer zones has been clearly demarcated. As for as the resistivity data interpretation is concerned the values of aquifer system are identified (Blasubramanium et al., 1985). The ranges for various geoelectric layers are very close and do not show wide variation and possess overlapping character. Hence, they create a situation of uncertainty and speculation. Whereas D-Z parameters have an upper hand as they reflect very clear, conspicuous and widely varying ranges for shows good, moderate, weak and poor ground water aquifers. The very good groundwater zone only one is present in the area is AMK20 at North West of Ramannagudem. In case of secondary priority for groundwater zones in the study area situated near at AMK20. Whereas 61 soundings out of 131 are moderate potential for groundwater zones, thus indicating major portion of study area is moderate groundwater potential zones. They do not possess an overlapping character and in turn facilitate easy resolution. Resistivity data interpretation may not be unique in the resolution of very good, good, moderate, weak and poor aquifers. The constant of uncertainty in the resistivity data interpretation can be reduced considerably, if more conspicuous and easily identifiable geophysical parameter supports the interpretation. D-Z parameters can therefore definitely support the aquifers resistivity data interpretation and reduce the risks of uncertainty, at widely varying ranges of the D-Z over the resistivity data interpretation results.

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