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Integrated approach using remote sensing & GIS for assessment of groundwater situation in parts of Chandrapur and Gadchiroli Districts of Maharashtra

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ABSTRACT

The present work deals with the assessment of groundwater potential zones in parts of Chandrapur and Gadchiroli districts of Maharashtra based on remote sensing and GIS approach, in which, the IRS-P6 LISS III geo-coded satellite data (21 April, 2006) and the Survey of India toposheet No. 55 P/14 on 1:50,000 scale were used. In the process of assessment of groundwater in the area, different thematic maps on lithology, lineaments, geomorphology and land use/land cover were prepared and assigned with differential weightage values as per their groundwater recharge and storage characteristics. Accordingly, the *Groundwater Potential Map* (GWP) for the study area was derived in the GIS environment by integrating all the thematic maps and considering their respective weightage values. Finally, the study area was classified into five zones of groundwater potentials *i.e. excellent, very good, good, poor- moderate* and *poor*.

In order to ascertain the validity of the derived GWP map, a field validation was carried out in the post-monsoon season of November, 2007. The well inventory study revealed that the GWP map derived through integrated approach using remote sensing and GIS techniques exhibits a good correlation with the actual groundwater scenario in the area. The study significantly demonstrates that the integration of thematic maps derived by using remote sensing technique in conjunction with collateral data in GIS environment is immensely helpful in delineating the groundwater potential zones at a micro-level.

INTRODUCTION

Water is a prime natural resource for human beings and hence a precious national asset. The easy and cheaply available groundwater is the most important resource for domestic, industrial and agricultural uses *etc.* (Lamas and Santos, 2005). However, rapid growth of population, vagaries of rainfall, expansion of irrigation, increased industrialization *etc.* have resulted into enhanced demand for groundwater in various parts of the country (Duriaswami, 2005). As a result, the groundwater prospecting, exploration and management have become a big task in India in general, and certain drought prone areas in particular (Pandya et al., 2007 ; Gurugnanam et al., 2008). Hence, in the current scenario, it has become crucial not only to find out groundwater potential zones, but also to monitor and conserve this important natural resource.

The remote sensing and GIS techniques have emerged as very effective and reliable tools in the groundwater studies (Singh et al., 1993; Akhouri, 1996; Reddy et al., 1996; Rokade, 2003; Singh and Prakash, 2004; Rokade et al., 2007; RGNDWM Manual, 2008). These techniques provides an authentic source of information for surveying, identifying, classifying, mapping and monitoring of natural resources in general and water resources in particular. The groundwater regime of any area is largely controlled by parameters like lithology, structures, geomorphology, slope, land use/ land pattern *etc.* These features are inter-related and important for understanding the hydrological set-up of any area (Saraf and Choudhury, 1998; Gurugnanam et al., 2008).

The relevant baseline information on such features can be generated and analyzed as an individual thematic layer in the GIS environment (Ramasamy et al., 1989; Adyalkar et al., 1996; Jeyaram et al., 1996; Prakash and Mohan, 1996; Subramanian et al., 1996; Tiwari and Brai, 1996; Reddy, 2002; Gupta, 2003). Subsequently, these thematic layers, generated by using

Key Words: *Remote sensing, GIS, groundwater potential, well inventory, GWP map.*

the remote sensing data can be integrated in a GIS framework and further analyzed by using models developed with logical condition to demarcate the different groundwater potential zones (Khan and Mohrana, 2002; Pandya et al., 2007; Gurugnanam et al., 2008). Based on remote sensing information combined with the adequate field details, particularly well inventory and dug well yield data, it is possible to predict the range of depth, yield, success rate and types of wells suited to different litho-units under different hydro-geological domains (Gurugnanam et al., 2008; Wath, 2008). In view of this a pilot study has been attempted here to understand the significance of remote sensing and GIS techniques in groundwater assessment.

STUDY AREA

The area considered for the present work is a part of Chandrapur and Gadchiroli districts of Maharashtra State, which falls in the eastern parts of Maharashtra within Godavari drainage basin. The total study area spreads over an area of nearly 360 sq. km and is covered under the Survey of India toposheet no. 55P/14, in between latitude $20^{0}30'$:$20^{0}40'$ and longitude $79^{0}45'$:$80^{0}00'$ (**Fig.1 & 2**). The average rainfall of the area is 1200 mm.

DATA USED AND METHODOLOGY

Three types of data sets were used for the groundwater assessment studies; a) topographical map (55 P/14) of Survey of India on 1:50,000 scale, b) remotely sensed data *viz.* IRS-P6 LISS III (21 April 2006) geo-coded on 1:50,000 scale and c) secondary data on hydrology collected in the field itself *i.e.* well inventory details. In order to demarcate the groundwater potential zones in the study area, thematic maps on lithology and structures (lineament), geomorphology, land use/land cover on 1:50,000 scales were prepared from the remote sensing data and Survey of India topographic maps. The image characteristics like tone, texture, pattern, shape, association, drainage *etc.* were used to identify different features and their respective units (Pande,

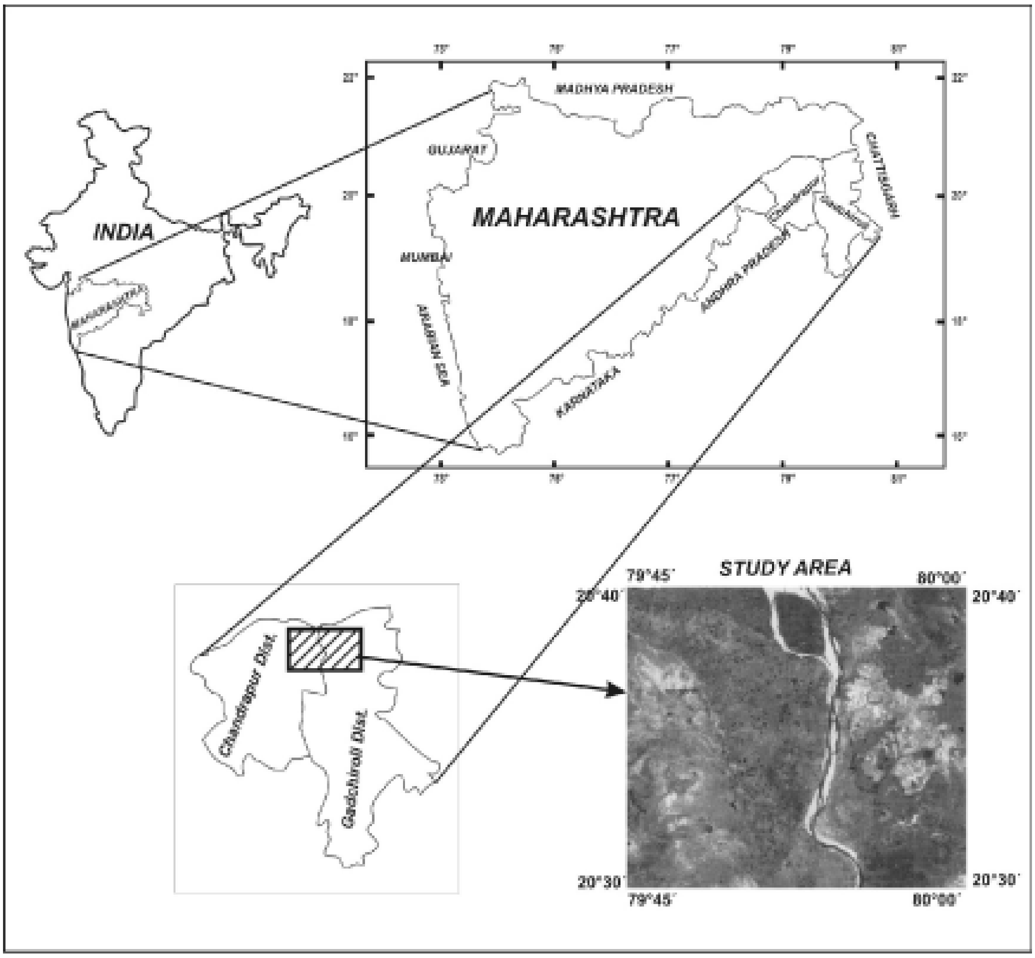

Figure 1: Index map of study area

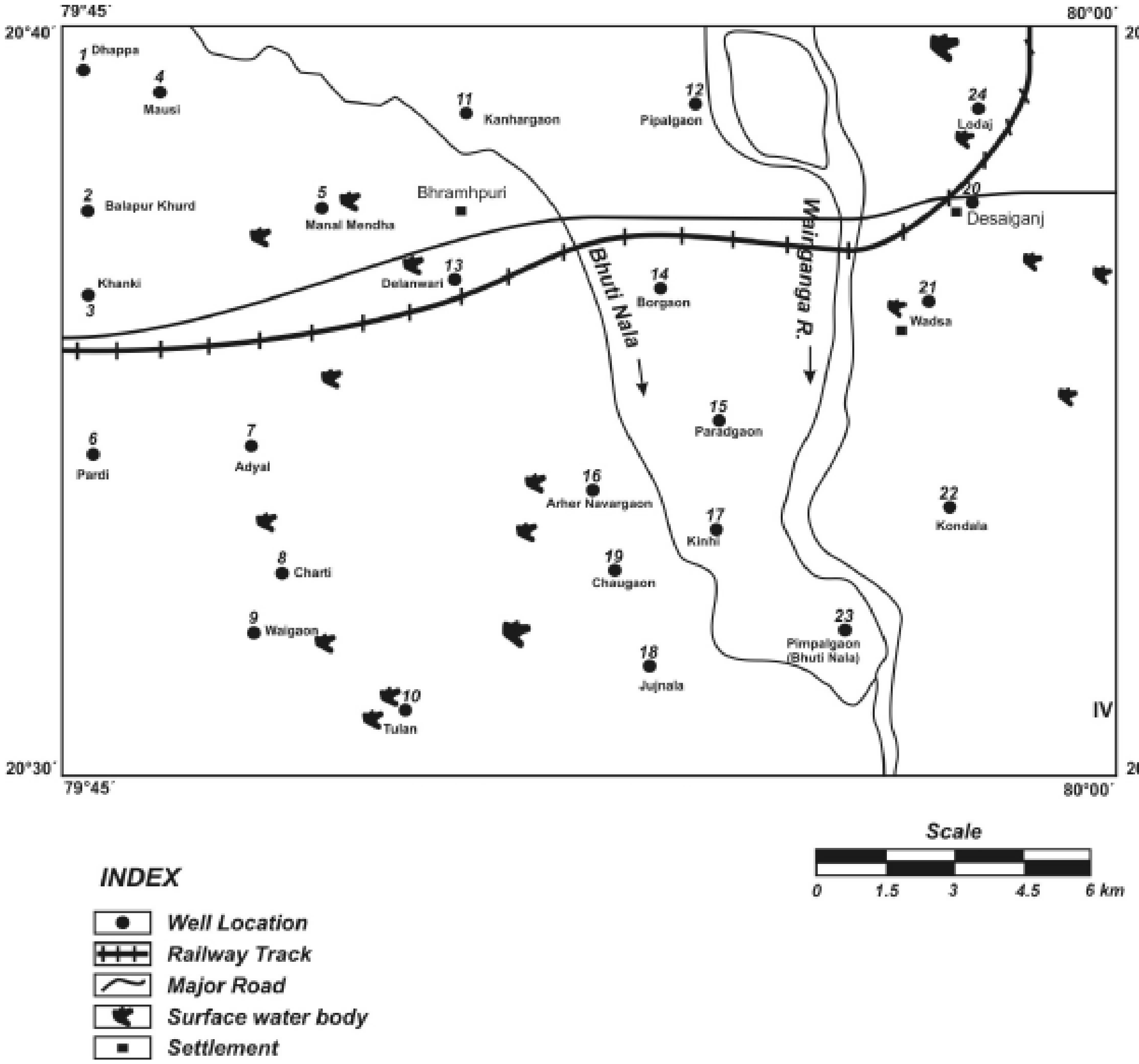

Figure 2: Base map of study area

1987; Lillisand et al., 2007). Accordingly, different thematic maps were prepared and subsequently digitized in the GIS environment with the help of Arc GIS 9.0 software. In the process, individual themes and their respective units were classified and assigned with different weightage values as per their groundwater storage and recharge characteristics. These weightage values represent the relative importance of a theme *vis-à-vis* the objective. The most favorable unit of an individual theme was assigned with maximum weightage value and the least value was given to the poor groundwater potential expected unit (**Table- 1 to 4**). Lineament plays a significant role in controlling the groundwater regime of any terrain (Mehr et al., 1989). By keeping this in view, additional value of one (1) was added to the area by expecting its comparatively better groundwater potentials.

DISCUSSION ON THEMATIC MAPS

A. Geology: The geological map as derived from satellite image shows that (**Fig.3**) the area is covered by various geological formations. The different geological formations exposed in the study area comprises of granitic gneisses belonging to Amgaon Gneissic Complex, quartzizes of Bailadila Group, mica schist of Sakoli Group, Vindhyan sandstone, ferruginous sandstone of Kamti Formation, laterites of Cenozoic Age and Quaternary Alluvium (DRM, 2003). The northeastern part of the study area found to be covered by schist, while the western part is mainly covered by granitic gneisses. The quartzite covers a very small part of the study area. The gneisses are overlain by Vindhyan sandstone and found exposed along the western boundary. The Gondwana sandstone (Kamti) is exposed in the eastern parts of

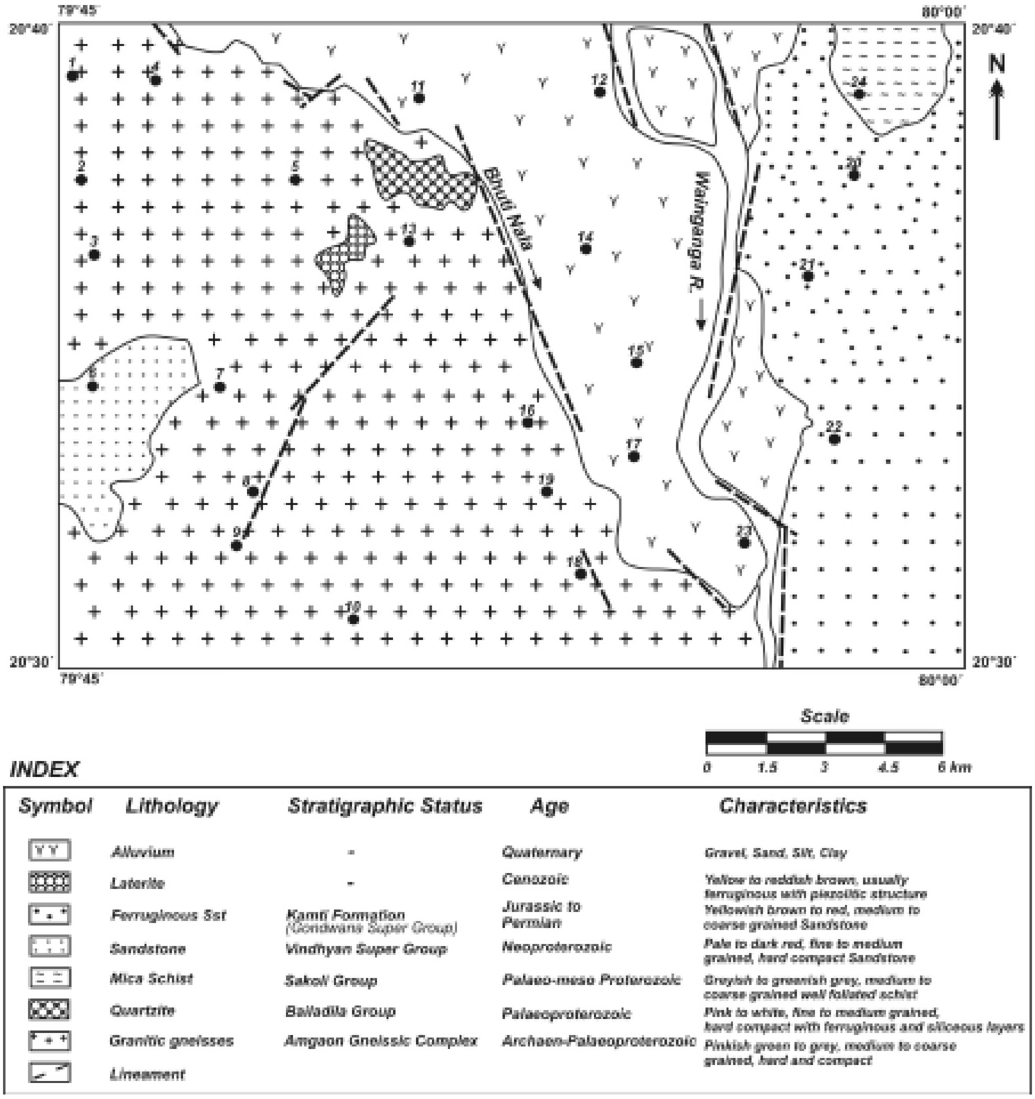

Figure 3: Lithology and lineament map of study area

study area. The area shows presence of laterite as a cap rock in the northern parts, lying over granitic gneisses. The central and central-east part of the area is covered by younger alluvium primarily along the Wainganga River and its tributary Bhuti-nala section. An attempt is also made to identify lineaments on the satellite imagery as these structures have direct bearing on the groundwater regime. It is observed that the course pattern of river Wainganga and its tributary Bhuti-Nala are largely controlled by prominent lineaments. Besides this, additional lineaments have also been mapped in the western part. The prominent lineament directions are NNW-SSE, N-S, NW-SE and NNE-SSW.

B. Geomorphology: The relief, slope, depth and type of weathered material and overall disposition of different landforms plays an important role in defining the groundwater regime of any area (Mondal et al., 2008; Raghu and Reddy, 2011). In view of this geomorphological map of the study area has been prepared (**Fig.4**). It is observed that the geomorphology of the study area comprises of alluvium, pediplain, pediment and denudational hills *etc.* In all, ten (10) geomorphological units have been delineated in the area and their details are as under;

1) Alluvium: Deposition of extensive alluvial plain is seen along the course of Wainganga River and its tributary Bhuti-nala section in the central parts of the study area. The constituents of alluvial plain are found to be mostly gravels, sands, clay and silty material and the situation is thus favorable for occurrence of groundwater. In view of this, the excellent groundwater potential is expected in this area.

2) Pediplain: The less dissected, low lying, gently

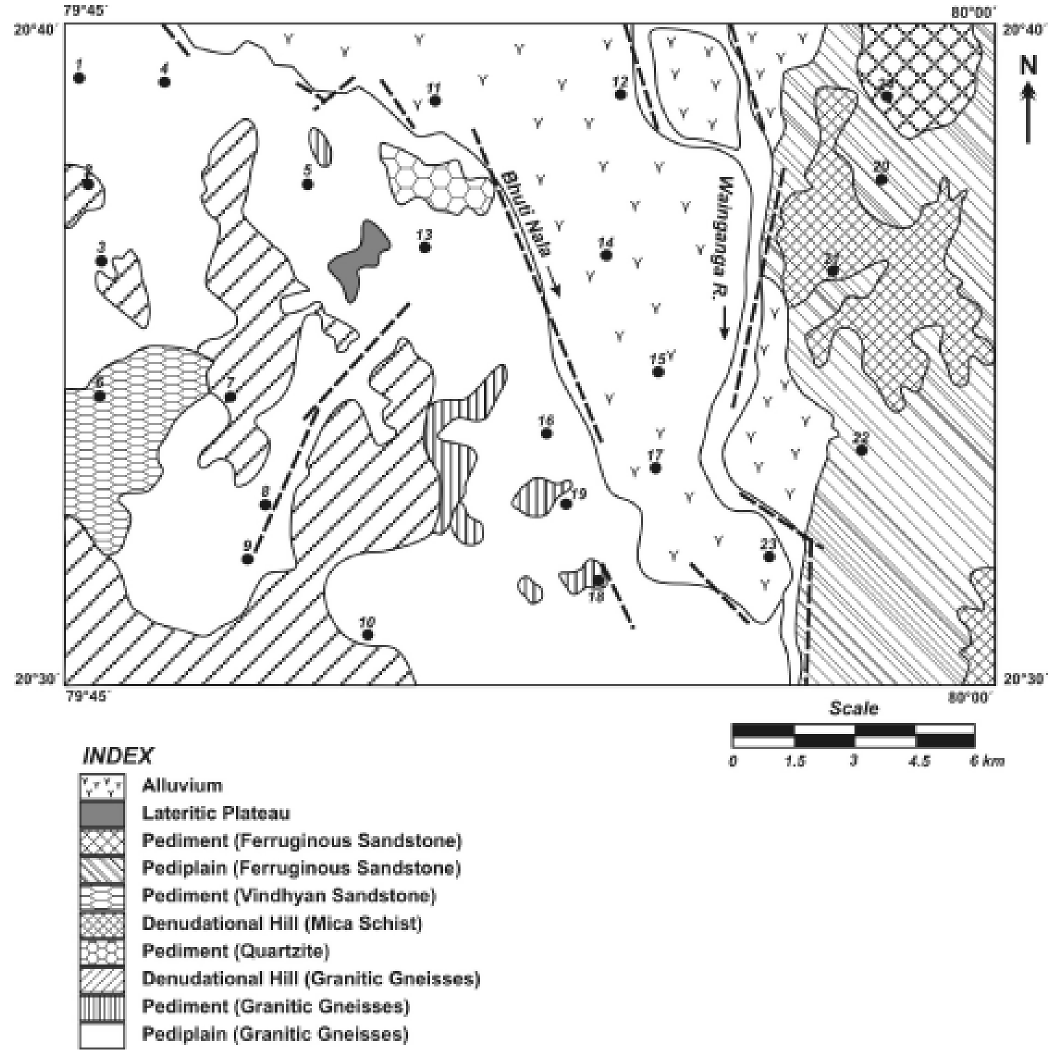

Figure 4: Geomorpholgical map of study area

sloping areas is defined as the pediplain feature. This feature exhibits gently undulating flat terrain dissected topography with moderate cover of weathered material and cover large part of granitic gneisses as well as Gondwana sandstone. The good weathered mantle on pediplain facilitates better groundwater recharge and therefore good groundwater potential in the area is expected.

3) Pediment: The bed rock portion of slope or rock cut surface of mountain side is called as pediment (Singh, 2000). This feature covers the northern, eastern and central parts of study area and found lying over granitic gneisses, quartzites and sandstone (both Vindhyan and Gondwana). The area acts as a run-off zone and therefore it is unsuitable for the groundwater occurrence.

4) Hill: The isolated, low relief and generally barren type of rocky areas have been classified as 'Denudational hills'. These features occur in the northwest part over the schist rocks and in the southwest part it is lying over the granitic gneisses. The area acts as a run-off zone due to high slope and therefore poor groundwater condition is expected in this area.

5) Lateritic Plateau: A small isolated lateritic plateau is observed in the central part of the study area. The lateritic plateau is unfavorable for storage of groundwater due to very high permeability, which causes draining of water from it.

C. Land use/Land cover: Land use refers to anthropogenic activities and uses that are carried out on land surface; however, land use/land cover has good correlation with lithological and morphological units. Therefore the study of land use/land cover also provides information on groundwater situation. By considering this, the land use/land cover map of the study area has been prepared and presented in **Fig. 5**. The main land use/land cover categories delineated in the study area are as under;

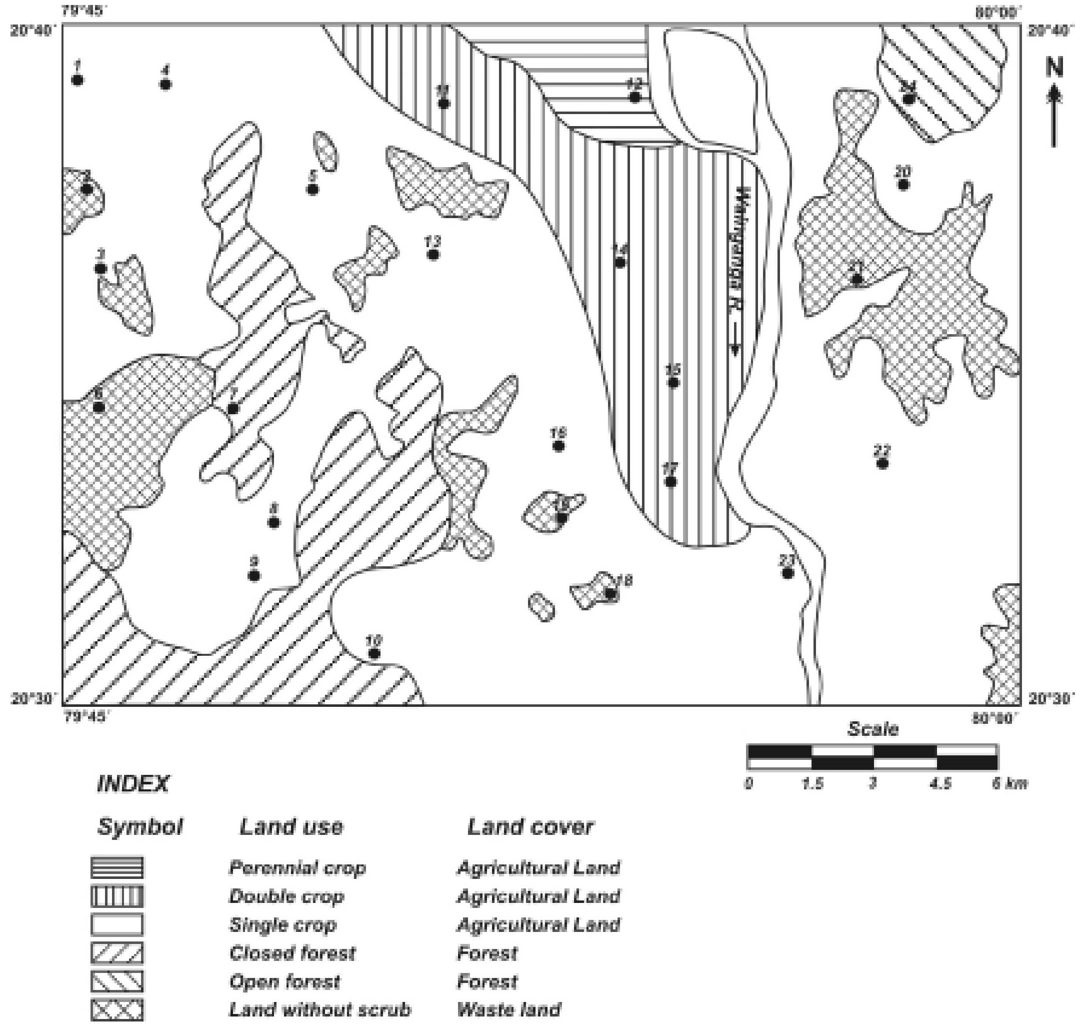

Figure 5: Land use/Land cover map of study area

1) Agricultural land: The land which is primarily used for the agricultural activity is classified as agricultural land. It is observed that the agricultural activity in the study area is confined to pediplain (both granitic and sandstone) and alluvial plain bearing areas. Further, the agricultural land is classified into three (3) units *viz.* perennial, double cropped and single cropped area. It is observed that the area covered by alluvium and sand bar is under perennial use for agricultural activity thereby implying better availability of groundwater in these units. The small part within the pediplain is observed to be covered by double crops indicating better availability of groundwater in the area. The pediplain is mostly occupied by single crop which is indicative of moderate groundwater availability.

***2) Forest land*:** It is observed that the forest land is confined to denudational hills (both granite and schist bearing area) and covers northwest and northeast part of the study area.

The close forest cover is observed on the denudational hills covered by granitic rocks, while the open forest is observed on the denudational hills of mica schist. The groundwater potential on these units is expected to be poor.

3) Waste land (land without scrub): The small barren patches form waste land and classified as 'land without scrub'. This unit occurs in scattered patches in the area and found associated with pediments (granite, quartzite, Vindhyan/Gondwana sandstone) and lateritic plateau. Such pediments being rocky in nature show poor groundwater conditions in them (MRSAC, 1989).

INTEGRATED STUDIES

In order to assess the groundwater conditions of the study area, initially, all the thematic maps along with their weightage values were integrated in GIS

Table 1: Weightage values for different Lithological units

Lithological Units	Weightage Values	Groundwater Potential
Alluvium	**6**	Maximum
Sandstone	**5**	
Gneiss	**4**	
Quartzite (BHQ)	3	
Schist	**2**	
Lateritic Plateau	**1**	Minimum

Table 2: Weightage values for Structural units

Structural Unit (Lineament)	Weightage Values
Present	**1**
Absent	**0**

Table 3: Weightage values for Land use/ Land cover units

Land Cover Units	Land Use Units	Weightage Values	Groundwater Potential
Agricultural Land	Perennial	**6**	Maximum
	Double Cropped	**6**	
	Single Cropped	**6**	
Forest	Close Forest	**3**	
	Open Forest	**3**	
Wasteland	Land without Scrub	**2**	Minimum

Table 4: Weightage values for Geomorphological units

Geomorphological Units			Weightages	Groundwater Potential
Alluvial Plain			**6**	Maximum
Pediplain			**5**	
Pediment	Sandstone Pediment	Kamti sandstone	**4**	
		Vindhyan sandstone	**3**	
	Gneissic Pediment		**3**	
Hill			**1**	Minimum
Lateritic Plateau			**1**	

Table 5: Groundwater Potential Categories

Weightage Values (Range)	Symbol on GWP Map	Groundwater Potential Zones	Wells falling in respective Polygons
4-6	*V*	*Poor*	24
7-9	*IX*	*Poor-Moderate*	2, 7, 18, 19
10-12	*III*	*Good*	6, 21
13-15	*II*	*Very Good*	1, 3, 4, 5, 8, 9, 10, 13, 16, 20
> 15	*I*	*Excellent*	11, 12, 14,15, 17, 22, 23

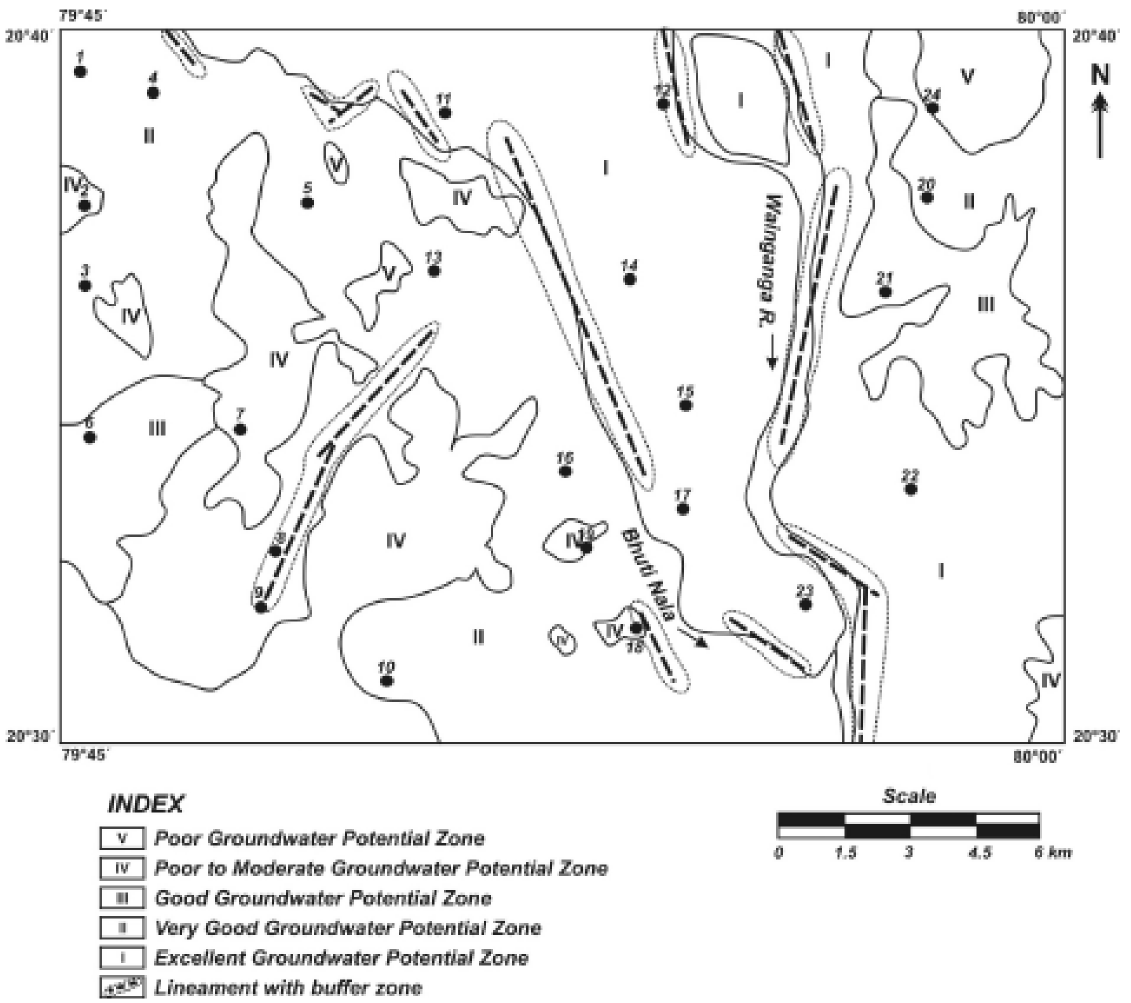

Figure 6: Groundwater Potential (GWP) map of study area

environment to identify total weightage of a polygon for its groundwater potential (**Table-5**). The groundwater potential zones were delineated by grouping the grids of final integrated layers into different potential zones *viz. 'Excellent', 'Very Good', 'Good', 'Poor-Moderate'* and *'Poor'* (**Fig. 6**).

Accordingly, five groundwater potential categories were delineated by grouping the grids of final integrated layers into different potential zones.

Finally, in order to confirm validity of the derived GWP map, a GPS aided ground survey was carried out in month of November, 2007. The well inventory details including dug well yield data, recuperation timings *etc.* obtained through the field investigations were correlated with the derived groundwater potential map of the study area (**Table-6**).

Table 6: Well inventory details of dug wells of study area

Well No.	Location/ Village	Use	Total Depth (mbgl)	Pre-Mon (2007) Water Level (mbgl)	Pre-Mon (2007) Water Column (m)	Post-Mon (Nov-07) Water Level (mbgl)	Post-Mon (Nov-07) Water Column (m)	Total Yield (KLPD)		Recuperation Time
								Winter	Summer	
1	Dhappa	A/D	11.2	9.8	1.4	7.1	4.1	90	36	8-10 hrs
2	Balapur Khurd	A	12.6	11.7	1.1	8.9	3.7	27	18	24 hrs
3	Khanki	A/D	9.8	7.9	1.9	5.2	4.6	90	36	10-12 hrs
4	Mausi	A/D	10.0	8.1	1.9	6.8	3.2	90	36	8-10 hrs
5	Manal Mendha	A	10.3	8.5	1.8	6.2	4	90	36	8-10 hrs
6	Pardi	A/D	11.5	9.9	1.6	7.7	3.8	36	27	12-18 hrs
7	Adyal	A/D	12.4	11.0	1.4	8.8	1.6	27	18	36 hrs
8	Charti	A/D	9.8	7.7	2.1	6.9	2.9	200	90	5-6 hrs
9	Waigaon	A/D	11.5	9.8	1.7	8.5	3.0	200	90	5-6 hrs
10	Tulan	A/D	9.8	8.2	1.6	5.8	4.0	90	36	10-11 hrs
11	Kanhargaon	A/D	9.6	7.0	2.6	4.0	5.6	254	72	2-3 hrs
12	Pimpalgaon	A/D	9.0	6.6	3.4	4.2	4.8	254	72	2-3 hrs
13	Delanwari	A/D	12	9.4	2.6	5.5	6.5	90	36	10 hrs
14	Borgaon	A/D	8.0	5.0	3.0	3.4	4.6	254	72	2-3 hrs
15	Paradgaon	A/D	9.7	7.1	2.6	2.8	6.9	254	72	30 min.-2 hrs
16	Arher Navargaon	A/D	9.6	8.7	0.9	6.6	3.0	90	36	12 hrs
17	Kinhi	A	10.0	7.2	2.8	4.6	5.4	254	72	1-2 hrs
18	Jujnala	A/D	12.5	10.8	1.7	7.8	4.7	180	90	6-7 hrs
19	Chaugaon	A/D	8.6	6.9	1.7	4.9	3.7	36	27	18-20 hrs
20	Desaiganj	A/D	12.8	11.2	1.6	9.6	3.2	90	36	7-10 hrs
21	Wadsa	A/D	9.5	8.2	1.3	5.8	3.7	36	27	18 hrs
22	Kondala	A/D	10.2	8.5	1.7	6.0	4.2	180	72	10-12 hrs
23	Pimpalgaon	A/D	9.5	8.5	1.0	3.6	5.9	254	72	3- 4 hrs
24	Lodaj	A/D	12.0	10.8	1.2	9.9	2.1	27	18	24-36 hrs

Explanations: Use: A-agriculture, **D**-drinking

RESULTS AND DISCUSSION

The groundwater potential map derived through integrated studies has been validated in the field by conducting well inventory study in the post-monsoon season of 2007. In all 24 dug wells covering the entire field area has been examined**.** The Table-6 shows that there exists a good correlation of performance of wells with the potential zones. The wells located in alluvial areas are very high yielding *e.g.* well no. **11, 12, 14, 15, 17** and **23**. The yield of these wells range from 254 to 72 KLPD between winter to summer seasons. The yield of the wells located in the pediplain which are **1, 3, 4, 5, 8, 9, 10, 13, 16, 20 and 22** ranges between 90 to 36 KLPD. Similarly the yield of the wells located on pediment *i.e.* well no. **6, 18, 19 and 21** is 27 to 18 KLPD. It is observed that there are three wells located on denudational hill *viz.* well no. **2, 7 and 24**. The yield of these wells varies in the narrow range of 36 to 18 KLPD. Further it is observed that the rate of recuperation in alluvium is very fast (i.e. 2-3 hrs). In pediplain it is 8-10 hrs, while on denudational hills it is maximum (*i.e.* 30-36 hrs.) The faster recuperation in pediplain and alluvium is indicative of permeable formations. It is also observed that the wells located in the vicinity of lineament structures are good yielding *i.e.* well no. 8, 9 and 18 in which the yield ranges in between 180 to 90 KLPD. Similarly the recuperation time required in these three wells is also less as compared to the other wells falling on pediplain and pediment units. The less recuperation time to retain the pre-existing static water level in these wells may be attributed to the vicinity of lineament structures.

CONCLUSIONS

The above observation reveals that the groundwater condition of the study area is closely related with the groundwater potential map (GWP) derived by remote sensing and GIS approach. The study depicts that the remotely sensed data provide a reliable source of information on the generation of thematic information for the groundwater potential studies. It is also observed that the integration of remotely sensed data in conjunction with collateral data in GIS environments has an immense help in delineating the groundwater potential zones at a micro-level. Further, the study significantly demonstrated that the remote sensing data provides spatial distribution on lithology, geomorphology, land use/land cover, structural features, which have direct bearing on the groundwater potential of study area, whereas, the GIS technique helps in integration of thematic maps and therefore found useful in the evolution of decision support system. The groundwater potential map generated through such integrated approach are realistic and therefore may be used for the optimum utilization of groundwater resources, preparation of better management plans and in improving the socio-economic condition of any area.

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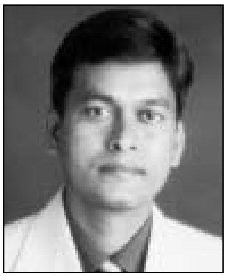

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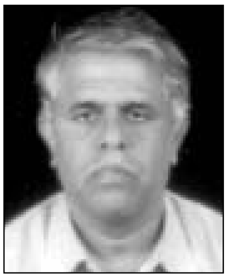

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