EXCELLENT PUBLISHERS

International Journal of Current Research and Academic Review

ISSN: 2347-3215 Volume 2 Number 1 (January, 2014) pp. 58-75

www.ijcrar.com

Delineation of Groundwater Potential Zones Using Geophysical and GIS Techniques in the Sarabanga Sub Basin, Cauvery River, Tamil Nadu, India

S.Venkateswaran[1*], M.Vijay Prabhu[2] and S.Karuppannan[2]

Department of Geology, Periyar University, Palkalai Nagar, Salem-11, Tamil Nadu, India

***Corresponding author**

KEYWORDS

Groundwater;
Sarabanga;
Geophysical data;
GIS;
Potential Zones.

A B S T R A C T

Water plays a vital role in the development of agricultural activities in the study area. The surface water resources are inadequate to fulfill the water demand. Productivity through groundwater is quite high as compared to surface water, but groundwater resources have not yet been properly exploited. Keeping this view, the present study to delineate various groundwater potential zones for the assessment of groundwater availability in the Sarabanga Sub-basin, Cauvery River and Tamil Nadu. 93 Schlumberger Vertical Electrical Sounding (VES) survey were carried out in the study area. The field data were interpreted by IPI2WIN software to determine the resistivity and thickness of the different layers. Results of geophysical data were used to prepare spatial distribution map using GIS. Integration analysis was carried with thickness of first and second layer fracture zone with the corresponding resistivity maps. This map was superposed over geology map. The suitable potential zones for groundwater were delineated from first layers combinations of low resistivity with more thickness in areas occupied by hornblende-biotite-gneisses and Charnockite. The depth for the construction of tube-wells and dug-wells were suggested. The spatial distribution variations in different resistivity layer results are given in the findings.

Introduction

Agriculture is the largest consumer of water in the country, because crop yield depends primarily on two factors, the total amount and the time distribution of water throughout the growing season. This demand will be met out mainly by surface and sub surface water resources. Exploration for groundwater is necessary for agricultural development. Agriculture is the main occupation for the majority of the population of the study area. The main source for irrigation in the area is groundwater. Groundwater is the largest available source of fresh water. It has become crucial not only to find out groundwater potential zones, but also to monitor and conserve this important resource (Rokade *et al*., 2004). GIS overlay analysis is highly helpful in locating the groundwater potential zones (Rokade *et al*., 2007) (Gurugnanam *et al*., 2008).

Schlumberger resistivity survey is the most suitable method for groundwater investigations in hard rock area compared to other geophysical methods. Delineation of fracture zones in low permeability hard rock area is still a very challenging task. Geophysical surveys for groundwater exploration in hard rock areas have been attempted by many authors Ronning *et al*.,(1995), Kaikkonen and Sharma (1997), Ramteke *et al*.,(2001), Krishnamurthy *et al*.,(2003), Sharma and Baranwal (2005),Porsani *et al*.,(2005), Flathe (1955),and Fitterman and Stewart (1986).

GIS has emerged as a powerful technology for instruction, for research, and for building the stature of programs (Openshaw1991; Longley 2000; Sui and Morrill 2004). GIS is an important technology for geologists.

Vertical electrical sounding (i.e. Schlumberger sounding) is effectively used for groundwater studies due to the simplicity of the technique, easy interpretation and rugged nature of the associated instrumentation. The technique is widely used in soft and hard rock areas (Van Overmeeren, 1998,Urish and Frohlich, 1990,Ebraheem *et al*., 1997). However, groundwater investigations in hard rock areas are often more difficult, as tube-wells must be located exactly to be successful. Tube-wells drilled without proper geophysical and hydrogeological study often fail to produce ground water. In the present study, detailed geophysical study was conducted. The interpreted results were taken in to GIS. In GIS, multiple thematic maps overlay analyses were carried out.

Study Area

The study area, lies between the latitudes 11°46’ N to 12°09’39” N and longitudes 78°12’27” E to 78°36’65” E covering an area of 1178.56 km^2. Out of which plain land covers an area of 1015.79 km^2 (Fig.1). The study area falls in Salem district of Tamil Nadu. The major source for recharge of water in this area is rainfall, during monsoon season. The average annual rainfall is 852 mm (2000 to 2009). As the study area is underlain by the Archean crystalline rocks surrounded by wavy hills and hillocks, groundwater mostly occurs in the fractured zones.

Materials and Methods

Base map was prepared from toposheets 57L/4, 8, 58 I/1, and 5 of 1:50,000 scale. The toposheet was registered and digitized for the drainages (Sarabanga sub-basin). The geology map was collected from Geological Survey of India (GSI). The map was traced, scanned, digitized and then taken to GIS. In the field, the rock samples were collected and identified to assess the quantity characteristics of groundwater.

Schlumberger Vertical Electrical Soundings (VES) surveywas carried out at 93 locations (Fig.1). Latitude and longitude of the survey locations was captured using GPS. Geophysical Schlumberger VES

(Vertical Electrical Sounding) survey was carried out maximum electrode spacing of 300 m. The current electrode (AB/2) spacing varied from 1 to 150 m and the potential electrode (MN/2) spacing varied from 0.5 to 15 m. All the data were plotted in the field to check the quality of data and to avoid mistakes. The field data were interpreted by IPI2WIN software to determine the resistivity and thickness of the different layers. Their attributes are added and analyzed in ArcGIS version 9.3 software. Spatial analysis tools were used for the preparation of interpolation map. The maps were interpolated by using inverse distance methods to arrive the spatial distribution map. Integration analysis was carried with thickness of first and second layer fracture zone with the corresponding resistivity maps. This map was superposed over geology map. The suitable zones for groundwater were low resistivity with more thickness in areas. The depth for the construction of tube-wells and dug-wells were suggested in the present investigation.

Result and Discussion

The interpreted sounding results show the top soil thickness and resistivity, weathered zone thickness and resistivity, and fracture zone thickness and resistivity. This result was taken as point information in GIS environment.

Geology

The study area is mainly underlain by fissile hornblendebiotite gneiss,charnockite and granite. Fissile hornblendebiotite gneiss is the dominant group of rocks covering major parts of the study area followed by the charnockite and granite rocks.. Hornblende-biotite-gneiss is relatively porous and can be considered as favorable for groundwater storage (Fig.2). This rock and its associated combinations usually act as a favorable zone for groundwater.

Resistivity and thickness of fracture zones

The results of the analysis giving first layer minimum and maximum resistivity and thickness values is shows in Table 2. The maximum resistivity value was observed in Reddipatti (VES No.63) as 79969 (ohm-m) at a depth of 17.50 m. The high resistivity indicates that the formation is compact at this depth. It is also evidenced in the field that, borehole is drilled near by this location dose not yield good amount of water. Low resistivity values indicate the water bearing formation. The highest fracture zone thickness was observed in Maramangalattupatti (VES No.60) having thickness of 25.5 m with its resistivity of 3.82 (ohm-m). This result shows drastic variation in resistivity and thickness values in the study area. The field evidence also proves that low resistivity (LR) areas with resistivity value of 3.82 ohm-m yield good groundwater at a depth of 25.5 m. Similarly, the high thickness zone indicates good amount of groundwater storage.

The results of the analysis showing minimum and maximum resistivity and thickness in the second layer are shows in Table 5. The maximum resistivity value was observed in Andiyur (VES No.7) as 96130 (ohm-m) at 16.1 m depth. Generally, the said location is favorable for groundwater only during northeast monsoon season. The high thickness and low resistivity values were noticed at Siranganur (VES No.37). This area is

Table.1 Geophysical Investigations Locations and its fracture zone resistivity and fracture zone thickness and total thickness and curve types are briefly mentioned

VES No.	Village Name	Resistivity Ohm-m /Thickness m				Total Thickness 'h' m	Curve Types
		ρ_1 &h_1	ρ_2 &h_2	ρ_3 &h_3	P_4 &h_4		
1	Elattur	11.6/1.61	77/39.82	3890/42.9	0	84.33	A
2	Muttanampatti	1.95/0.93	52507/20.8	51555/57.3	50659/56.2	135.23	KQ
3	Periyavadagampatti	10.7/2.26	487/2.18	37/7.5	3056329.12	41.06	KH
4	Kukkalpatti	10.4/2.06	119/27.5	1596/12	17588/24	65.56	A
5	Kuppakalipatti	108/0.5	210/20.2	36742/9.14	57243.6	73.44	AK
6	Amaram	24.9/0.5	309/3.48	797/12.7	35322.4	39.08	AK
7	Andiyur	15.1/2.69	4012/8.02	4012/7.52	96130/16.1	34.33	A
8	Maniyakkaranur	15.9/1.46	1.43/1.85	7457/21.2	29.4/52.8	77.31	HK
9	Rangappanur	43.4/0.5	30.2/6.24	2393/21.3	2317/26.3	54.34	HK
10	Agraharam	0.019/0.5	8.07/3.41	539/24.9	0.027/53.1	81.91	AK
11	ChinnaYercaud	4.49/1.09	38.6/9.46	235/3.63	5862/6.42	20.6	AA
12	Danishpet	24.2/0.5	37.1/6.77	24.4/17.1	9584/33.3	57.67	KH
13	Kolippatti	255/0.5	58.9/1.1	710/17.1	425/68.1	86.8	HK
14	Karappatti	32.3/3.3	22.7/2.16	4027/7.64	87111/40	53.1	HA
15	Malalyyanur	25/0.56	329/5.96	1141/6.56	326/23.2	36.38	AK
16	Bommiyampatti	525/0.5	85.4/1.58	11.7/6.54	2.44/27.1	35.72	Q
17	Marakkottai	1.76/0.493	2357/8.2	7599/8.56	4979/0.104	17.357	A
18	Kanjinayakkanpatti	10.6/0.672	8.68/92.2	67.6/46.32	5847/13.99	153.19	HK
19	ChinnaNagalur	12.3/0.5	104/7.54	54222/28.6	56457/48.4	85.04	A
20	Tinnappatti	0.173/0.5	315/2.03	36965/19	254/78.5	100.03	AK
21	Kanjeri	22.8/1.67	31.7/7.72	10386/17	70542/45.1	71.49	A
22	Palakkaranur	39.1/1.84	40.1/6.91	54.7/17.2	38217/63.7	89.65	A
23	Kalikavundanur	29.7/1.93	227/4.42	13.7/12.4	28826/41.5	60.25	KH
24	Sengattur	0.68/0.5	4483/18.3	4614/17.7	344/36.3	72.8	k
25	Sattappadi	23/1.54	31.8/7.67	15593/11.4	6449/20.7	41.36	A
26	Semmandapatti	17.2/0.5	163.9/8.9	21843/31.5	4895/35.7	40.9	AK
27	Darapuram	11/1.93	51682/15.2	2379/23.7	6838/43.3	84.13	KH
28	Sattur	28.5/0.5	9.23/9.53	1756/13.2	11655/72.9	96.13	HQ
29	Nangavalli	58.3/2.49	32.2/2.01	290/44.8	56930/32.9	82.2	HA

30	Olaippatti	1.11/0.5	3.96/4.04	381/5.54	398/38.9	48.98	A
31	Maramangalam	1.85/0.51	66792/0.255	34.9/36.5	9037/79	116.265	KH
32	Palikkadai	1.77/0.5	2126/24.9	3.19/30.3	3.31/33.1	88.8	KQ
33	Balbakki	1.36/0.5	4.285/3.86	27196/8	187/7.39	19.75	AQ
34	Mailappalaiyam	6015/2.93	4.74/16.3	6542/30.5	84.5/52.8	102.53	HQ
35	Sanarpatti	523/0.503	1.25/0.518	105/38.4	743/33.1	72.521	HA
36	PeriyaSoragai	0.622/0.5	51.2/13.2	15382/31.3	196/35.6	80.6	AQ
37	Siranganur	55.2/1.82	251/0.812	10.8/16.3	4546/109	127.932	KH
38	Amarakundi	809/1.16	855/0.877	163/39.4	32.6/39.7	81.137	Q
39	Periyerippatti	22/1.83	2244/3.65	152/20.1	3692/53.6	79.18	KH
40	Vellakavundanur	6545/0.547	37.1/3.7	56796/35.1	3978/36.1	75.447	HK
41	Omalur	32.8//1.95	4215/4.7	116/18.4	1058/45.8	25.05	KQ
42	Vettalaikkaranur	58.6/1.9	126/2.36	527/42.8	7715/25.7	72.76	AA
43	Karuppur	0.104/0.949	31.3/2.59	36.9/5.93	5289/35.4	44.869	AA
44	Jalakandapuram	47.3/4.11	178155/8.47	194/42.9	261/59.4	114.88	KH
45	Chinnakovundanur	16.2/0.51	1261/5.8	1082/16	5990/52.7	75.01	AA
46	Vellakkalpatti	39.7/0.902	0.826/1.09	4528/25.9	174/15.6	43.492	HK
47	Chikkampatti	0.63/1.86	3756/2.59	0.189/11.17	490/27.4	43.02	KH
48	Mottaiyanteruvu	10.1/2.94	97639/16.6	142/43.6	2614/31.3	94.44	KH
49	Ellavur	0.627/0.5	11.5/1.1	5.11/19	0.603/43.7	64.3	AQ
50	Pakalpatti	5.31/0.5	10.21/5.43	13.4/15.9	11695/31.3	53.13	AA
51	Nallakovundanpatti	0.031/0.5	13.2/2.49	27/4.68	1903/25.7	33.37	AA
52	Puliyampatti	63.1/2.26	957/7.4	31/27.9	9505/50.6	88.16	KH
53	Ramakavundanur	90.2/3.52	771/4.59	184/11.3	2709/24.6	44.01	KH
54	Sivadanur	25.4/1.95	1490/5.13	215/15.4	25083/43.4	65.88	KH
55	Nattakkattanur	2.56/1.19	8.71/7.52	1.48/12.5	22296/2.19	23.4	KH
56	Tadikaranpatti	3.54/0.5	2797/0.175	24.4/4.93	32041/53.1	58.705	KH
57	Kuttakkattanur	14.4/0.5	2382/0.76	56.6/3.46	614/101	105.72	KH
58	Attikkattanur	32.3/1.22	228/1.6	22.5/35.1	6326/53.9	91.82	KH
59	Kanganur	20.6/3.31	88/9.23	2665/5.75	299/26.2	44.49	AA
60	Maramangalattupatti	24.8/1.48	5.15/35	3.82/252	33.8/93.38	381.86	QH
61	Sarkar Gollapatti	72.7/3.74	20.3/0.789	3827/1.66	39.3/9.71	15.899	HK
62	Nattappatti	21.1/0.5	64623/2.38	21623/5.16	1985/18.2	26.24	KQ

63	Reddippatti	87.5/4.13	9969/3	79969/17.5	254/99.7	124.33	AK
64	Panmalaiyur	4.34/1.4	1634/3.18	110/6.16	2512/11.2	21.94	KH
65	Tirumalur	5.3/0.5	4176/2.25	62.9/7.09	2198/44.1	53.94	KH
66	Samudram	62.1/4.61	129/9.66	2871/32.4	1735/0.663	47.333	AK
67	Upparappatti	9.37/4.12	1354/5.12	4423/41.5	22/94	144.74	AK
68	Chinnappampatti	1479/0.331	33.4/3.28	4240/13.9	1.66/106	123.511	HK
69	Mattaiyampatti	23.3/3.86	2.73/1.55	585/5.29	4491/24.4	35.1	HA
70	Sittanur	95.6/4.01	106/12	503/28.3	95.5/19.8	64.11	AK
71	Nallakkampatti	85.9/0.77	2.32/2.52	48912/32.4	9.29/50.4	86.09	HK
72	Makkanur	84.2/0.5	120/1.37	160/13.5	2570/6.83	22.2	AA
73	Kottapalayam	1.58/1.65	1557/5.27	1736/21.6	537/22.3	50.82	KQ
74	Kartikanakkanur	119/4.66	488/13.2	301/24.7	9411/31.3	73.86	KH
75	Oddapuram	85.7/0.957	17.5/1.67	48.8/8.97	6481/55.5	67.097	HA
76	Kottapalayam	65/6.57	7260/13.1	1758/5.9	718/12.3	37.87	KQ
77	Sadayampalayam	68.6/0.678	14.3/8.02	1260/23.2	7045/40.1	71.998	HA
78	Pachchallyur	51.4/2.82	98.2/0.197	294/8.7	2782/14.9	26.617	AA
79	Konangiyur	8133/0.16	78/0.918	344/2.62	31.6/8.68	12.378	HK
80	Velaiyachettippatti	0.216/0.5	475/13.1	825/26.6	9188/60.8	101	KA
81	Nallanampatti	567/1.62	2127/2.39	301/9.69	7696/19	32.7	KH
82	Pattakkaranur	448/1.31	14/4.87	19710/63.1	66105/66.2	135.48	HA
83	Kalaravallipattipudur	103/2.34	6.56/0.914	1129/2.57	124/16.6	22.424	HK
84	Nachchiyur	10.6/4.32	3188/1.22	1161/6.88	3635/59.1	71.52	KH
85	Kundarasampalayam	112/0.5	376/2.66	500/17.1	3336/6.25	26.51	AA
86	Ayyampalayam	112/0.5	376/2.58	496/15.4	1472/13.1	31.58	AA
87	Tannirdasanur	57/1.4	150/2.44	37.9/4.63	8200/61.7	70.17	KH
88	Marikavundankuttai	81.9/1.28	224/2.38	25.3/8.27	49606/40.9	52.83	KH
89	Annamalaipalaiyam	16.2/1.53	181/0.859	8.9/2.06	894/63.4	67.849	KH
90	Kavadikkaranur	4.59/0.974	59377/1.6	2166/24.1	29706/79.5	106.174	KH
91	Madattur	85.9/4.94	2769/2.12	155/11.6	39634/58.6	77.26	KH
92	Kurukkuparaiyur	16/0.59	10.8/3.27	176/12.6	166/30.64	47.1	HK
93	Pullipalikadu	14.6/1.44	39/7.79	7367/2.22	142/24.6	36.05	AK

Table.2 Maximum and minimum values of first layer resistivity and thickness variation in entire Sarabanga Sub-Basin

Max./Min.	Village Name	Fracture zone Resistivity and Thickness	Village Name	Fracture zone Thickness and Resistivity
Maximum	Reddipatti (63)	79969 Ωm. (17.5 m)	Maramangalattupatti (60)	252 m.(3.82 Ωm)
Minimum	Chickampatti (47)	0.189 Ωm. (11.17 m)	Salur (52)	1.66 m. (3827 Ωm)

Table.3 Maximum and minimum values of second layer resistivity and thickness variation in entire Sarabanga Sub-Basin

Max./Min.	Village Name	Fracture zone Resistivity and Thickness	Village Name	Fracture zone Thickness and Resistivity
Maximum	Andiyur (7)	96130 Ωm. (16.1 m.)	Siranganur(37)	109 m. (10.8 Ωm.)
Minimum	Agraharam(10)	0.027Ωm. (53.1 m)	Marakottai (17)	0.104 m. (7599Ωm.)

Table.4 Spatial distribution results of first layer resistivity of different class and its percentage in entire Sarabanga Sub-Basin

Class	Fracture zone - First layer resistivity (Ohm-m)	Area in Km^2	Area in Percentage
Very low resistivity	Less than 917.58	174.68 km^2	17.17 %
Low resistivity	917.58 – 6394.38	557.38 km^2	54.78 %
Medium resistivity	6394.38 – 29214.39	258.48 km^2	25.40 %
High resistivity	More than 29214.39	26.90 km^2	2.64 %

Table.5 Spatial distribution results of first layer thickness of different class and its percentage in entire Sarabanga Sub-Basin

Class	Fracture zone - First layer thickness (m)	Area in Km^2	Area in Percentage
Low thickness	Less than 10.48	235.77 km^2	22.73 %
Medium thickness	10.48 to 21.29	239.64 km^2	23.10 %
High thickness	21.29 to 40.94	449.17 km^2	43.30 %
Very high thickness	More than 40.94	112.86 km^2	10.88 %

Fig.1 Geophysical survey and water sample collection locations of entire Sarabanga Sub-basin (Interval between the two points average of 4Kms)

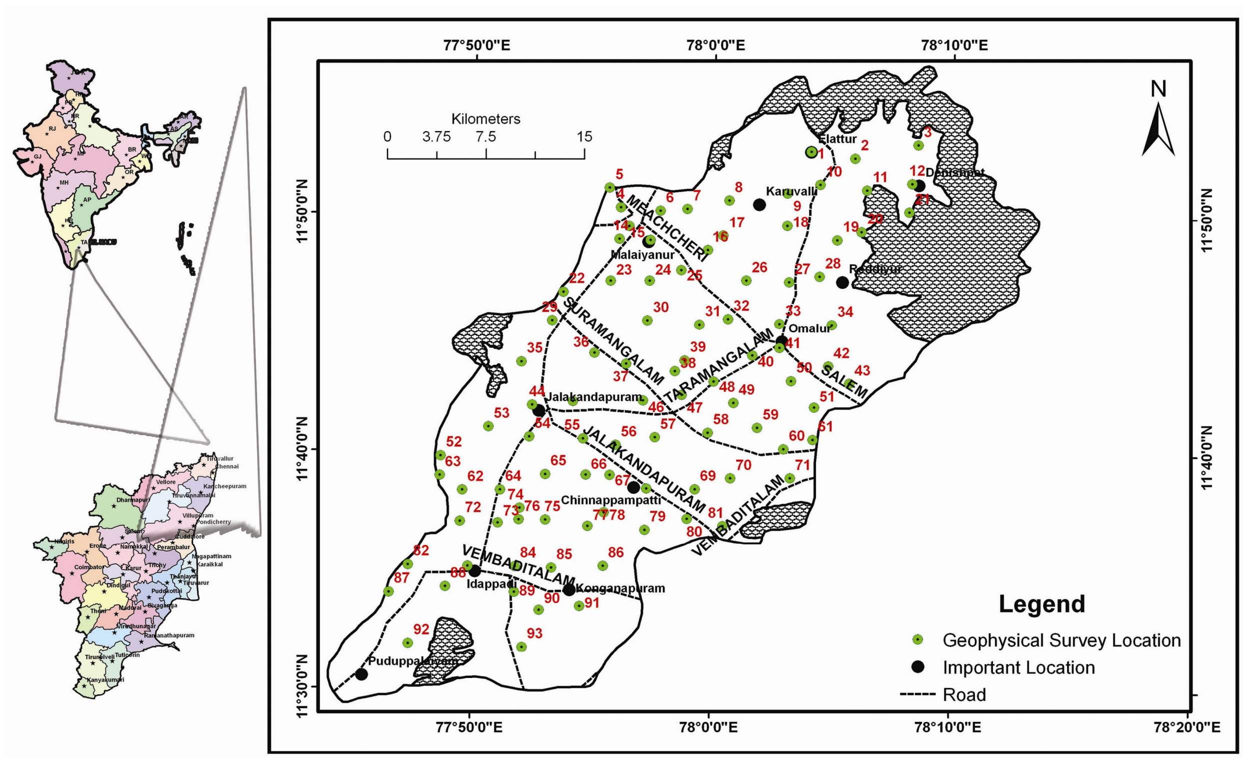
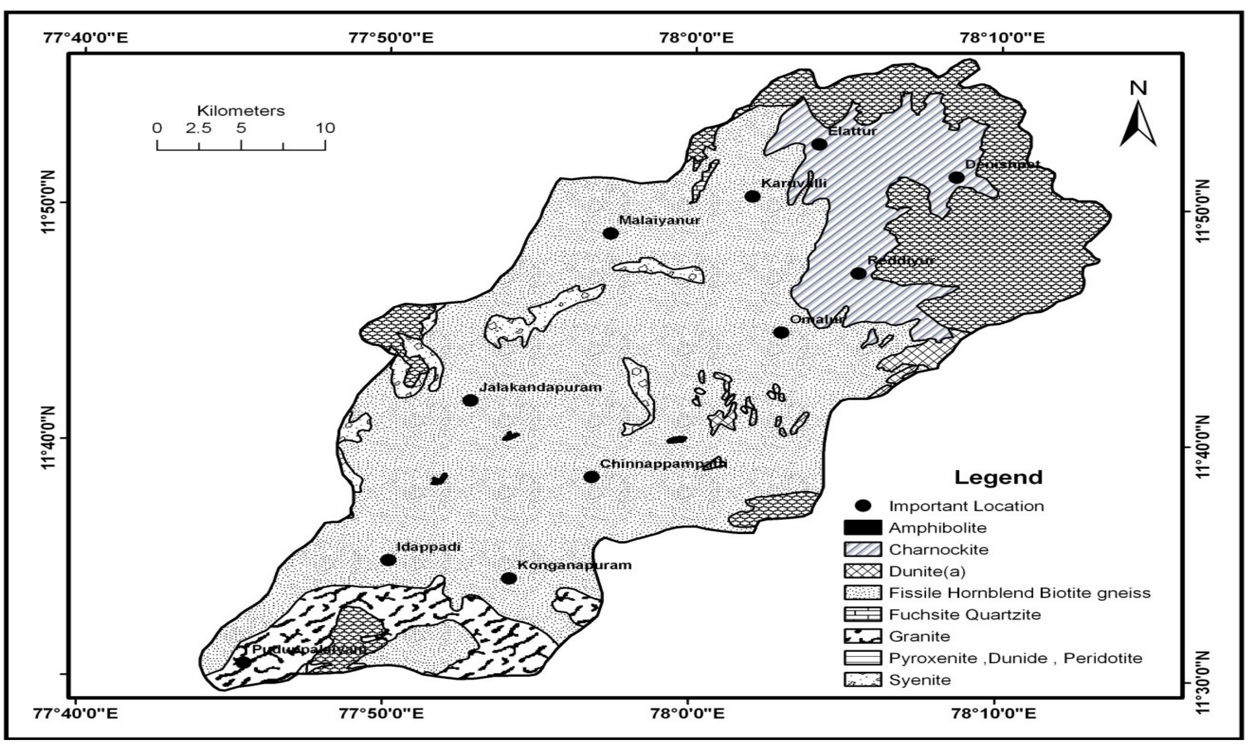


Fig.2 Geological variation map and its spatial distribution of the Sarabanga Sub-Basin



highly suitable for storage of huge amount of groundwater.

Spatial distribution results of subsurface first layer

The spatial resistivity distribution map (Fig.3) was prepared using the geophysical results. The results of the spatial distribution map are given in the Table 4.In the present investigation, first layer resistivity can be classified in to four classes, such as first fracture zone very low resistivity, first fracture zone low resistivity, first fracture zone medium resistivity and first fracture zone high resistivity. Groundwater potential zones are relates by 1VLR (Very Low Resistivity). Very low resistivity zones cover an area of 174.68 km^2.

Similarly spatial distribution map of first layer thickness (Fig.4)was prepared using GIS which is given in Table 5. The first layer thickness can also be classified in to four classes, such as First layer Low Thickness, first layer medium thickness, and first layer high thickness and first layer very high thickness, out of which the best groundwater potential area is indicated by 1VHT (Very High Thickness). Very high thickness zones cover an area of 112.86km^2.

Spatial distribution results of subsurface second layer

The spatial resistivity distribution map (Fig.5) and the results of spatial distribution (Table 6) indicates that second layer resistivity can be classified in to four classes, such as second layer very low resistivity, second layer low resistivity, second layer medium resistivity and second layer high resistivity. Deeper groundwater favorable zones relate to 2VLR (Very Low Resistivity) values. Very low resistivity zones cover an area of 152.96km^2.

Similarly spatial distribution map of second layer thickness (Fig.6)was prepared using GIS which is given in the Table 7.Thesecond layer thickness can also be classified in to four classes, such as second layer low thickness, second layer medium thickness, second layer high thickness and second layer very high thickness, the best groundwater potential area is indicated by 2VHT (Very High Thickness). The possibility of the best groundwater potential areas are related to 2VHT (Very High Thickness) zones. Very high thickness zones cover an area of 67.13km^2.

GIS Analysis

The fracture zone first layer resistivity map was superimposed over fracture zone first layer thickness map and output map 1 was derived (Fig.7). Its results are given in the Table 8. The result shows sixteen numbers of combinations. It is highly helpful in assessing the best groundwater potential zones. The sixty two combinations are LT-VLR, LT-LR, LT-MR, LT-HR, MT-VLR, MT-LR, MT-MR, MT-HR, HT-VLR, HT-LR, HT-MR, HT-HR, VHT-VLR, VHT-LR,VHT-MR, VHT-HR Among these LR& MT (Low Resistivity and Medium Thickness) combination covers a large area of 0.429 km^2. The second dominant polygons are MR&MT groups. It covers an area of 0.121 km^2. LR& HT combination comes in third level and covers an area of 0.241 km^2. VLR-VHT and VLR-HT combinations cover an area of 0.031 km^2 and 0.106 km^2 these combinations favors shallow depth of groundwater. This is also verified in the field. This area is highly suitable for construction of dug well. Similarly, the fracture zone second layer resistivity map was superimposed over

Table.6 Spatial distribution results of second layer resistivity of different class and its percentage in entire Sarabanga Sub-Basin

Class	Fracture zone – Second layer resistivity (Ohm-m)	Area in Km^2	Area in Percentage
Very low resistivity	Less than 2468.59	152.96 km^2	14.74 %
Low resistivity	2468.59 – 10790.53	539.63 km^2	52.02 %
Medium resistivity	10790.53 – 43202.32	323.00 km^2	31.13 %
High resistivity	More than 43202.32	21.85km^2	2.11 %

Table.7 Spatial distribution results of second layer thickness of different class and its percentage in entire Sarabanga Sub-Basin

Class	Fracture zone – Second layer thickness (m)	Area in Km^2	Area in Percentage
Low thickness	Less than 19.86	160.74 km^2	15.49 %
Medium thickness	19.86 to 38.76	405.26 km^2	39.06 %
High thickness	38.76 to 60.73	404.32 km^2	38.97 %
Very high thickness	More than 60.73	67.13 km^2	6.47 %

Table.8 Integration results of first layer resistivity and thickness of different class and its distribution percentage in overallSarabanga Sub-Basin

Sl.No.	Class	Area in Km^2	Sl.No.	Class	Area in Km^2
1	LT& VLR	0.075	9	HT& VLR	0.106
2	LT& LR	0.148	10	HT& LR	0.241
3	LT& MR	0.023	11	HT& MR	0.108
4	LT& HR	0.004	12	HT& HR	0.014
5	MT& VLR	0.195	13	VHT& VLR	0.031
6	MT& LR	0.429	14	VHT& LR	0.136
7	MT&MR	0.121	15	VHT& MR	0.198
8	MT& HR	0.007	16	VHT & HR	0.034

Table.9 Integration results of second layer resistivity and thickness of different class and its distribution percentage in overallSarabanga Sub-Basin

Sl.No.	Class	Area in Km^2	Sl.No.	Class	Area in Km^2
1	LT& VLR	0.053	9	HT& VLR	0.097
2	LT& LR	0.110	10	HT& LR	0.344
3	LT& MR	0.019	11	HT& MR	0.291
4	LT& HR	0.005	12	HT& HR	0.041
5	MT& VLR	0.123	13	VHT& VLR	0.072
6	MT& LR	0.383	14	VHT& LR	0.154
7	MT&MR	0.233	15	VHT& MR	0.040
8	MT& HR	0.019	16	VHT & HR	0.005

Table.10 Groundwater potential zone delineation with resistivity, thickness and geology overlay results

Sl.No.	Combinations			Area in Km^2	Sl.No.	Combinations			Area in Km^2
	1st Layer	2nd Layer	Geology			1st Layer	2nd Layer	Geology	
1	High Thickness -High Resistivity -Very High Thickness -Very Low Resistivity -Charnockite			0.05	27	Medium Thickness -Low Resistivity -Medium Thickness -Very Low Resistivity Fissile HornblendBiotite gneiss			5.58
2	High Thickness -High Resistivity -Very High Thickness -Very Low Resistivity -Fissile HornblendBiotite gneiss			1.05	28	Medium Thickness -Low Resistivity -Medium Thickness -Very Low Resistivity Syenite			0.12
3	High Thickness -Low Resistivity - Very High Thickness -Very Low Resistivity -Dunite(a)			2.93	29	Medium Thickness -Low Resistivity -Very High Thickness -Low Resistivity -Dunite(a)			2.22
4	High Thickness -Low Resistivity - Very High Thickness -Very Low Resistivity -Fissile HornblendBiotite gneiss			17.39	30	Medium Thickness -Low Resistivity -Very High Thickness -Low Resistivity -Fissile HornblendBiotite gneiss			34.52
5	High Thickness -Low Resistivity -High Thickness -Low Resistivity -Fissile HornblendBiotite gneiss			31.05	31	Medium Thickness -Low Resistivity -Very High Thickness -Very Low Resistivity -Dunite(a)			0.36
6	High Thickness -Low Resistivity -High Thickness -Low Resistivity -Syenite			3.27	32	Medium Thickness -Low Resistivity -Very High Thickness -Very Low Resistivity -Fissile HornblendBiotite gneiss			6.47
7	High Thickness -Low Resistivity -Very High Thickness -Low Resistivity -Charnockite			0.05	33	Medium Thickness -Very Low Resistivity -High Thickness -Medium Resistivity -Granite			1.93
8	High Thickness -Low Resistivity -Very High Thickness -Low Resistivity -Dunite(a)			3.64	34	Medium Thickness -Very Low Resistivity -High Thickness -Very Low Resistivity -Fissile HornblendBiotite gneiss			0.53

9	High Thickness -Low Resistivity -Very High Thickness -Low Resistivity -Fissile HornblendBiotite gneiss	25.83	35	Medium Thickness -Very Low Resistivity - High Thickness -Very Low Resistivity - Syenite	0.53
10	High Thickness -Very Low Resistivity - High Thickness -Low Resistivity - Amphibolite	0.27	36	Very High Thickness -Low Resistivity - Very High Thickness -Very Low Resistivity - Dunite(a)	0.94
11	High Thickness -Very Low Resistivity - High Thickness -Low Resistivity -Fissile HornblendBiotite gneiss	14.93	37	Very High Thickness -Low Resistivity - Very High Thickness -Very Low Resistivity - Fissile HornblendBiotite gneiss	10.24
12	High Thickness -Very Low Resistivity - High Thickness -Low Resistivity -Syenite	0.93	38	Very High Thickness -Low Resistivity -High Thickness -Low Resistivity - Charnockite	2.00
13	High Thickness -Very Low Resistivity - High Thickness -Very Low Resistivity - Charnockite	0.02	39	Very High Thickness -Low Resistivity -High Thickness -Low Resistivity - Fissile HornblendBiotite gneiss	0.00
14	High Thickness -Very Low Resistivity - High Thickness -Very Low Resistivity - Dunite(a)	0.07	40	Very High Thickness -Low Resistivity -High Thickness -Low Resistivity -Charnockite	0.65
15	High Thickness -Very Low Resistivity - High Thickness -Very Low Resistivity - Fissile HornblendBiotite gneiss	1.15	41	Very High Thickness -Low Resistivity -High Thickness -Low Resistivity -Fissile HornblendBiotite gneiss	2.40
16	High Thickness -Very Low Resistivity - High Thickness -Very Low Resistivity - Syenite	0.07	42	Very High Thickness -Low Resistivity -High Thickness -Low Resistivity -Fuchsite Quartzite	0.05
17	High Thickness -Very Low Resistivity - High Thickness -Very Low Resistivity Dunite(a)	0.00	43	Very High Thickness -Low Resistivity -High Thickness -Very Low Resistivity - Charnockite	0.84
18	High Thickness -Very Low Resistivity - High Thickness -Very Low Resistivity Fissile HornblendBiotite gneiss	2.48	44	Very High Thickness -Low Resistivity -Very High Thickness -Low Resistivity - Charnockite	0.09
19	High Thickness -Very Low Resistivity - High Thickness -Very Low Resistivity Syenite	1.32	45	Very High Thickness -Low Resistivity -Very High Thickness -Low Resistivity -Fissile HornblendBiotite gneiss	0.39
20	High Thickness -Very Low Resistivity - Medium Thickness -Low Resistivity - Charnockite	0.14	46	Very High Thickness -Very Low Resistivity - High Thickness -Low Resistivity -Fissile HornblendBiotite gneiss	0.04
21	High Thickness -Very Low Resistivity - Medium Thickness -Low Resistivity - Dunite(a)	0.01	47	Very High Thickness -Very Low Resistivity - High Thickness -Low Resistivity -Fissile HornblendBiotite gneiss	0.01
22	High Thickness -Very Low Resistivity - Medium Thickness -Low Resistivity - Fissile HornblendBiotite gneiss	4.31	48	Very High Thickness -Very Low Resistivity - High Thickness -Very Low Resistivity - Charnockite	0.10
23	High Thickness -Very Low Resistivity - Medium Thickness -Low Resistivity - Syenite	1.62	49	Very High Thickness -Very Low Resistivity - High Thickness -Very Low Resistivity - Fissile HornblendBiotite gneiss	0.46
24	High Thickness -Very Low Resistivity - Medium Thickness -Very Low Resistivity -Dunite(a)	0.05	50	Very High Thickness -Very Low Resistivity - Very High Thickness -Very Low Resistivity - Dunite(a)	0.02
25	High Thickness -Very Low Resistivity - Medium Thickness -Very Low Resistivity -Fissile HornblendBiotite gneiss	1.61	51	Very High Thickness -Very Low Resistivity - Very High Thickness -Very Low Resistivity - Fissile HornblendBiotite gneiss	0.29
26	High Thickness -Very Low Resistivity - Medium Thickness -Very Low Resistivity -Syenite	0.17	**Total Area**		185.17

Fig.3 Spatial Distribution Map of First Fracture Zone Resistivity types and its area of the Sarabanga Sub-Basin

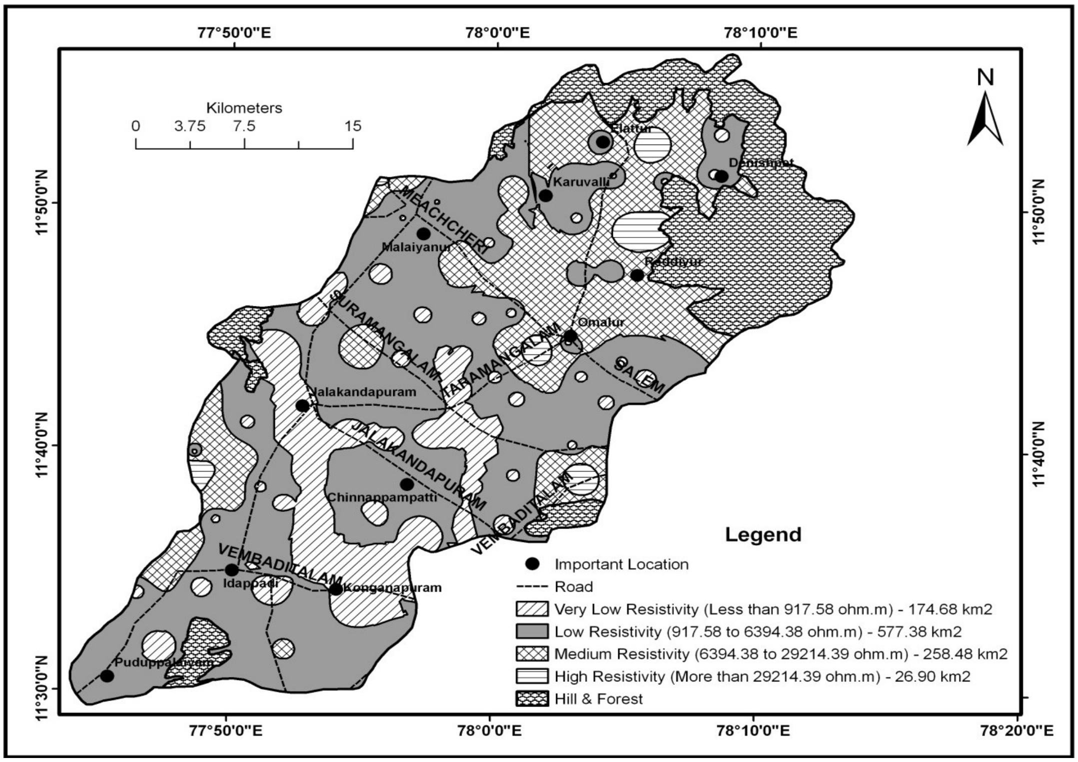


Fig.4 Spatial Distribution Map of First Fracture Zone Thickness types and its area of the Sarabanga Sub-Basin

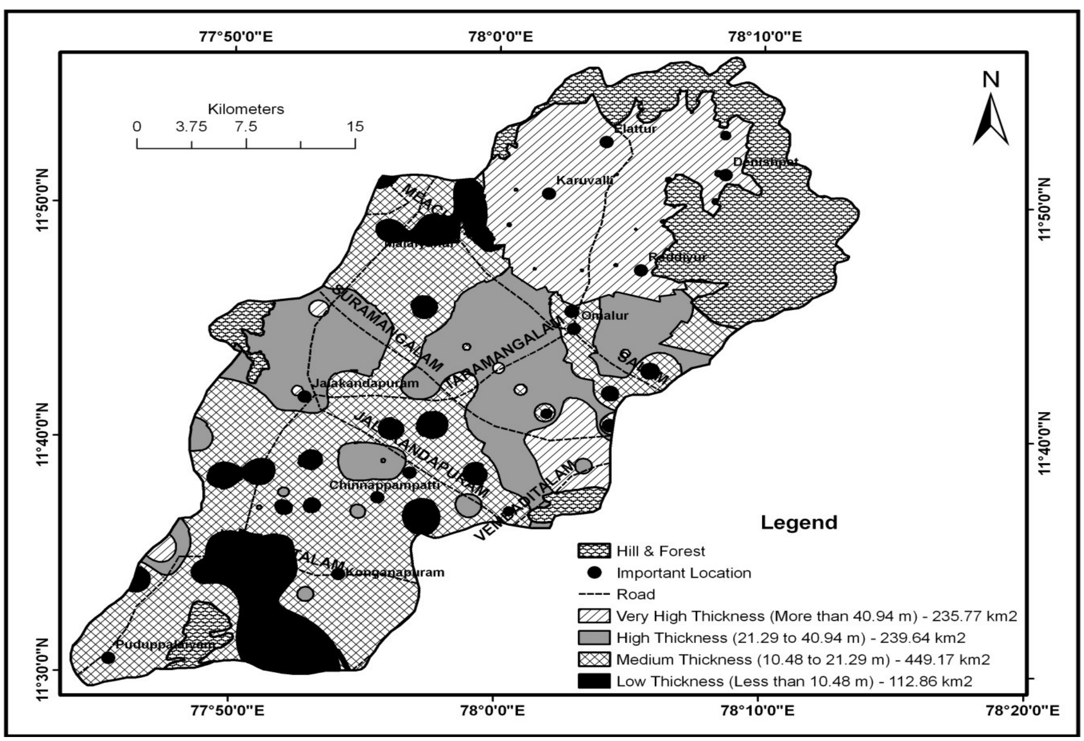


Fig.5 Spatial Distribution Map of First Fracture Zone Resistivity types and its area of the Sarabanga Sub-Basin

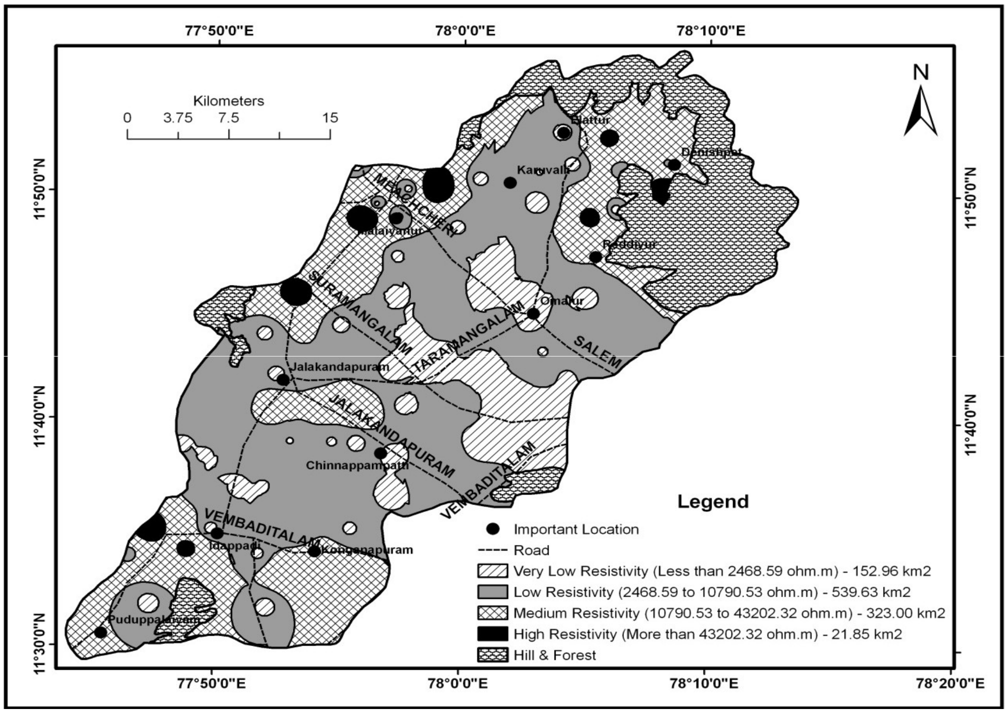


Fig.6 Spatial Distribution Map of Second Fracture Zone Thickness types and its area of the Sarabanga Sub-Basin

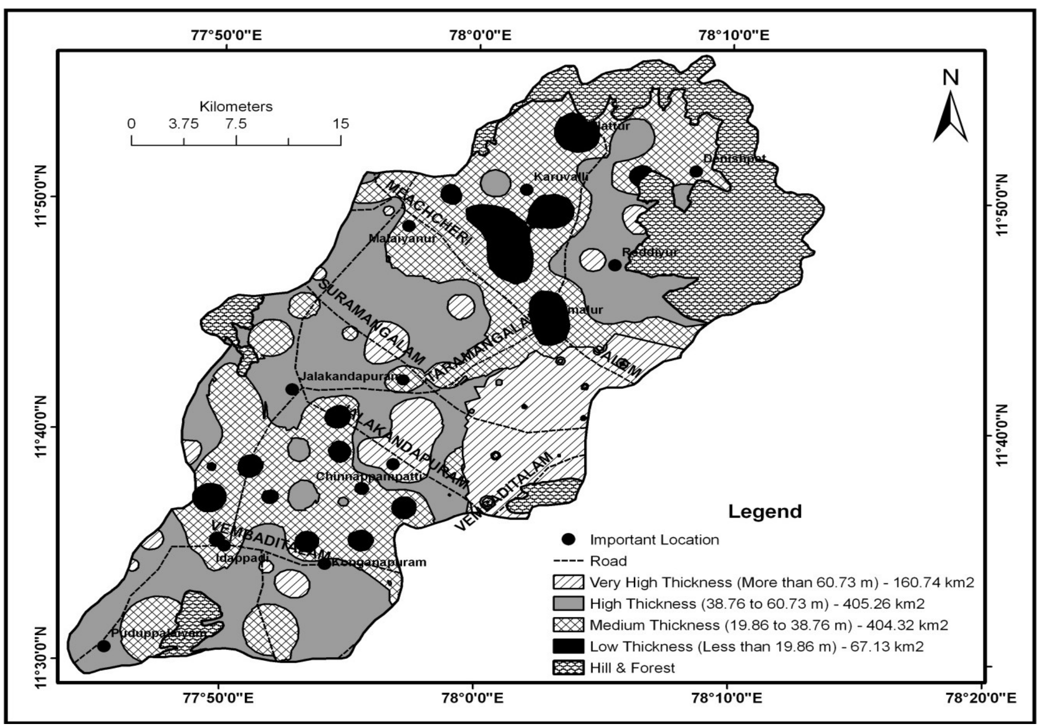


Fig.7 Spatial DistributionIntegration map of first layer resistivity and first layer thickness types and its area of the Sarabanga Sub-Basin

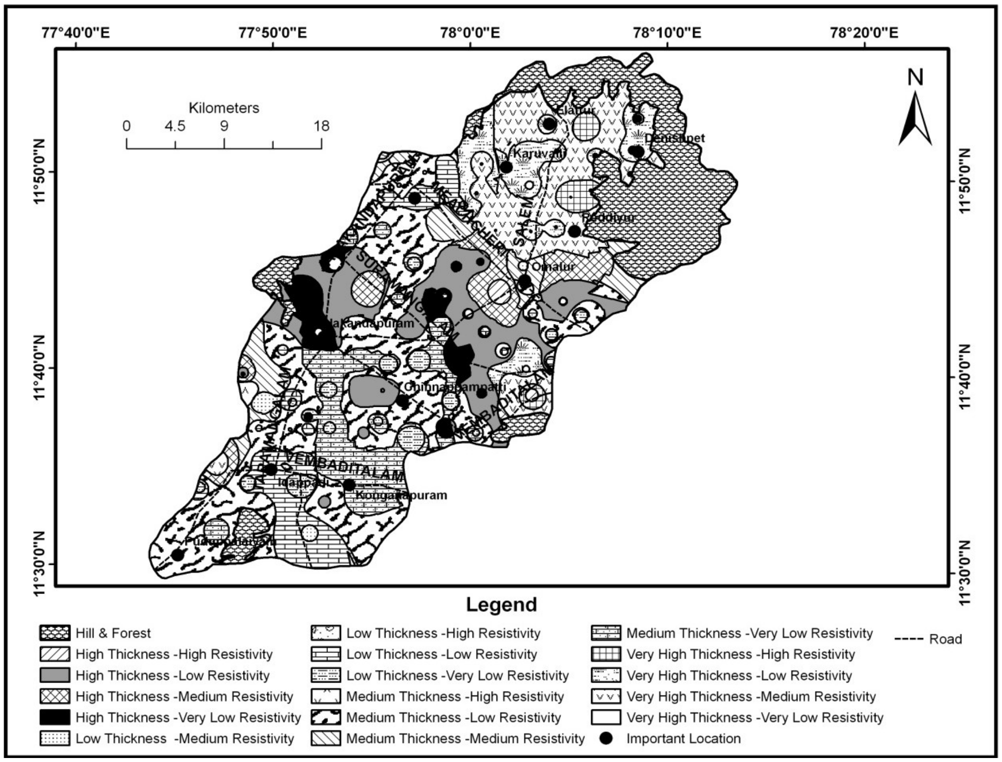


Fig.8 Spatial DistributionIntegration map second layer resistivity and second layer thickness types and its area of the Sarabanga Sub-Basin

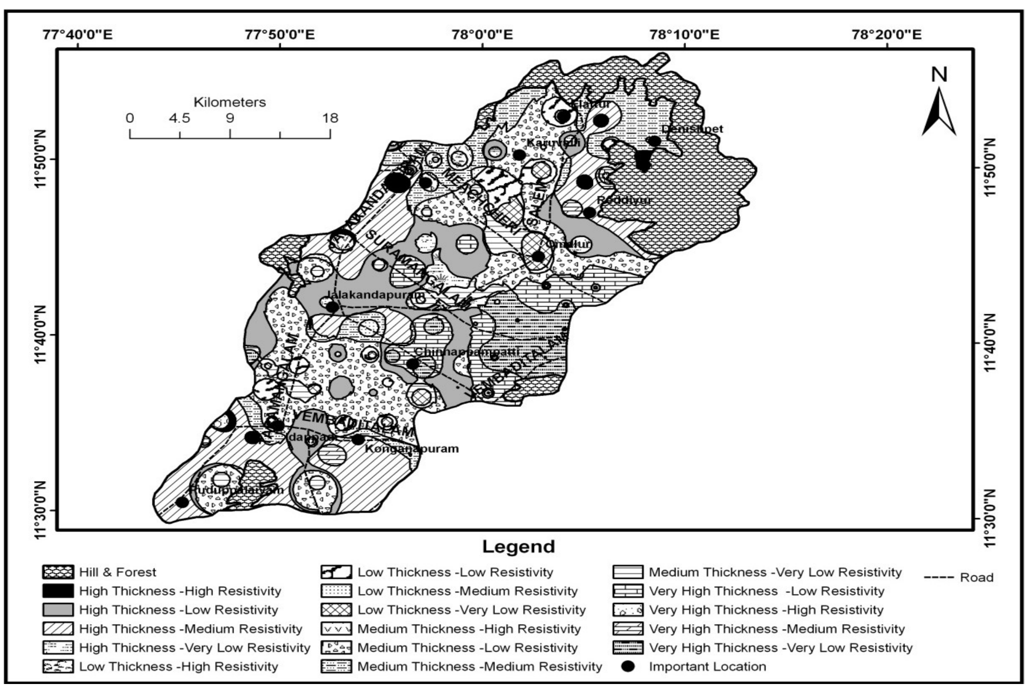
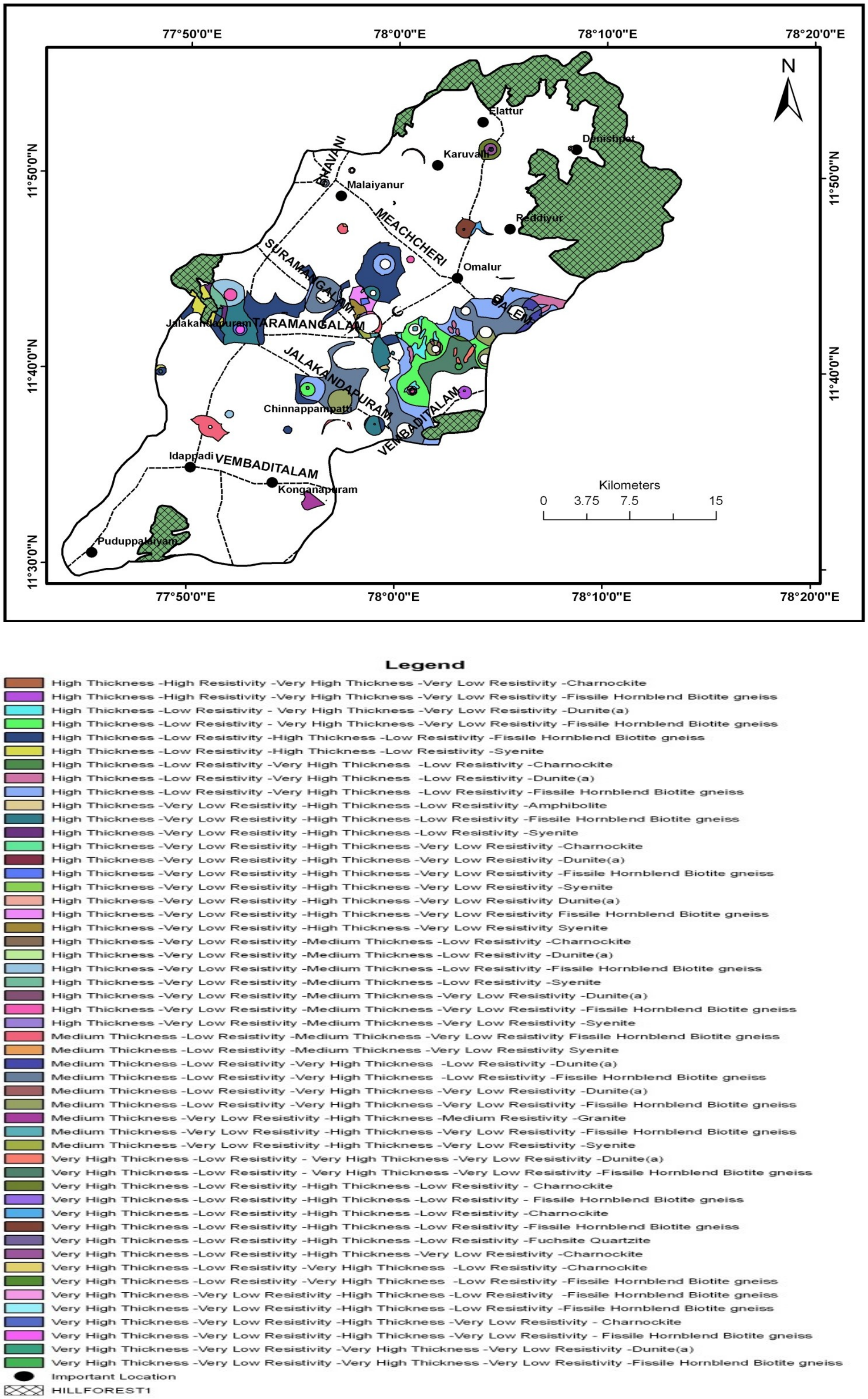


Fig.9 Integration results map of first and second layers resistivity and second layer thickness overlay with geology and its output types area of the Sarabanga Sub-Basin



fracture zone second layer thickness map and the output map-2 was derived (Fig.8). The output map 2 and its results are given in the Table 9. The 2VLR&2VHT combination covers an area of 0.072 km^2. This is the very smallest combination among this group. This combination shows deeper depth of water level and high thickness of water bearing formation. This area is recommended for the construction of tube well.

The output map of 1st layer was superposed over the output map of 2nd layer giving a final output map 3(first and second layers resistivity and thickness integration map). This final output map 3 was superposed over geology map giving the resultant output map 4 showing 51best combinations for groundwater exploration.

The combinations like (Fig.9) very high thickness-very low resistivity-very high thickness-very low resistivity in fissile hornblende biotite gneiss 0.29 km^2, very high thickness-very low resistivity-very high thickness-very low resistivity in dunite(a) 0.02 km^2 and very high thickness-very low resistivity-high thickness-very low resistivity in fissile hornblende biotite gneiss0.46 km^2 are high groundwater potential zones which are also verified in the field. This combination in alluvium is noticed in the foot hill areas and river course and is recommended for the construction of dug wells or tube wells. The overlay analysis combinations Next category of groundwater favorable zones is given in the Table 10.

The final map gives 351 combinations (Lithology along with first and second layer resistivity and thickness). The very high thickness-very low resistivity-very high thickness-very low resistivity combination is good and found in the fissile hornblendebiotite gneiss region, very high thickness-very low resistivity-very high thickness-very low resistivity in dunite and very high thickness-very low resistivity-high thickness-very low resistivity in fissile hornblendebiotite gneiss covering an area of 0.29 km^2, 0.02 km^2 and 0.46 km^2. Field verification of surrounding area bore wells and dug wells are good groundwater potential zones. Next, a very high thickness -very low resistivity -high thickness -low resistivity -fissile hornblendebiotite gneiss and very high thickness -low resistivity -very high thickness-low resistivity -fissile hornblendebiotite gneiss covering areas of 0.05 km^2& 0.39 km^2respectively are also good for groundwater potential. These combinations are the best for constructing dug wells and bore wells.

Acknowledgement

The authors are thankful to the University Grand Commission (UGC) Division, Government of India, New Delhi for providing financial support for sanction the "WATER GIS" Major Research Project vide letter Reference. F.No.40-301/2011 (SR) dated 30.06.2011.

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