Integration of Thematic Maps Through GIS for Identification of Groundwater Potential zones

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Abstract

The remote sensing and geo-electrical data combined with Geographical Information System (GIS) technique has proved to be very efficient in assessing the groundwater potential of any area. In the present paper, IRS 1C, LISS III data, geo-electrical data and litho-log data have been used to identify the groundwater potential zones by integrating various thematic maps generated on 1: 50,000 scale. These maps are integrated after assigning weight factors to the identified features in each thematic map depending upon their infiltration characteristics and the groundwater potential zones in Nagar block of Mirzapur district , Uttar Pradesh are demarcated. The area of investigation has been classified into eight categories of groundwater potentiality. The present results show that integration of all attributes provide more accurate results in identification of groundwater potential zones.

Introduction

The remote sensing & geoelectrical technologies and GIS tools have opened new paths in water resources studies. Temporal data from remote sensing enables identification of groundwater aquifers and assessment of their changes, subsurface information inferred from geo-electrical survey enables identification of vertical & horizontal aquifer system, whereas, geographical information system (GIS) enables integration of multi-thematic data. The concept of integrated remote sensing and GIS has proved to be an efficient tool in groundwater studies (Krishnamurthy et al., 1996; Saraf and Chaudhary, l998; Khan & Mohrana, 2002). Inclusion of subsurface information inferred from geoelectrical survey can give more realistic picture of groundwater potentiality of an area (Amaresh Kumar Singh et al, 2000). Keeping this in view, an attempt is made to identify groundwater potential using integrated approach of remote sensing, geoelectrical and GIS techniques in Nagar block of Mirzapur district, Uttar Pradesh.

Study Area

The study area, is nagar block of Mirzapur district of Uttar Pradesh, India bounded by longitudes $82^0$25' to 82^0 41'30"E and latitudes $25^0$00' to $25^0$14'N, (Fig. 1) covered in Survey of India toposheet no. 63K/12 & K/8. The total geographical area is 255.7 sq.km. The holy river Ganga forms the northern boundary of the study area. Delhi-Howrah rail rout and National Highway no. 7 passes through the area, which connect the area from other part of the country.

Geologically, the northern part of study area covered by flood and alluvial plain (Ganga plain) and rest parts of the area comprises of upper Vindhyan formations consisting of sandstone, quartzite and shale (CGWB, 1985). Vindhyan formation is overlain by quaternary alluvium, which was deposited on the eroded basement.

Physiographically, the area is mainly flat and gently undulating terrain except in few parts. Groundwater usually occurs in unconfined to confined condition at depth. The area is fed by southwest monsoon rainfall, which starts in last week of June and extends until the end of September. The average annual rainfall is about 1045 mm.

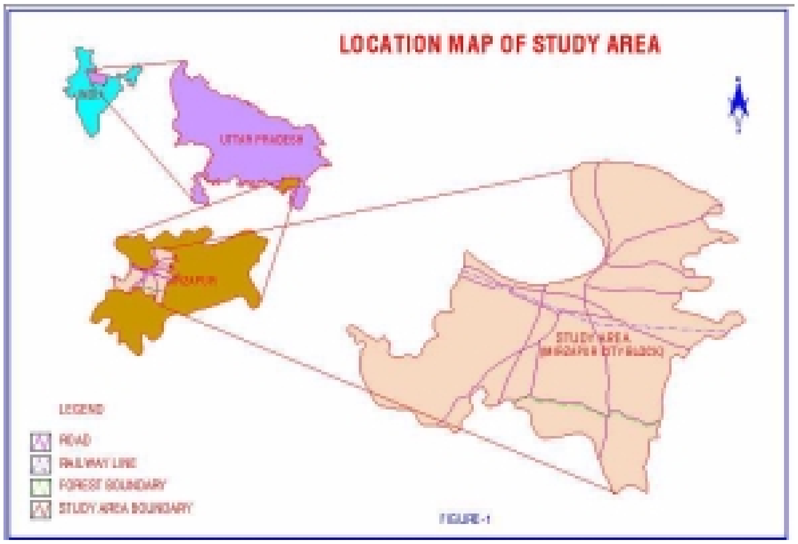


FIGURE-1

Data Used

- The three types of data sets have been used for the study:
- Remotely sensed data, viz. IRS 1C LISS III, geocoded of scale 1:50,000.
- The survey of India toposheet 63K/12 & K/8 of scale 1:50,000.
- Field data, viz. depth to water level (pre & post monsoon) data, geo-electrical sounding data and drilling data.

Methodology

1. In order to demarcate the groundwater potential zones of study area different thematic maps on 1:50,000 scale were prepared from remote sensing data, topographic maps, depth to the water level data and resistivity data.
2. The thematic maps on hydrogeomorphology and lineaments were prepared using IRS 1C LISS-III data by visual interpretation on 1:50,000 scale.
3. Drainage map was prepared from SOI toposheet & satellite data.
4. Contour map and spot elevation map were prepared from SOI toposheets.
5. All primary input maps (hydrogeomorphology, lineament, contour & spot elevation, drainage, well location and geo-electrical sounding location) were digitized in Arc/Info, GIS software package and slope map was prepared from digital elevation data.
6. Depth to water level (pre & post monsoon) and annual water level fluctuation maps prepared through GIS.
7. Interpretation of geo-electrical soundings data of 77 sites.
8. Correlation of geoelectrical parameters of drilled sites with lithology.
9. Based on above co-relation lithology was inferred at other sounding locations for identifying horizontal and vertical variation in subsurface lithology and estimating depth to the hard rock.
10. Using inferred lithology and thickness from geoelectrical parameters at respective locations; aquifer layer thickness and overburden thickness maps were prepared through GIS.
11. The different polygons in the thematic layers were labeled separately and then they were registered. In the final thematic layer initially each one of the polygons were qualitatively visualized into one of the categories like (i) excellent (ii) very good (iii) good (iv) moderate and (v) poor in terms of their importance with respect to groundwater occurrence and suitable weights have been assigned.
12. Finally thematic layers were converted in to grid with related item weight and then integrated and analysed, using weighted aggregation method. The grids in the integrated layer were grouped into different ground water potential zones by a suitable logical reasoning and conditioning. The final ground

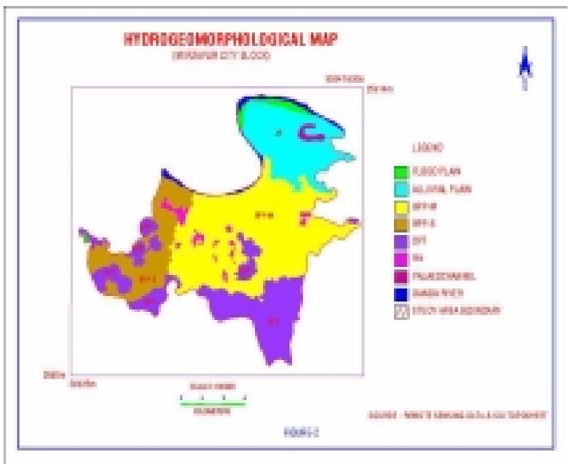
water potential zone map thus generated was verified with the yield data to ascertain the validity of the model developed.

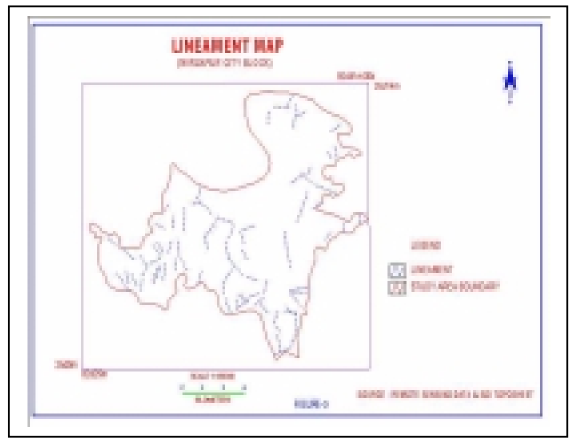
Analysis and Discussion

Generation of Thematic Layers

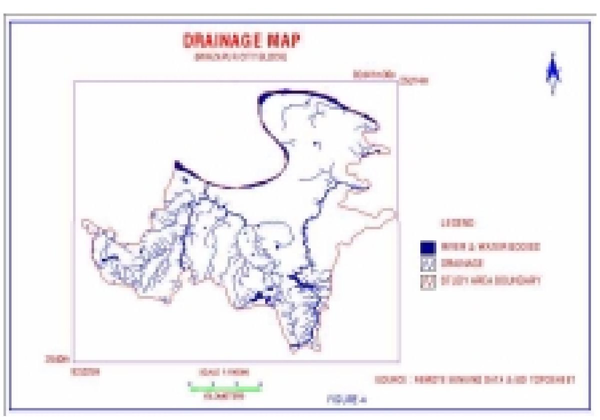
Hydrogeomorphology, Lineament & Drainage:

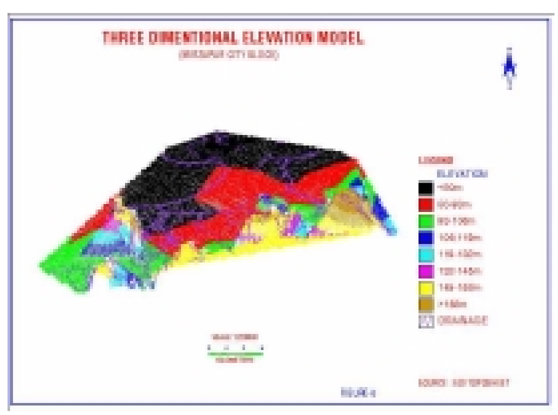
Hydrogeomorphological map was prepared from remotely sensed data. On the basis of specific relief and characteristic nature, the hydrogeomorphological features, present in study area were classified into (i) flood plain, (ii) alluvial plain, (iii) palaeochannels, (iv) Moderate weathered buried Pediplain (BPP-M), (v) Shallow weathered buried Pediplain (BPP-S), (vi) Ravines (RA) and (vii) Dissected plateau (DPT) (Fig. 2).



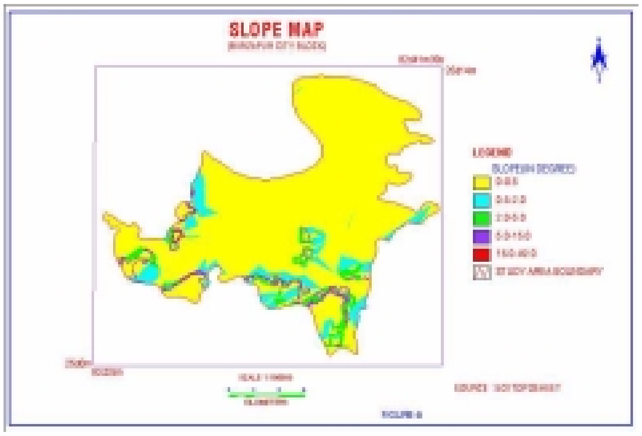


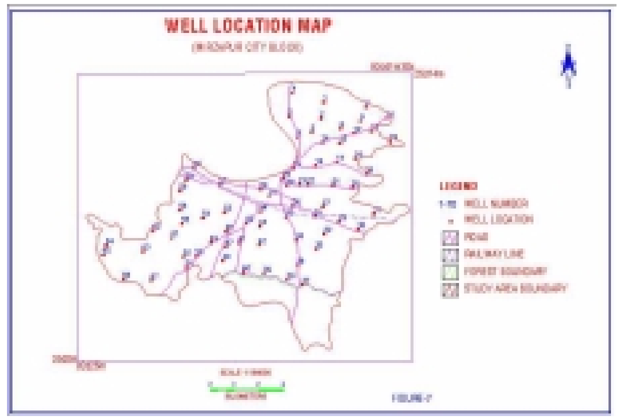
Structural lineaments delineated from satellite image were cross- verified in the field. They are NE-SW, NW-SE, ENE-WSW, NNE-SSW, E-W, N-S, NNW-SSE (Fig. 3).
Drainage in the study area is dendritic pattern. The main river Ganga is flowing in the northern end of the study area. Khajuri nala and Ojhala nala are main drains, which are merging in Ganga River (Fig. 4).





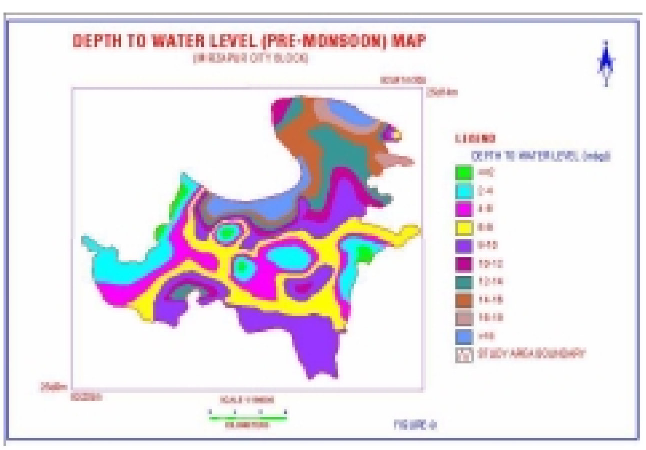
Topography : Topographic information has been collected from SOI toposheet at 1:50,000 scale and a TIN has been generated from elevation contour at 20m intervals and spot elevations. Most of the area shows more or less flat topography excepting a few parts. The maximum and minimum elevations are 165 m and 67 m respectively. A three dimensional perspective model of the study area has been prepared using TIN to understand the role of surface drainage pattern and their topographic locations in controlling groundwater conditions (Fig. 5). Slope map in degree have been prepared from TIN and the same was verified by superimposing drainage (Fig. 6). Slope degree map was classified. Most of the study area is categorized as 0 to.5 degree class. But some parts of western and southern areas fall 0.5 to 2 degree. Slope 2 to 5 and 5 to 15 degree are also appeared due to presence of dissected plateaus. Maximum slope 49 degree founds in the study area.

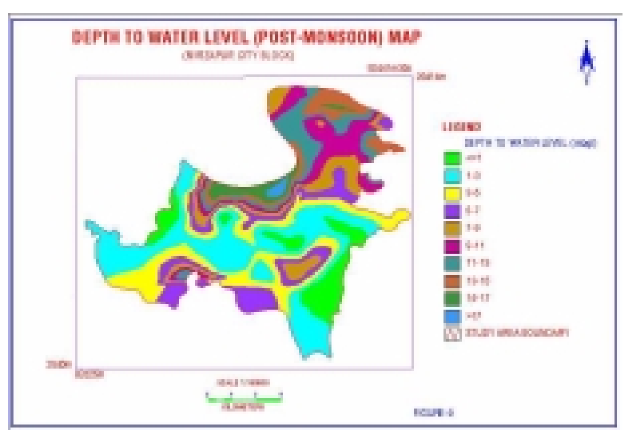




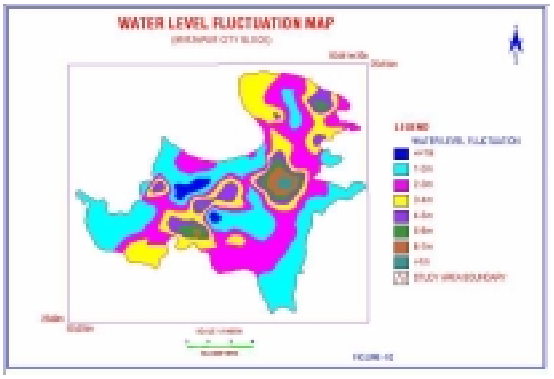
Depth to water level : Groundwater is developed in the study area through dugwell, dug-cum borewells, borewells to meet domestic and irrigation needs. Depth to water level data of pre-monsoon and post monsoon period were collected from 70 dugwells in the study area (Fig. 7).

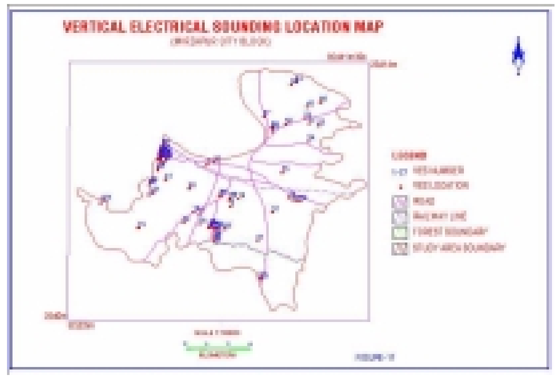
Depth to water level (pre & post monsoon) maps of year 2001 have been prepared by using water level data of these dugwells (Fig. 8 & Fig. 9). The review of the pre-monsoon map shows that depth to water level is quite variable, ranging between 2 to 20 mbgl. Generally the depth to water level ranges 4 to 10 mbgl over greater part of the study area. The trend of depth to water level in post monsoon is similar of pre-monsoon. During post monsoon period depth to water level ranges between 1.5 to 19 mbgl. Pre and post monsoon water level maps generate a DEM of ground water table, an imaginary groundwater surface which depicts the spatial pattern of the groundwater table.



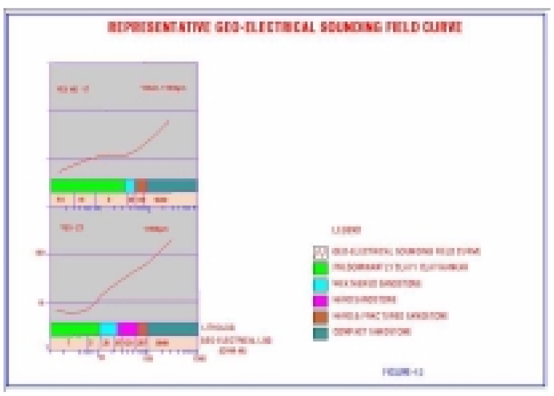


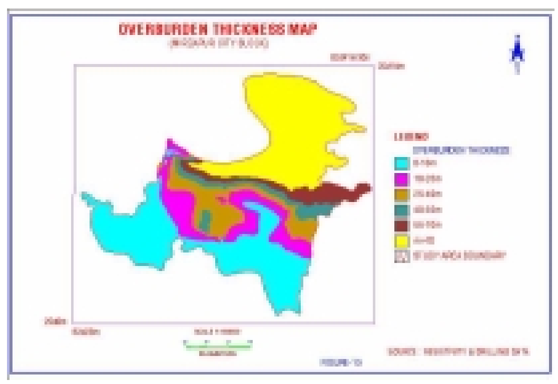
Seasonal fluctuation of groundwater table is directly related to groundwater recharge. To study the water level rise from pre to post monsoon, annual water level fluctuation map has been prepared using above dugwell data (Fig. 10). In most of the study area, the water level fluctuation varies from 2 to 4m. The highest fluctuation 7.5m is observed at Devpura village.





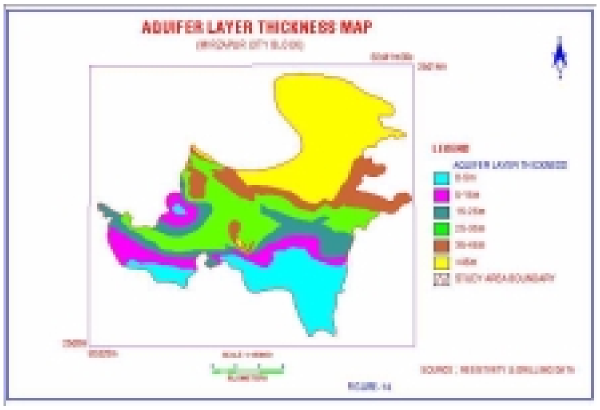
Subsurface Lithology : Surface electrical resistivity surveys were conducted at 77 sites to get subsurface lithological information, identification of horizontal and vertical disposition of aquifer system and also for pin pointing of suitable sites for drilling. The geoelectrical layer parameters of drilled sites were correlated with the lithological data to infer the subsurface lithology at other sounding locations. Geoelectrical sounding locations and details of the layer parameters of representative sites are shown in Fig.11 and Fig.12.

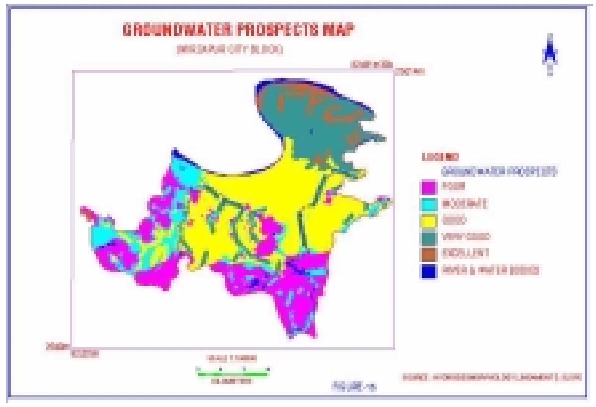




On the basis of above, following subsurface lithology has been inferred. In most of the cases, the first layer is predominantly clay / clay with kankar and is characterised by resistivity ranges of 5 ohm-m to 30 ohm-m depending upon the proportion of constituents, its thickness varies between 2 m to 43 m. The second layer is weathered and / or hard sandstone which is non-water bearing, poorly fractured and is characterized by resistivity range of 30 ohm-m to 80 ohm-m, its thickness varies between 6 m to 57 m. The third layer with resistivity ranges from 80 ohm-m to 300 ohm-m indicating the presence of hard and fractured sandstone, which is water bearing and forms the aquifer zone in the area. The thickness in city block of Mirzapur district U.P of aquifer zone varies between 0 m to 47 m. Depth to the hard rock having very high resistivity in general, (compact & massive, occ. fractured sandstone) varies from 11 m to 105 m below ground surface. But in the area of Ganga plain (northern part of study area), second layer is fine sand / sandy clay (resistivity ranges 20 – 30 ohm-m), third layer is medium sand (resistivity ranges 30 – 50 ohm-m) and forth layer is course sand (resistivity ranges 50 – 100 ohm-m). The main aquifer in this part of study area is medium and medium to course sand and its thickness varies from 25m to 60m.

From the above-inferred lithology & their thickness, overburden thickness and aquifer layer thickness maps were prepared (Fig. 13 and Fig. 14).





Ntegration of Thematic Layers and Modelling Through GIS

As discussed in earlier sections, each one of the classes in thematic layers was qualitatively placed into one of the following categories, viz. (i) excellent, (ii) very good, (iii) good, (iv) moderate and(v) poor, depending on their ground water potential level. After understanding their behavior with respect to groundwater control, the different classes were given with suitable weights, according to their importance with respect to other classes in the same thematic layer. The weights assigned to different classes of all the thematic layers are given in Table 1.

TABLE – 1

WEIGHTAGE OF DIFFERENT PARAMETER FOR GROUNDWATER PROSPECTS

Sl.No.	Criteria	Classes	Weight
1.	Hydrogeomorphology	Flood Plain, Palaeochannel	5
		Alluvial Plain	4
		BPP-M	3
		BPP-S	2
		DPT & RA	1
2.	Slope (degree)	0 – 0.5	5
		0.6 – 2.0	4
		2.1 – 5.0	3
		5.1 – 15.0	2
		> 15.0	1
3.	Lineament (around 200 m)	Present	2
		Absent	1
4.	Overburden thickness	> 55 m	5
		40 – 55 m	4
		25 – 40 m	3
		10 – 25.0 m	2
		< 10.0 m	1
5.	Aquifer thickness	> 35 m	5
		25.0 - 35.0 m	4
		15.0 – 25.0 m	3
		5.0 – 15.0 m	2
		< 5.0 m	1

The thematic layers which include hydrogeomorphology, lineament, slope, overburden thickness and aquifer thickness were converted into grid with related item weight and integrated with one another through GIS (Arc / Info grid environment). As per this analysis, the total weights of the final integrated grids were derived as sum of the weights assigned to the different layers based on suitability (ESRI 1997).

TABLE - 2

INTEGRATED GROUNDWATER CATEGORIES FOR GROUNDWATER PROSPECTS WITH LOWER AND UPPER WEIGHT VALUE			
Sl. No.	**Groundwater Category**	**Lower & Upper weight Value**	**Area (Sq.km)**
1.	Excellent	11 –12	16.18
2.	Very good	10 - 10	51.92
3.	Good	9 – 9	93.26
4.	Moderate	8 – 8	33.02
5.	Poor	> 7	61.35

In the present study, groundwater prospects map has been generated by integration of hydrogeomorphology, lineament, and slope (Fig. 15). The delineation of groundwater prospects zones was made by grouping the grids of the integrated layers into different prospect zones, excellent, very good, good, moderate and poor. Table 2 gives the way in which upper and lower limits of the weights derived for ground water prospect of the areas. This provides a broad idea about the groundwater potentiality of the study area. Groundwater potential map generated by integration of aquifer thickness, with hydrogeomorphology, lineament, drainage, overburden thickness and slope gives the more realistic picture. The delineation of groundwater potential zones was made by grouping the grids of final integrated layer into different potential zones, excellent, very good to excellent, very good, good to very good, good, moderate to good, moderate and poor. Table 3 gives the way in which the upper and lower limits of the weights derived for demarcation of the ground water potential areas. By utilizing the above-discussed model a map showing different groundwater potential zone was prepared (Fig. 16).

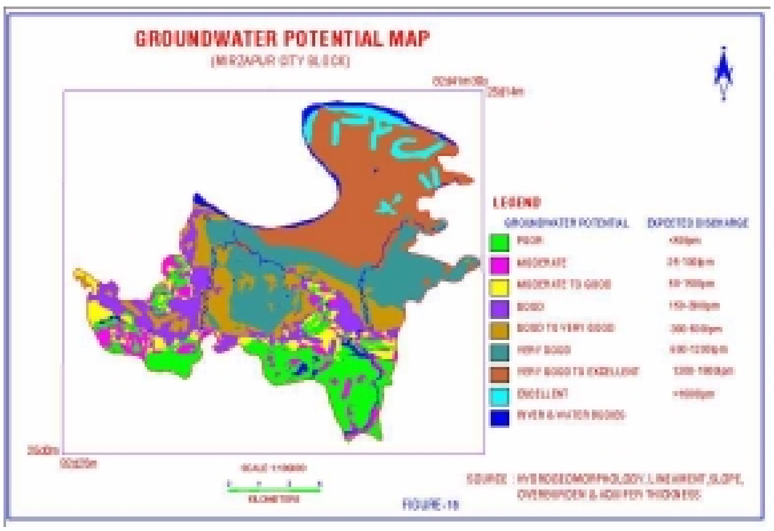


TABLE – 3

INTEGRATED GROUNDWATER CATEGORIES FOR GROUNDWATER POTENTIAL WITH LOWER AND UPPER WEIGHT VALUE			
Sl. No.	**Groundwater Category**	**Lower & Upper weight Value**	**Area (Sq.km)**
1.	Excellent	21 – 22	14.86
2.	Very good to excellent	19 – 20	65.48
3.	Very good	16 – 18	51.56
4.	Good to very good	14 – 15	29.29
5.	Good	12 – 13	26.25

6.	Moderate to good	11 – 11	13.46
7.	Moderate	10 - 10	15.23
8.	Poor	> 9	39.6

TABLE - 4

VALIDATION OF MODEL WITH ACTUAL BOREWELL YIELD DATA

Sl. No	Category of Ground water prospect	Category of Groundwater potential	Site location No.	Village	Actual yield (in lpm)
1.	Excellent	Excellent	43	Khutaha	1820
2.	Excellent	Excellent	45	Gursandi	1820
3.	Very good	Very good to excellent	50	Masari	1592
4.	Good	Very good to excellent	10	Mirzapur city	1365
5.	Good	Very good to excellent	54	Kurkutia	1668
6.	Good	Very good to excellent	55	Hariharpur	1510
7.	Moderate	Very good	56	Amghat	758
8.	Good	Very good	59	Bhewarkarman pur	758
9.	Good	Very good	5	Amoi	793
10.	Good	Very good	19	Sirsigaharwar	793
11.	Moderate	Very good	8	Bhawa Mahabir	1008
12.	Poor	Very good	22	Tulsitalia	793
13.	Good	Good to very good	31	Lohandi Kalan	1160
14.	Moderate	Good to very good	41	Chintamanpur	793
15.	Good	Good to very good	77	Birmauha	505
16.	Moderate	Good	72	Mahuwai Kalan	190
17.	Poor	Good	66	Tulsitalia	505
18.	Good	Moderate to good	61	Barkachha	130
19.	Poor	Moderate	71	Duhauva	80
20.	Poor	Poor	47	Amrawati	24

Model Evaluation and Results

The validity of the model developed was checked against the bore well yield data, which reflects the actual groundwater potential. Table 4 shows that groundwater potential zones prepared through this model are in good agreement with yield data. Yield of most drilled sites covered in this model have ranges from 1200 to 1800 lpm in excellent and very good to excellent zone, 600 to 1200 lpm in very good zone, 300 to 600 lpm in good to very good zone, 150 to 300 lpm in good zone, 50 to 150 lpm in moderate to good zone, 25 to 100 lpm in moderate zone and less than 50 lpm in poor zone.

Conclusion

In order to delineate the groundwater potential zones, in general, different thematic layers viz: hydrogeomorphology, lineaments and slope have used to be integrated without consider subsurface lithology. This provides a broad idea about the groundwater prospect of the area. Presently groundwater potential zones have been demarcated by integration of aquifer thickness & overburden thickness derived from surface electrical resistivity survey and drilling data with above thematic layers, using a model developed through GIS technique.
The groundwater potential zones map generated through this model was verified with the yield data to ascertain the validity of the model developed and found that it is in agreement with the bore wells yield data. This illustrates that the approach outlined has merits and can be successfully used elsewhere with appropriate modifications. The above study has demonstrated the capabilities of using remote sensing, geoelectrical data and Geographical Information System for demarcation of different ground water potential zones, especially in diverse geological setup. This gives more realistic groundwater potential map of an area, which may be used for any groundwater development and management programme.

Acknowledgement

The authors are gratefully to Director, RSAC-UP, Lucknow for his kind permission to undertake this study.

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