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Mapping Groundwater Potential Zones in Meja Block, Allahabad District Using Remote Sensing and GIS Techniques

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ABSTRACT

Remote Sensing (RS) and Geographic Information System (GIS) has become one of the leading tool for managing water resources. It allows manipulation and analysis of individual thematic layer of spatial data. It is used for analyzing and modelling the interrelationship between the layers. This article mainly deals with the integrated approach of RS and GIS techniques to delineate groundwater potential zones in a sedimentary area of Meja block of Allahabad District. The satellite image (LANDSAT-VIII, February 2016) and DEM have been used for the preparation of groundwater prospective map by integrating drainage-density, landuse, geomorphology, and groundwater level contour maps. The results revealed that about 32.21% of the area have excellent groundwater potential, 25.62% as good groundwater potential zone, 20.41% have moderate groundwater potential, 12.92% area comes under poor potential zone and only 8.85% area have very poor groundwater potential. Assessment of the groundwater potential map showed that the distribution is more or less a reflection of drainage density, geomorphology, depth to water level contours, land use maps and in addition is well correlated with the bore well yield data. The groundwater prospective map could be helpful in better planning and management of groundwater resources especially in the hard rock area.

Key words: *Remote Sensing, GIS, Groundwater prospect map, Sedimentary area, Allahabad district, India.*

INTRODUCTION

In recent times, Remote Sensing (RS) and Geographic Information System (GIS) are proving to be a cost-effective technique in the identification of groundwater potential zones[1]. Javed and Hussain[1] and Narendra *et al.*[2] have used remote sensing and GIS techniques for delineation of groundwater potential zones Krishnamurthy *et al.*[3] demonstrated the capabilities of RS and GIS techniques for groundwater resource development in hard rock terrains, specifically for the demarcation of suitable sites for artificial recharge of groundwater aquifers.

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The occurrence and movement of groundwater in an area is governed by several factors such as topography, geological structures, drainage pattern, landuse, climatic conditions and interrelation of satellite data in conjunction with sufficient ground truth information makes it possible to identify and outline various features such as geological structure, geomorphic features and their hydraulic characters, that may serve as direct or indirect indicators of the presence of groundwater[4].Remote Sensing and GIS tool produces valuable data on geomorphology, geology, landuse and land cover, slope, lineament density, drainage density, etc. which helps to decipher groundwater recharge potential zones[5]. A set of weights for the different themes and their individual features were decided based on personal judgments considering their relative importance from the artificial recharge viewpoint[6]. Remote sensing and GIS has been widely used for the preparation of different types of thematic layers and integrating them for different purposes[7]. It has been increasingly used for recharge estimation, draft estimation, mapping of prospective zones, identification of over exploited and undeveloped areas and prioritization of areas for recharge structures[8]. This groundwater potential zone map is useful for future irrigation planning and for framing sustainable groundwater development plans[9]. In the present study an attempt has been made for mapping groundwater prospective zone using RS and GIS Techniques. The study was conducted in a selected area in the Meja block of Allahabad District, Uttar Pradesh state (India).

1.1 ABOUT THE STUDY AREA

The Study area is a part of Meja Block, Allahabad District, Uttar Pradesh, India and is confined between the latitudes 25° 06' 45" to 25° 11' 33"N and longitudes 81° 52' 30" to 82° 00' 00"E and fallen under the Survey of India toposheet no. 63 G/16. Total study area is around 62.84 km^2 (Fig. 1) and it is characterized by Active Flood Plains, Older Alluvial Plain and Rocky Surface (Denudational hills). The active flood plain is quite localized and confined only to the river system, whereas the older alluvial plain is characterized by depositional and erosional terraces found in patches along the active plain. The denudational hills found prominent in trans Yamuna area formed mainly of quartzite[10].

1.2 GEOLOGY AND HYDROGEOLOGY

Rocks exposed in the area belong to Dhandraul Formation of Kaimur group of Vindhyan Super group comprising medium to coarse grained, white to greyish and white sandstone in the study area. The rock exhibits sedimentary structure like ripple marks and cross bedding. The rocks were moderately jointed (Fig. 2). The deposition of horizontal and vertical joints has given the blocky nature to the rock. Also, the area exposes quaternary sediments represented by Banda Alluvium (Older Alluvium). The area is covered with thick overburden comprising yellowish brown variegated silty clay with ubiquitous kankar and coarse to fine sand and reddish-brown silt. Available drill hole data revealed that the thickness of overburden varies from 3.00 to 34.25 m,bgl in the study area and in Kohrar (21.30 m), Salaiya Khurd (1.65 m)[11]. Groundwater occurs in alluvium and in the weathered and joint sandstones in areas which are underlain by the hard rocks. Two broad hydrogeological units, namely, unconsolidated (Alluvium) and consolidated (hard rock) are the major components. The Alluvial formations occur in the Trans-Ganga and Doab region. Occurrence of consolidated formations is restricted primarily to Trans Yamuna tract. In the study area, the thickness of alluvium is more than 300 m with the discharge rates of 2000-3000 lpm[12].

I N D E X M A P

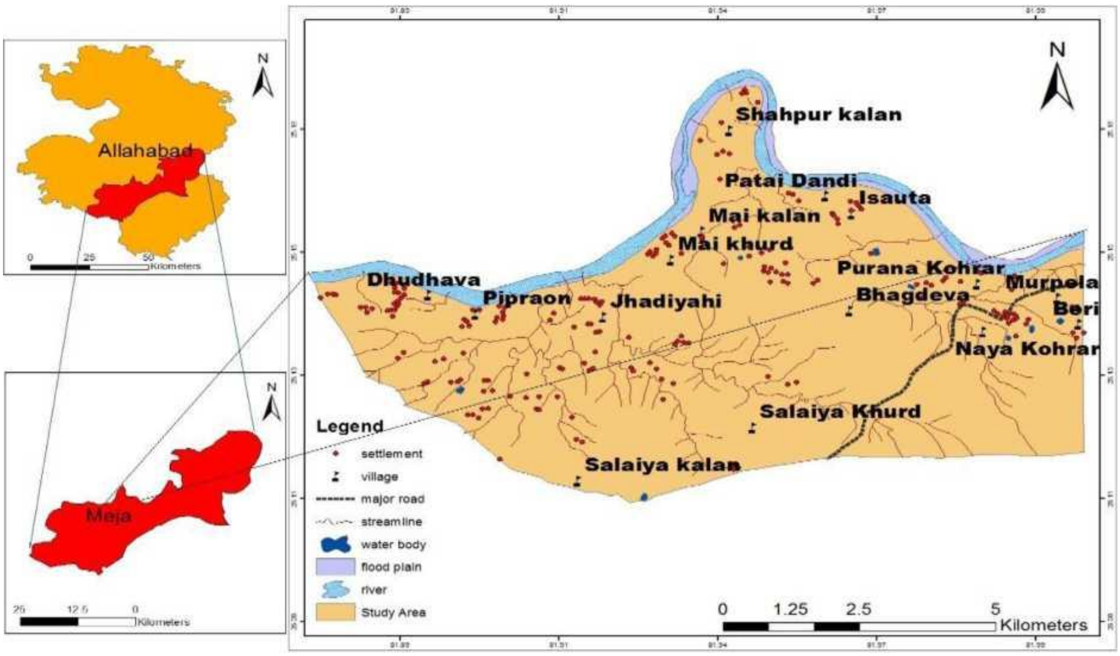


Fig. 1: Location map of the study area along with drainage system

Fig. 2: Blocky nature of rock due to disposition of horizontal and vertical joint sets

MATERIAL AND METHOD

With the help of Toposheets, DEM, Satellite Imagery and Geospatial tools the extraction of various hydrogeological thematic layers have been carried out. The four thematic layers viz., Drainage density, Landuse, Geomorphology and Groundwater level contours were considered in the mapping of groundwater potential zones for the study area. The inter-relationships between these influencing factors were weighted according to their response for groundwater occurrence. The weights were assigned to drainage density, landuse, geomorphology and groundwater level contours as 25, 20, 35 and 20, respectively, on the basis of literature reviewed[8] and[5]. as well as suitability factors responsible for groundwater recharge. Further ranks were assigned in decreasing order to the individual feature class within the thematic layers according to their contribution and potential to groundwater and its recharge[8] and[6]. Index values were used to reclassify the thematic layer which can be calculated as,

$$\text{Index} = \text{Rank} * \text{Weight} \quad (1)$$

A factor with a higher weight value shows larger impact and a factor with a lower weight value shows a smaller impact on groundwater potential. Finally, the computed index values which is the product of weightage and ranking is been used for quick assessment of groundwater potential zones[8] and[4]. Thematic layers formed and assigned weights for preparation of groundwater prospective map which is shown in Fig. 3.

2.1 DATA USED

1. LANDSAT-VIII digital data (February 2016)
2. Digital Elevation Model (DEM)
3. Meteorological data
4. Survey of India (SOI) Toposheet No. 63 G/16 and published geomorphological and geological map, Groundwater level data.

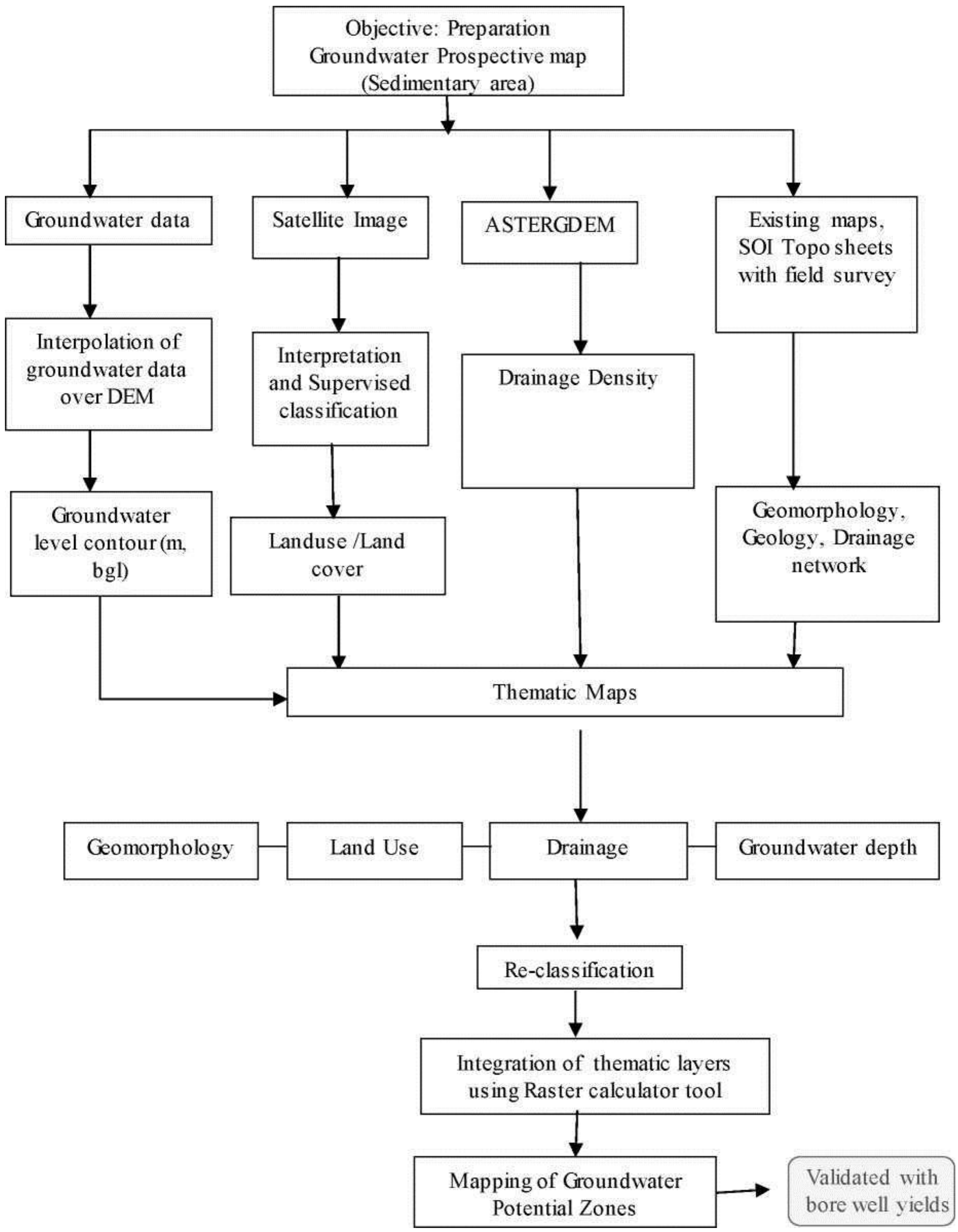


Fig. 3: Schematic flowchart for groundwater potential zone mapping

RESULTS AND DISCUSSION

3.1 DRAINAGE DENSITY

Drainage density is defined as the length of drainage per unit area. It was prepared in Arc GIS tool using DEM (Fig. 4). A high drainage density reflects highly dissected drainage basin with a relatively rapid hydrologic response to rainfall events while a low drainage density means a poorly drained basin with a slow hydrologic response[13]. Low drainage density value is more favorable for high groundwater potential and assigned higher weight[9]. (Table 1). The higher drainage density was observed in and around Dhudhanva, Pipraon, Jhadiyahi areas whereas low drainage density is observed in Patai Dandi and Salaiya Khurd.

Table 1: Weights and ranks assigned to drainage density

Sl. No.	Density Aspect	Drainage Density (in m/km^2)	Rank	Weight	Index
1	Low	0-2	3	25	75
2	Medium	2-4	2		50
3	High	4-6	1		25

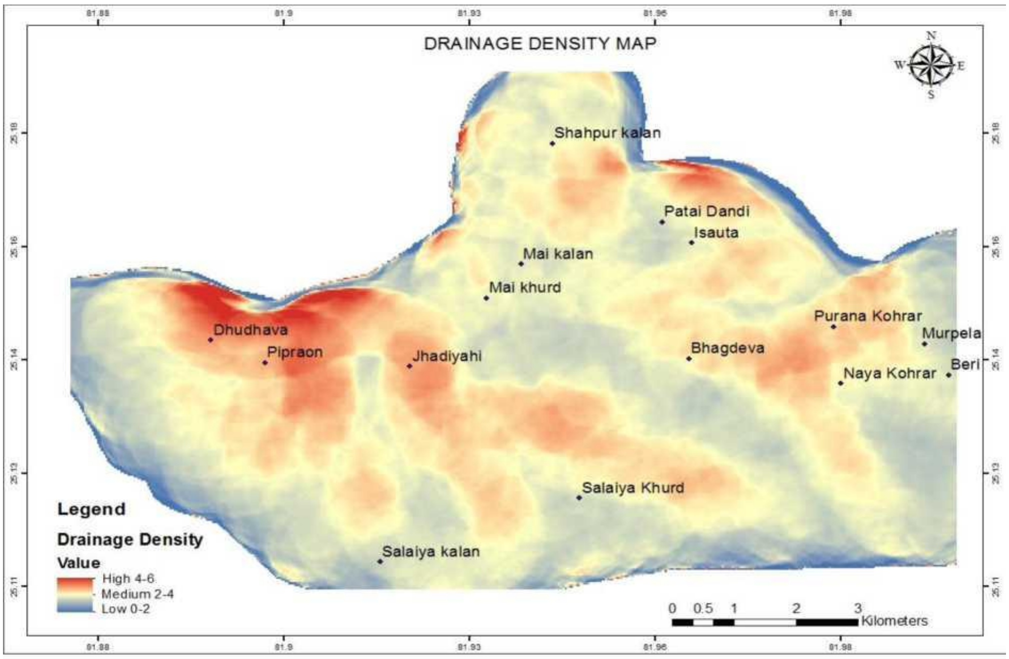


Fig.4. Drainage density map of the study area

3.2 LANDUSE

Landuse map was prepared by using satellite imagery of the area (dated: 10-02-2016). The map was processed by using a supervised classification technique in ERDAS Imagine Software. In supervised classification, homogeneous pixels were grouped together in known landuse classes. The various landuse classes (Fig. 5) were identified using GPS points, Toposheet and Google Earth. Landuse map was assigned 20% weight. The landuse of study area was grouped into water bodies, agriculture land, forest, barren land, loose soil, consolidated soil, rocky terrain and settlement. Higher weightage value was assigned for the water bodies and lowest value to the rocky terrain (Table 2). From the landuse map, it was found that rocky terrain covers about 17.87 km^2 which is the highest followed by settlement with 14.30 km^2. The other landuse classes i.e., barren land, forest, consolidated soil, loose soil, agriculture land and water bodies covers 7.89 km^2, 7.15 km^2, 4.97 km^2, 3.93 km^2, 3.83 km^2 and 2.9 km^2, respectively.

Table 2: Weights and ranks assigned to land uses

	Weightage and ranks assigned to Landuse				
Sl.No.	Class Name	Rank	Weight	Index	Area (Sq.km)
1	Water bodies	8	20	160	2.9
2	Agriculture Land	7		140	3.83
3	Forest	5		100	7.15
4	Barren Land	6		120	7.89
5	Loose soil	3		60	3.93
6	Consolidated Soil	4		80	4.97
7	Settlement	2		40	14.3
8	Rocky Terrain	1		20	17.87

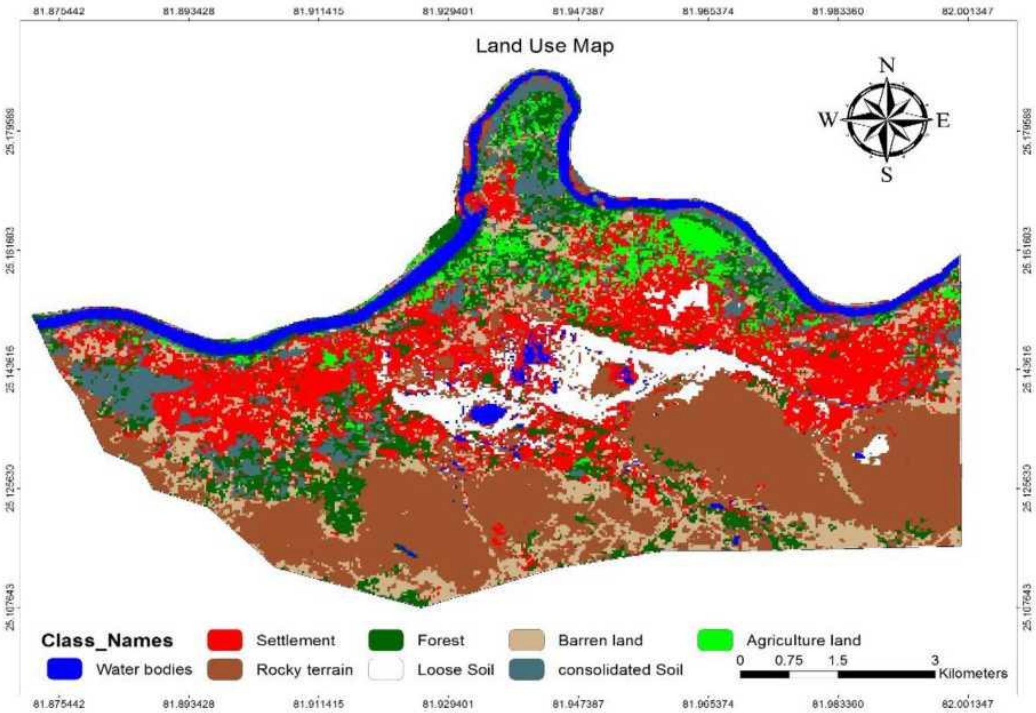


Fig.5: Landuse map of the study area

3.3 GEOMORPHOLOGY

Geomorphological map is an important feature for identifying occurrence and movement of groundwater. As far as groundwater potentiality is concerned the hilly and undulating topography forms runoff zone, whereas plain and depressed topography forms infiltration zone[14]. The geomorphology map (Fig. 6) for the study area was generated by using a map of the geological survey of India for Allahabad district and validated with the field survey. The geomorphological features of the study area were distinguished into three classes namely, alluvium plain, denudational hill, and flood plain. On the basis of high recharge potential alluvium plain was assigned the highest rank (= 3) followed by flood plain (= 2) and denudational hill (= 1), respectively (Table 3).

Table 3: Weights and ranks assigned to geomorphology

Sl.No.	Class Name	Rank	Weight	Index
1	Alluvium Plain	3	35	105
2	Denudational Hill	1		35
3	Flood Plain	2		70

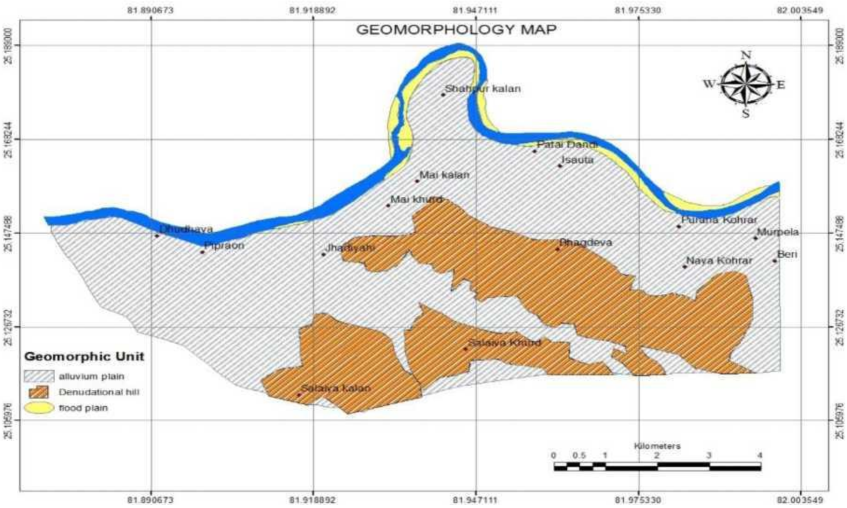


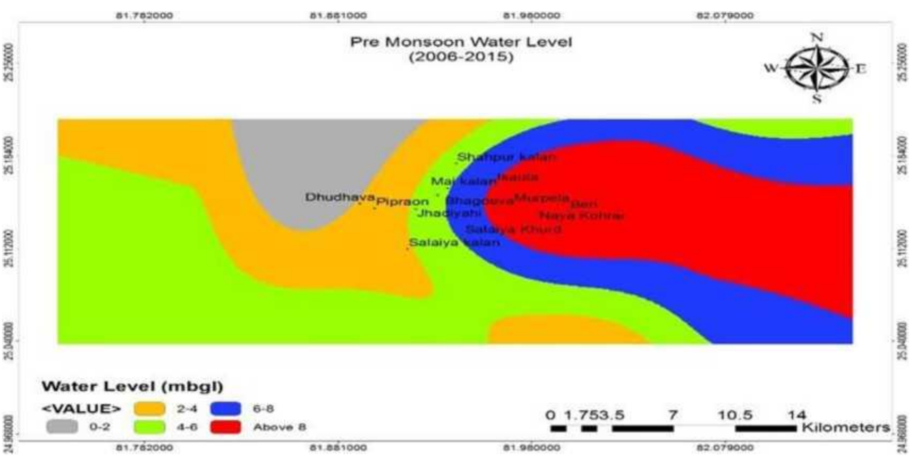
Fig. 6: Geomorphological map of the study area

3.4 GROUNDWATER LEVEL CONTOUR

The Groundwater level contour map was generated by taking an average of 10 years of groundwater level data. The pre- and post-monsoon water level contour map as well as water level graph was observed and compared with the 10 years' rainfall data to understand the movement of groundwater and the behavior of the aquifer (Fig.7). The groundwater level map was assigned 20% weight and grouped into 5 classes and ranked according to the availability of water table below ground level (bgl) i.e., the area with water level> 8.0 m, bgl was assigned lowest rank, whereas area with water level 0.0-2.0 m, bgl assigned the highest rank (Table 4).

Table 4: Weights and ranks assigned to groundwater level

Sl. No.	Water Level (m, bgl)	Rank	Weight	Index
1	0.0-2.0	5	20	100
2	2.0-4.0	4		80
3	4.0-6.0	3		60
4	6.0-8.0	2		40
5	Above 8.0	1		20



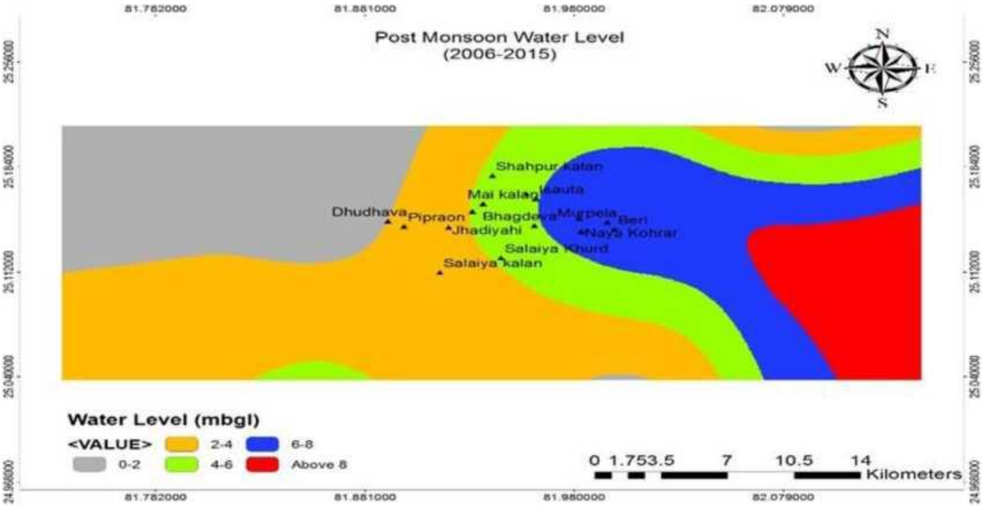


Fig. 7: Groundwater level map (mbgl) for (a) pre- and (b) post-monsoons

3.5 GROUNDWATER PROSPECTIVE MAP

Groundwater condition in hard rock area is multivariate due to the heterogeneous nature of the aquifer owing to the varying composite ion, compaction and density of weathering[15]. Overall the major lineaments having mainly NE-SW direction through Mai kalan to Pipraon, and NNW-SSE direction through Pipraon to Salaiya Khurd (Fig.8). The groundwater potential map for the study area was obtained by integrating drainage density, geomorphology, landuse and groundwater level (Fig.9). The same was validated with the exploratory well data of CGWB (Table.6). The delineated GWPZ map was classified into five zones, viz, 'very poor', 'poor', 'moderate', 'very good' and 'excellent'. The poor zone indicates the least favorable area for groundwater prospect, whereas the excellent zone indicates the most favorable area for groundwater prospect[16]. It is apparent from the groundwater potential map that about 32.21% of the study area have excellent groundwater potential, 25.62 *%* have good groundwater potential zone, 20.41% have moderate groundwater potential, 12.92 % area comes under poor potential zone and only 8.85 % area have very poor groundwater potential (Table 5). Assessment of the groundwater potential map also revealed that the distribution is more or less a reflection of drainage density, geomorphology and depth to water level in addition to the landuse.

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Table 5: Groundwater potential zones

Classes	Area (sq.km)	Area (%)
Very Poor	5.56	8.85
Poor	8.12	12.92
Moderate	12.83	20.41
Good	16.10	25.62
Excellent	20.24	32.21
Total	**62.84**	**100.00**

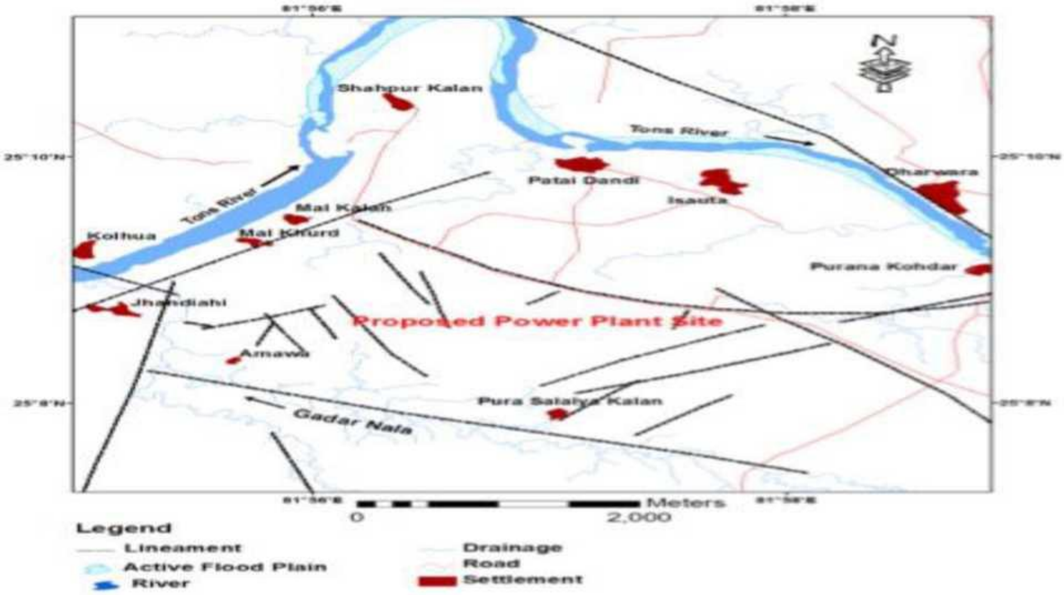

Fig.8: Lineament map of Meja thermal Power Plant Site.

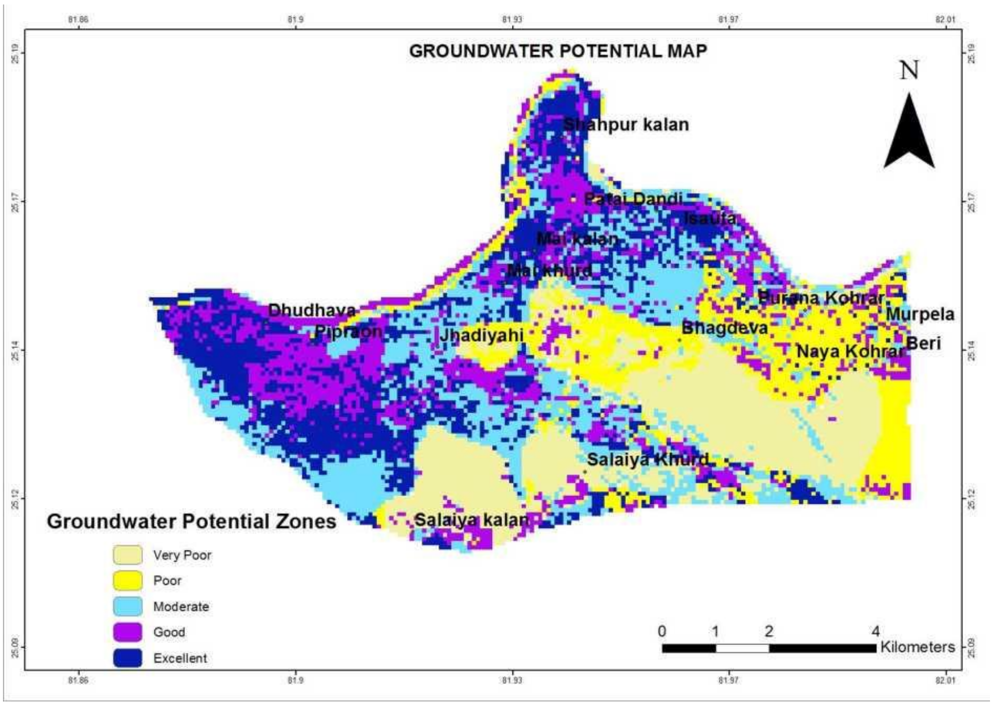

Fig. 9: Groundwater potential zones of the study area

3.6 VALIDATION WITH BOREHOLE YIELD DATA

Overall the major lineaments spread along NE-SW direction through Mai kalan to Pipraon, and NNW-SSE direction through Pipraon to Salaiya Khurd[17] attributing good to excellent groundwater prospective areas which were also corroborated with the findings of the present study. Further the data of existing wells were collected from CGWB for 3 bore well in the study area in order to validate the classification of the groundwater potential zones as revealed by the RS & GIS tools. The borehole locations, the expected bore hole yield descriptions from the potential map and the actual yield descriptions obtained from the pumping tests are shown in Table 6. Out of 3 bore wells, yield obtained at Pipraon village was about 770 lpm which has been deciphered as good to excellent on groundwater prospective map whereas yield of 107 lpm encountered at Saliya Khurd village belongs to very poor prospective area.

Table 6: Accuracy assessment of the developed groundwater potential model map

Village (s)	Latitude	Longitude	Well Depth (m)	Water Level (m, bgl)	Yield of well (lpm)	Actual yield description	Expected yield on prospective map
Pipraon	25°08'40"	81°54'10"	30.80	11.5	770	Excellent	Good to Excellent
Shahpur Kalan	25°10'30"	81°56'30"	33.94	20.45	450	Good	Good to Excellent
Saliya Khurd	25°06'50"	81°55'30"	41.41	2.00	107	Very poor	Very poor

CONCLUSIONS

Geographic Information System (GIS) technique has been used to integrate various geo-informative thematic maps, which play major role in occurrence and movement of groundwater in study area. The integrated groundwater potential zones have been categorized on the basis of weightage assigned to different features of thematic maps. Further, comparison of individual thematic maps supports that the distribution is more or less a reflection of drainage density, geomorphology and depth to water level in addition to the landuse in the study area. It has been also well correlated with the bore well yield data of CGWB. The integrated map thus deciphered, could be useful for various purposes such as development of sustainable schemes for groundwater in this area. Secondly, the findings of this study will be very useful to planners related to groundwater resource management particularly exploration and extraction of the groundwater in the area.

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