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Mapping of groundwater potential zones in the Musi basin using remote sensing data and GIS

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ABSTRACT

The objective of this study is to explore the groundwater availability for agriculture in the Musi basin. Remote sensing data and geographic information system were used to locate potential zones for groundwater in the Musi basin. Various maps (i.e., base, hydrogeomorphological, geological, structural, drainage, slope, land use/land cover and groundwater prospect zones) were prepared using the remote sensing data along with the existing maps. The groundwater availability of the basin is qualitatively classified into different classes (i.e., very good, good, moderate, poor and nil) based on its hydrogeomorphological conditions. The land use/land cover map was prepared for the *Kharif* season using a digital classification technique with the limited ground truth for mapping irrigated areas in the Musi basin. The alluvial plain in filled valley, flood plain and deeply buried pediplain were successfully delineated and shown as the prospective zones of groundwater.

1. Introduction

Groundwater is a form of water occupying all the voids within a geological stratum. Water bearing formation of the earth's crust acts as conduits for transmission and as reservoirs for storing water. The occurrence of groundwater in a geological formation and the scope for its exploitation primarily depend on the formation porosity. In the presence of interconnected fractures, cracks, joints, crushed zones (such as faults zones or shear zones) or solution cavities, rainwater can easily percolate through them and contribute to groundwater [16]. The conventional methods used to prepare groundwater potential zones are mainly based on ground surveys. With the advent of remote sensing and Geographic Information System (GIS) technologies, the mapping of groundwater potential zones within each geological unit has become an easy procedure [4,13]. The groundwater conditions vary significantly depending upon the slope, depth of weathering, presence of fractures, surface water bodies, canals, irrigated fields etcetera. These factors can be interpreted or analyzed in GIS using remote sensing data. Jain [4] demonstrated the use of hydrogeomorphological map by using Indian Remote Sensing Satellite Linear Imaging Self-Scanning II geocoded data on 1:50,000 scale along with the topographic maps to indicate the groundwater potential zones in qualitative terms (i.e., good to very good, moderate to good and poor).

Minor et al. [7] developed an integrated interpretation strategy to characterize groundwater resources for identification of well locations in Ghana using GIS. Gustafsson [3] used GIS for the analysis of lineament data derived from SPOT imagery for groundwater potential mapping. For the assessment of groundwater resources of Northwest Florida water management district, Richards et al. [10] took the advantage of GIS for spatial analysis and data visualization. Krishnamurthy et al. [5] developed a GIS based model for delineating groundwater potential zones of Marvdaiyar basin, Tamil Nadu, India by integrating different thematic layers

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derived from remote sensing data. The field verification of this model established the efficacy of GIS in demarcating the potential groundwater reserves. Applications of GIS for groundwater resource assessment have also been reported by Sander [11], Teevw [15] and others.

A GIS framework was developed and analyzed by Das et al. [2] with logical conditions to derive groundwater zones in Sali river basin, Bankura district, West Bengal using thematic layers like geology, geomorphology, drainage density, slope and land use/land cover generated using IRS 1B data by applying GIS technique using Arc/Info and ILWIS 2.1 software. Based on the status of groundwater irrigated areas through remote sensing artificial recharge structures such as percolation tanks, check dams and subsurface dykes can be recommended upstream of groundwater irrigated areas to recharge wells in the downstream areas to augment groundwater resources. Singh et al. [13] prepared groundwater potential maps on 1:50,000 scale for Mirzapur District of Uttar Pradesh, India based on visual interpretation of IRS IC LISS III data. They evaluated the groundwater potentials by combining thematic maps of hydrogeomorphology, lineament, drainage map, topographic maps, and lithology in GIS environment. Sikdar et al. [12] visually delineated geomorphic and land use/land cover units from satellite data in conjunction with the topographical maps. Eleven geomorphographic units were qualitatively interpreted for groundwater prospects on the basis of geology structure, geomorphology and recharge conditions at Raniganji Coal field area, west Bengal. Remote sensing technique has been used to map the irrigated areas along the Musi river bed using digital image supervised classification technique through specification approach, with limited ground truth for mapping the broad categories and their areal extent and location [8]. These maps were prepared using IRC-1C LISS III and PAN satellite data and other collateral information.

A study conducted to develop a digital database of groundwater availability qualitatively in the Musi Basin using geological (lithology and structural), geomorphological and hydrological information and also to map irrigated areas using remote sensing data is presented in this paper.

2. Data and methodology

2.1. Description of study area

The Musi basin is the most important agricultural production center in the State of Andhra Pradesh (India) with fast growing population and increasing urbanization, consequently increasing water demand in the cities and industries. There is a growing awareness of the need for adequate water resources to maintain environmental requirements. In contrast to land resources, there is a high interdependency among water users due to the movement of water in the hydrologic cycle. The Musi basin, a sub-basin of Krishna basin, is situated in Andhra Pradesh, India, and spread in parts Rangareddy, Nalgonda, Mahabubnagar, Warangal and Hyderabad districts. The upper part of the Musi basin was considered for the present study (Fig. 1). It is spread in Rangareddy, Nalgonda, Mahabubnagar and Hyderabad districts. The area lies between the longitudes from 77° 50′ 29.38″ to 78° 58′ 26.43″ and latitudes from 16° 43′ 48.82″ to 17° 45′ 27.97″. The total geographical area is 5653.20 km^2. There are three major reservoirs in the Musi basin, namely Osmansagar, Himayatsagar and Musi. The Musi basin has an average altitude of 726 m in the upstream, this gradually decreasing towards the southeast till 450 m. The Musi basin consists of 71 mandals in the different districts. The basin has a semi-arid climate with precipitation during the rainy season, from June to October with total average of 710 mm per year. The Musi River drains into the Musi sub-basin. The basin has a drainage den-

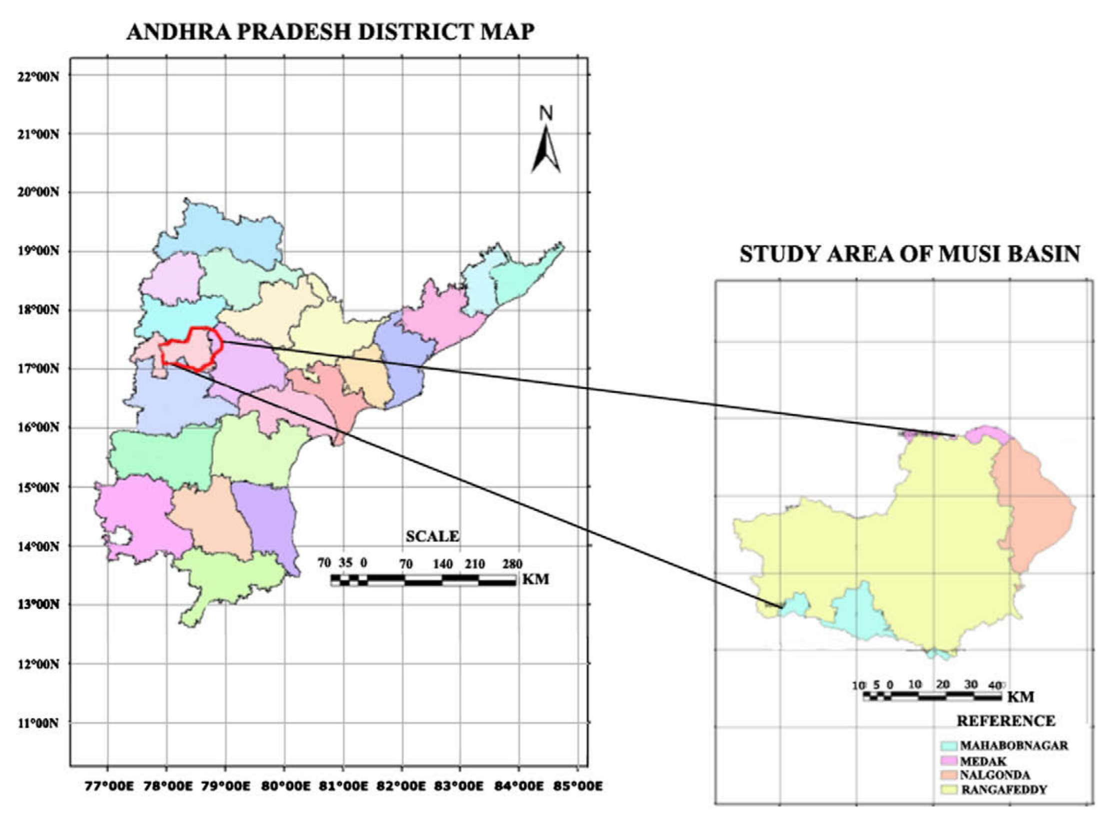

Fig. 1. Location map of upper part of Musi Basin.

sity of 0.8–1 km/km^2. The Musi River originates at the Ananthagiri hills near Sivareddipet village, in Vikarabad mandal, and joins the Krishna River near Wadenapalli in Nalgonda district. In the Musi basin, irrigation is mainly from groundwater due to the depletion of water in surface water bodies and tanks particularly in *Rabi* season.

The area consists mainly of granite and gneisses intruded by dolerite, dykes, quartz veins and pegmatite veins of archaic age. In the western part of the basin Deccan traps (upper cretaceous to Eocene) and laterite (recent) are found. The weathering zones for granite, basalt and laterite have a respective thickness 20 m, 2–9 m and 4–25 m. The main crop in the basin is paddy. Other crops are: vegetables, groundnuts, red chilli, sugarcane, sorghum (*jowar*), pearl millet (*bajra*), maize, wheat, ragi and gram. Paddy, vegetables and other commercial crops are irrigated using the wells and tanks. *Jowar*, *bajra* and gram are cultivated as rainfed. The area has a tropical climate, characterized by hot summers during April and May and pleasant winters from December till February with temperatures varying 12 °C in the winters from December till 43 °C on a hot summer day. The study area receives most rainfall from the southwest Monsoon (85%) and the average annual rainfall is 812 mm. The rest of the rainfall is from the northeast monsoon and occasional cyclones. Dug wells, bore wells and hand pumps are used to tap water from the groundwater. The hand pumps have an average yield of 4 m^3/d. The dug wells have an average yield in granite of 35–70 m^3/d and have a depth of 10–20 m. The bore wells have a yield of 108–336 m^3/d and have a depth extending to 70 m. Irrigation demands are nowadays mainly supplied from the groundwater. Other sources could be noted as surface water, tanks, channels, canals and springs. The groundwater use for irrigation has increased because of drying up of surface water bodies due to lack of rain and also it takes a lot of work to maintain the tanks properly.

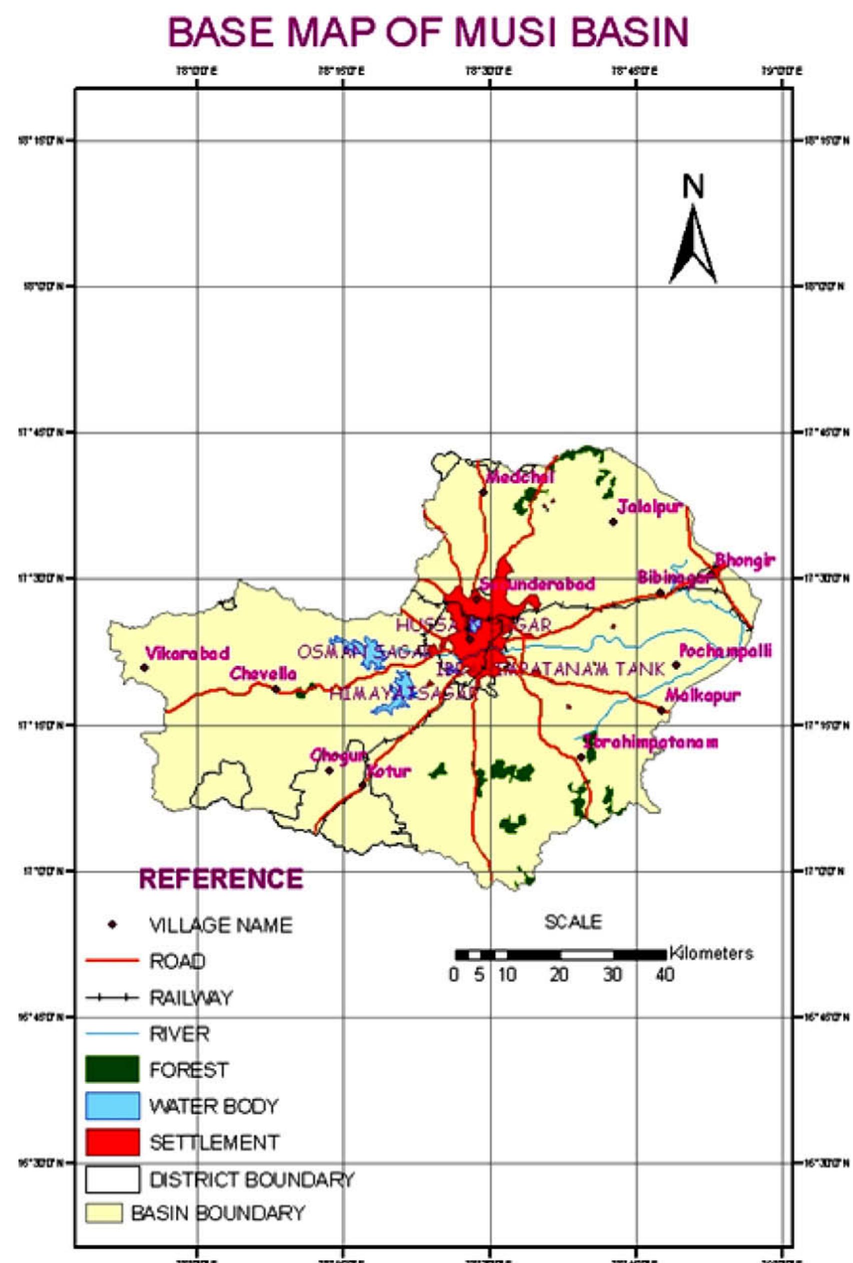

Fig. 2. Base map of Musi sub-basin.

2.2. Data products used in the study

Remotely sensing data are composed of Shuttle Radar Topographic Mission-Digital Elevation Model (SRTM DEM) data and Land sat 7 THEMATIC MAPPER data. Maps used in the analysis are Survey of India Toposheet –1:2,50,000 (56 k, 56 l, 56 o and 56 p); geology maps – 1:2,50,000; and geomorphology maps – 1:2,50,000.

2.3. Methodology

The SRTM recorded both radar images simultaneously using two antennas for transmitting and receiving in the cargo bay of the Shuttle Endeavor, and a second receiving antenna at the tip of a 60 m deployable mast. Both radar and phase data were recorded in C-band (5.56 cm wavelength) and X-band (3.1 cm wavelength) frequencies. The numerical values indicate wavelengths of C and X-bands which are the operating frequency bands of the antennas. The shorter wavelengths of C and X-bands are more sensitive to small scale variations in surface roughness that can be related to the extent of soil erosion, size of surface lag gravels and the extent of landscape truncation. Martinez and Le Toan [6] used these bands to detect water under marsh vegetation (sedges, grasses, herbs, macrophytes) whereas longer wavelengths (L-band and above) allows water to be detected under forest cover.

During the 11-day mission, data were acquired along 225 km wide swath imaging Earth's entire land surface between 60° north and 56° south latitude, with data points spaced every 1 arc second of latitude and longitude (approximately 30 m). X-band coverage occurred along narrow 50 km wide swaths and cover 40% of the area mapped by the C-band data. The absolute horizontal and vertical accuracy of the C-band data are 30 m

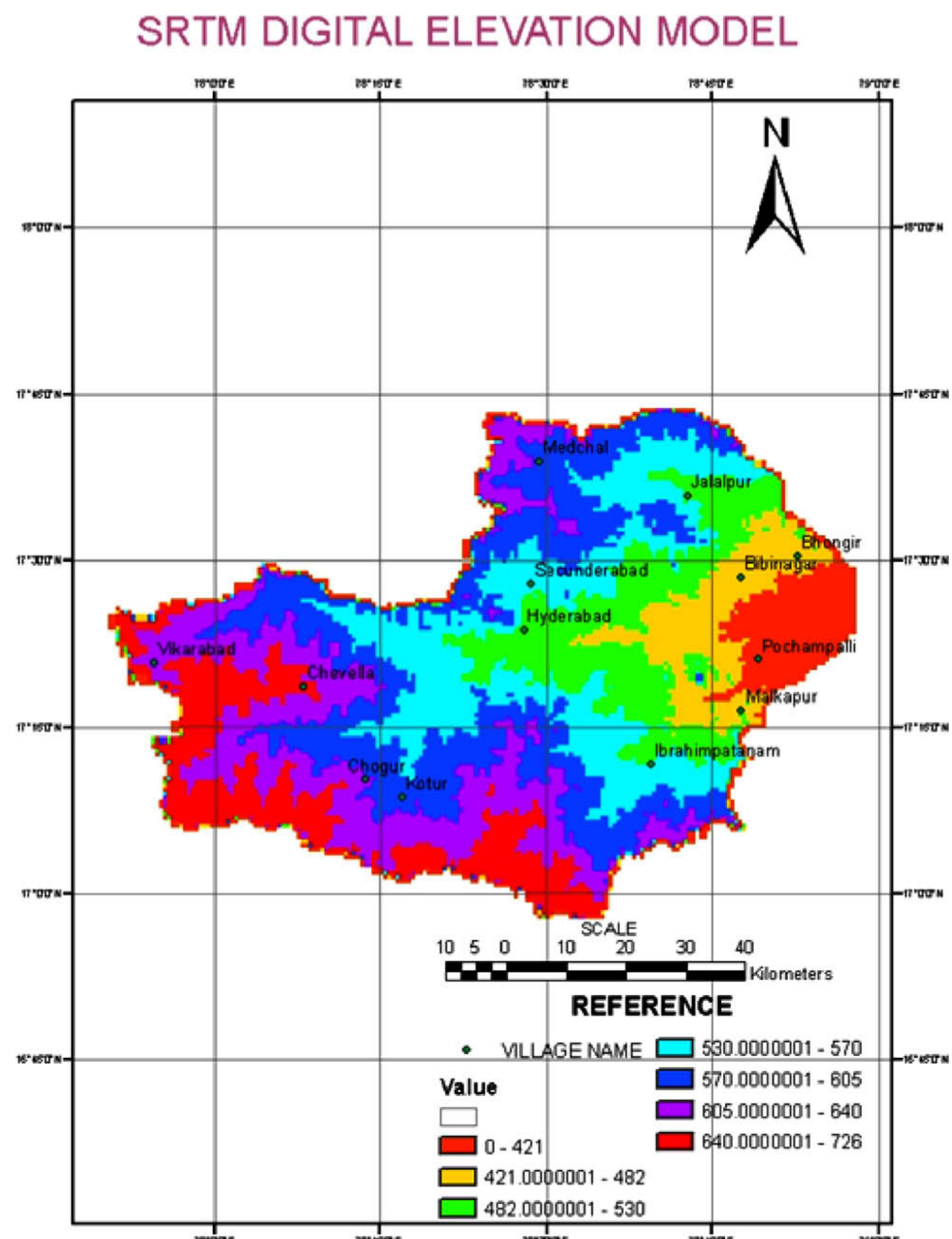

Fig. 3. DEM map of Musi sub-basin.

and 16 m, respectively. Relative height accuracy is 10 m. Data spatially degraded to 90×90 m horizontal resolution but retaining the initial height accuracy, are available at the low cost of re-gridding the data to a $1° \times 1°$ area. X-band DEM data of the narrower 50 km wide swath have a horizontal resolution of 30 m and relative and absolute height accuracies of 6 m and 16 m, respectively. These data are unclassified and available for public use from the German Aerospace Centre. Both C and X-band datasets are geometrically corrected and projected to the WGS84 datum. Extensive information describing the data products and their availability is available on the SRTM home page (http://www.jpl.nasa.gov/srtm/) and DLR home page (http://www.jpl.nasa.gov/dlr-mirror/srtm/).

The growing availability of DEM data from radar interferometer (i.e., SRTM DEM data) provides new possibilities to earth scientists and was successfully compared with other DEM extracted from aerial photography, SPOT-PAN, RADARSAT and ASTER [9,14]. With the advent of geographical information systems (GIS) DEM can be used together with other spatial datasets such as geological information, airborne magnetic, gamma-ray spectroscopy and hyper spectral datasets. The DEM provides a basic spatial reference system and images, and then vector data can automatically be draped over the DEM for more advanced spatial analyses which include tools for generating geomorphometric models such as slope.

3. Analysis approaches and results

In order to demarcate the groundwater potential zones (availability) in the study area different thematic maps have to be prepared from remote sensing data, topographic maps and geological maps in conjunction with the existing maps. The methodology followed for preparing groundwater prospects map for the Musi basin is as follows.

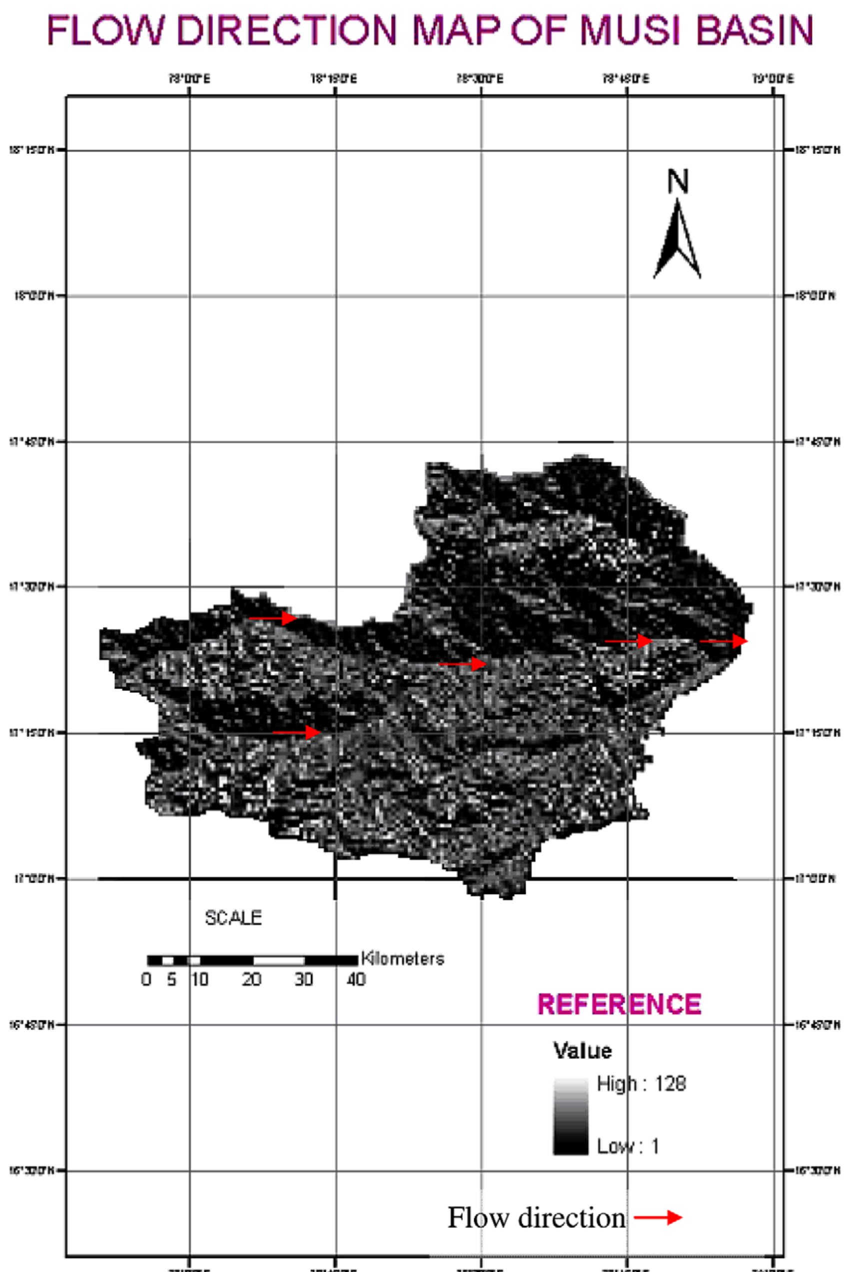

Fig. 4. Flow direction map of Musi sub-basin.

3.1. Preparation of base map

The base map has to be prepared in Arc Map application of the ArcGIS software using geocoded toposheet. The base map (Fig. 2) contains the following details with the appropriate symbols: (i) rivers, (ii) all water bodies (both perennial and ephemeral have to be mapped), (iii) canals, (iv) roads, (v) railway lines, (vi) cities/major towns/villages, and (vii) district boundary. It is important to note that drinking water availability is a big issue in many of these regions and water has to be transported to the scarce regions and the connectivity of the roads and railways give a good picture of the nearest places for meeting their requirements for the planners. For this reason we deemed suitable to include the details roads and railways lines in mapping groundwater potential zones.

3.2. Topography

Topographic information has to be collected from SRTM DEM data (Fig. 3). Drainage map is extracted from the SRTM DEM data by using the flow direction grid map. A raster of flow direction shown in (Fig. 4) gives us the flow across a surface which will always be in the steepest down-slope direction and is used to determine the stream network. Flow direction map created from a raster shows the direction of flow of the river is from west to east and joins Krishna River near Wadenapalli in Nalgonda district and reaches Bay of Bengal. A raster of flow accumulation created is shown in (Fig. 5), indicated that the low accumulation values represent ridge tops whereas higher accumulation values represent valleys and stream channels. The drainage pattern observed in the Musi basin is dendritic in nature and the basin has a drainage

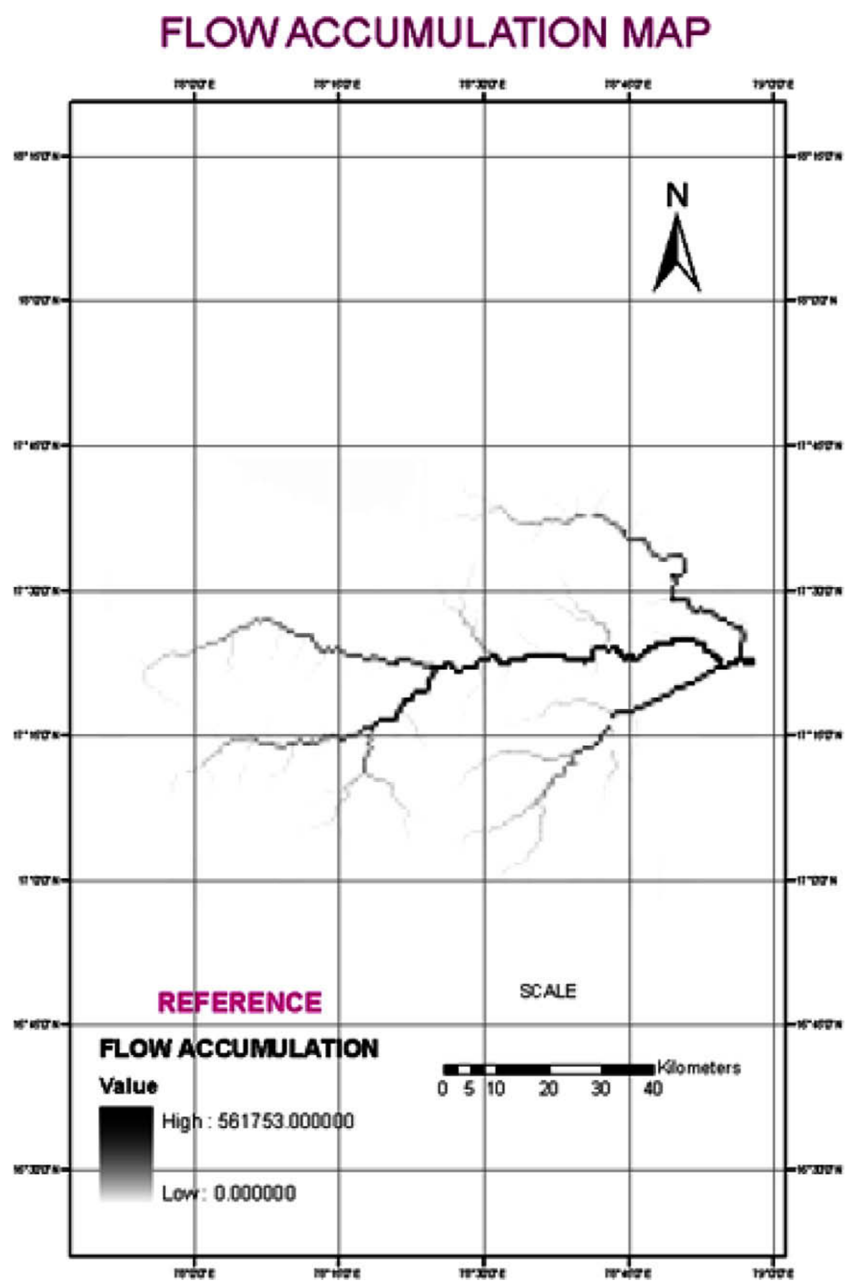

Fig. 5. Flow accumulation map of Musi sub-basin.

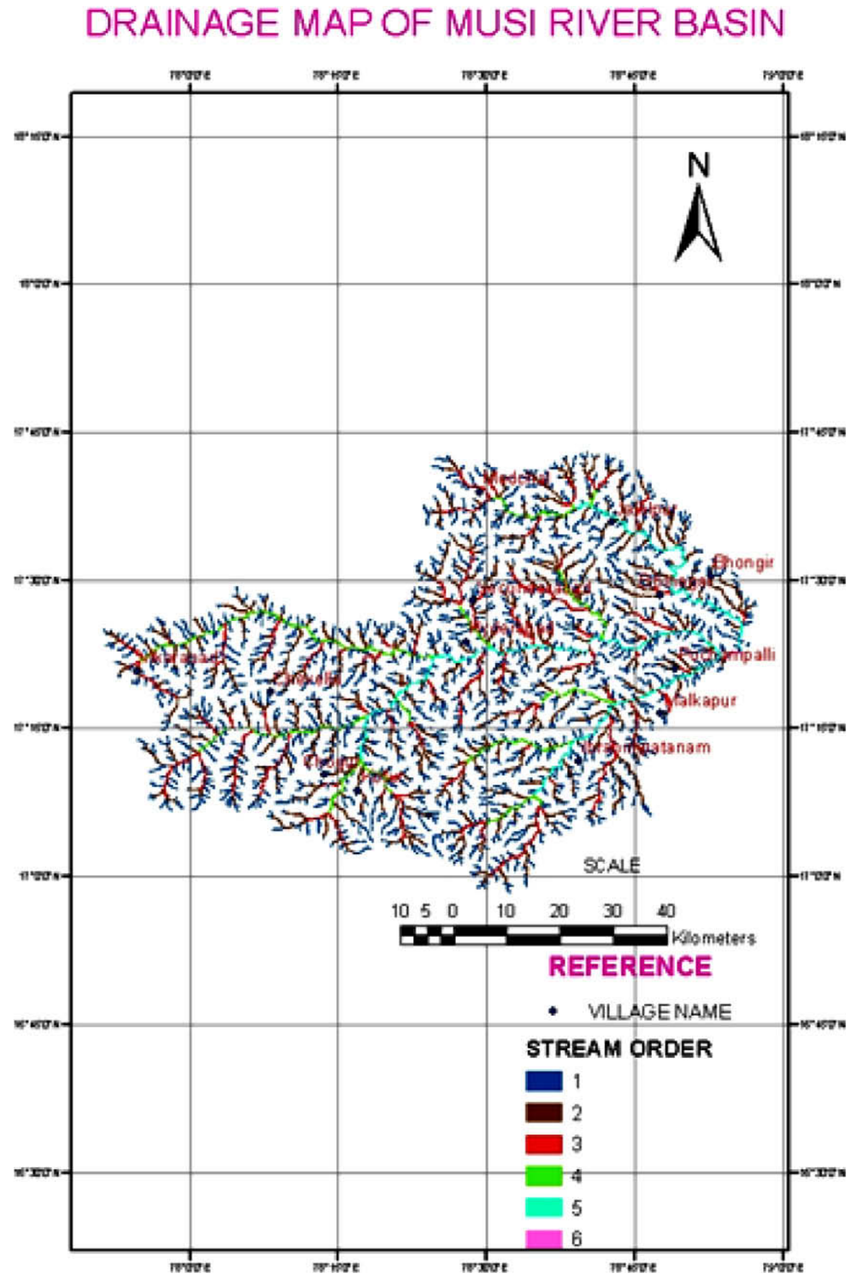

Fig. 6. Drainage map of Musi sub-basin.

density of 0.8–1 km/km^2. Stream ordering is given by using DEM and Drainage network in Arc GIS by using Hydrology module (Fig. 6). Drainage network helps in the delineation of watersheds and for suggesting various water harvesting structures and soil conservation measures. Slope Map (Fig. 7) in degree has been prepared from SRTM DEM range from 0° to 90°. Most of the area is categorized into four categories (i.e., 0–89.80901337, 89.809–89.934, 89.9344–89.9707, and 89.9707–89.999).

3.3. Preparation of lithology map

Lithology map was prepared by digitizing each lithologic unit/rock type in ArcGIS software package from geology maps obtained from geological survey of India, Hyderabad. Moreover each lithologic unit or rock type is classified based on the legend available on the geology map (Fig. 8).

3.4. Preparation of geological structural map

Geological structural map (Fig. 9) was prepared by digitizing lineaments, faults in ArcGIS software package from the geology map. Different structures that should be mapped have been represented on the map with appropriate line symbols.

3.5. Preparation of geomorphological map

The geomorphological maps were obtained from National Remote Sensing Agency, Hyderabad, Andhra Pradesh. The methodology for preparing geomorphology maps is as follows. The synoptic view of satellite imagery facilitates better appreciation of geomorphology and helps in mapping of different landforms and their assemblage. The photo-interpretation criteria, such as tone, texture, shape, size, location, association, physiography,

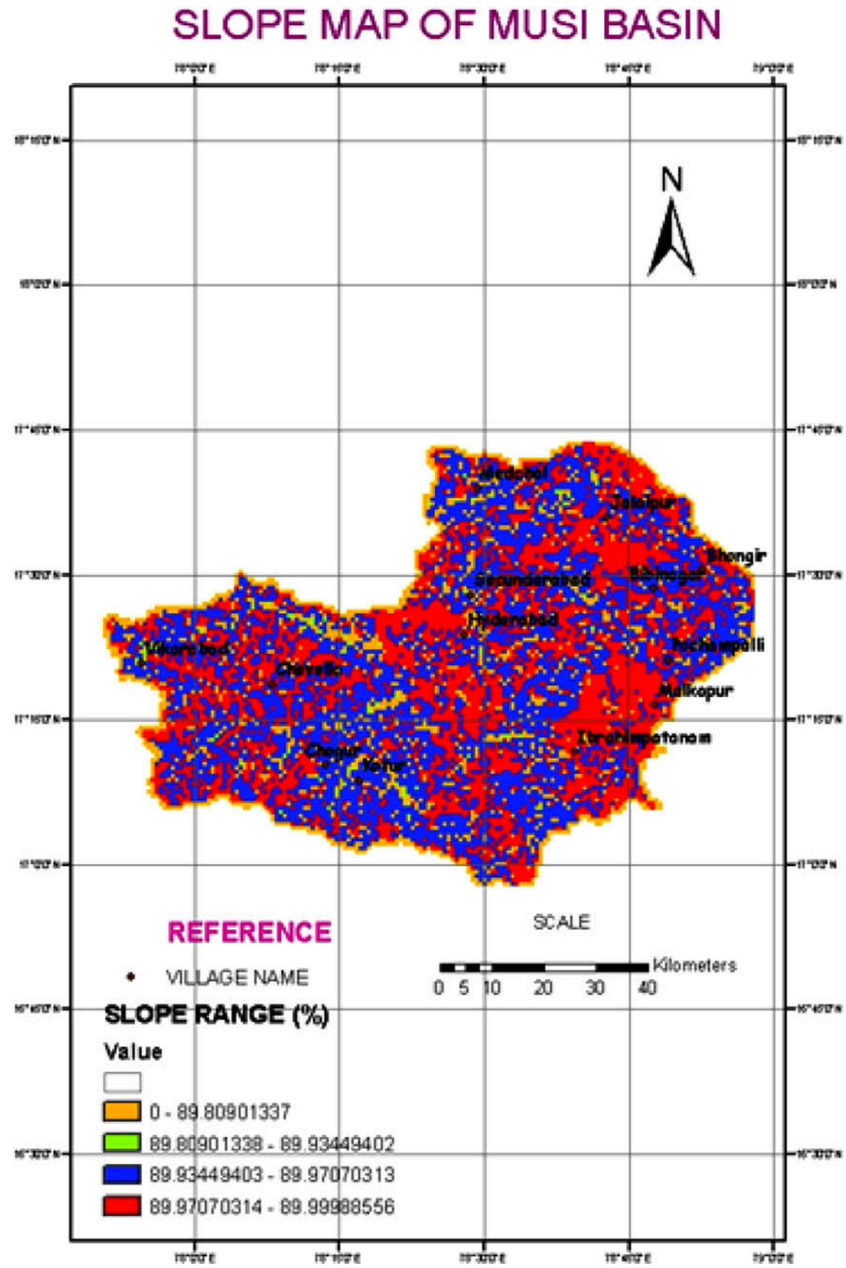

Fig. 7. Slope map of Musi sub-basin.

genesis of the landforms, nature of rocks/sediments, associated geological structures, are to be used for identification of different landforms/geomorphic units. Initially, the entire image has to be classified into three major zones; that is, hills and plateaus, piedmonts ones and plains considering the physiography and relief as the criteria. Then with in each zone, different geomorphic units have to be mapped based on the landform characteristics, their aerial extent, depth of weathering, thickness of deposition etc., as discussed earlier. Subsequently with in the alluvial, deltaic, coastal, eolian and flood plains was mapped and represented on map using the standard alphabetic codes shown against each landform.

These geomorphic units/landforms interpreted from the satellite imagery have to be verified on the ground during the field visit to collect the information on the depth of weathering, nature of weathered material, thickness of deposition and nature of deposited material, etc. For this purpose, nala/stream cutting, exiting wells lithologs of the drilled have to be examined. By incorporating these details in the pre-field interpretation map, the final geomorphic map overlay has to be prepared.

For the preparation of a geomorphic map overlay, information from the following sources is required: (i) lithological map overlays, (ii) interpretation of satellite imagery, and (iii) field visits/surveys.

If previous maps/literature is available, the subsequent procedures become easier; even otherwise, a good geomorphological map showing assemblage of different landforms can be prepared based on the above sources of information. The satellite image along with the interpreted lithological map overlay should be kept on the light table. A fresh transparent overlay should be kept on

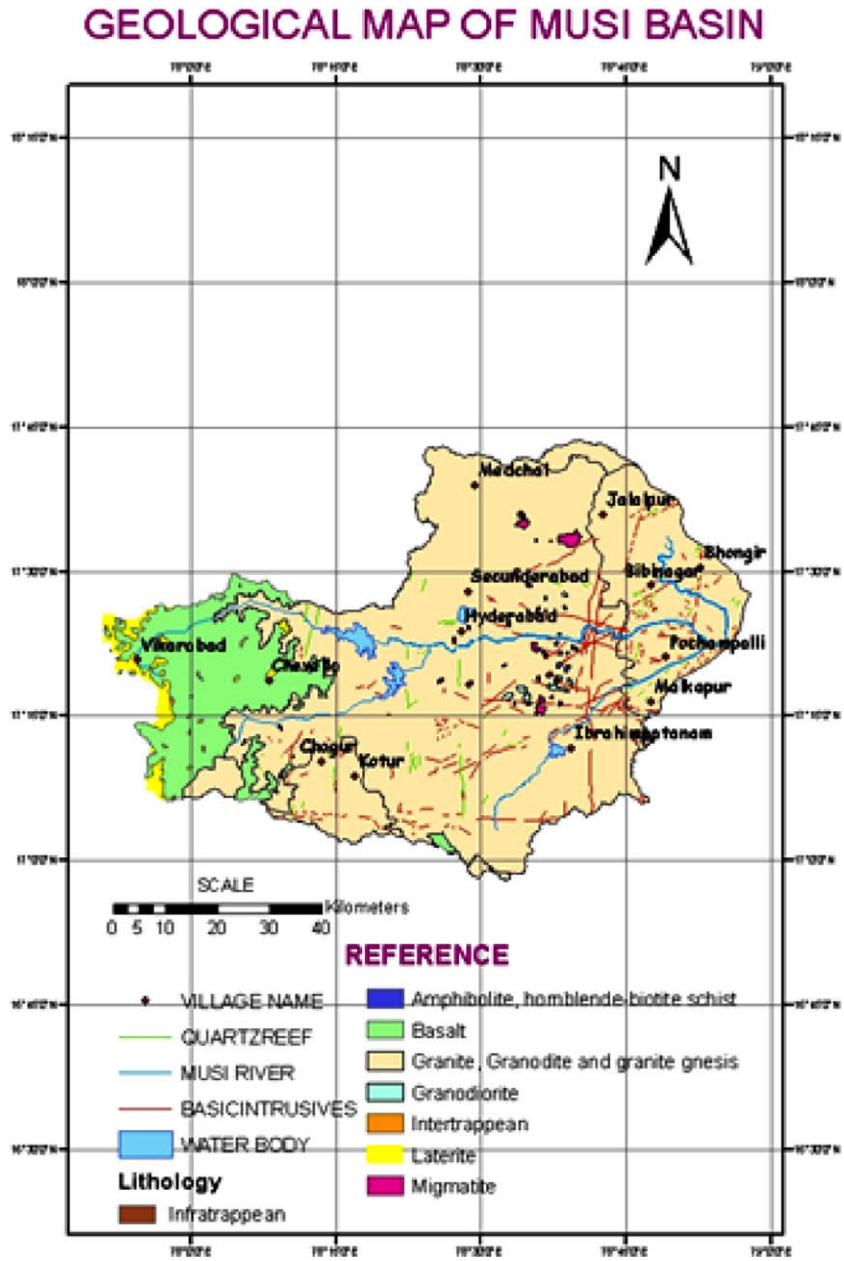

Fig. 8. Geological map of Musi sub-basin.

the top and each rock type should be classified into different geomorphic units/landforms as per the classification system suggested. Sometimes one lithologic unit may be classified into 2 or more geomorphic units/landforms and vice versa. It should be noted that wherever the lithologic/geomorphic boundaries are common, they need to be made co-terminus. All the geomorphic units/landforms should be labeled with alphabetic annotation residual hills, inselbergs, etc.

3.6. Preparation of hydrological map overlay

Satellite imagery provides excellent information on hydrologic aspects like steam/river courses, canals, major reservoirs, lakes, tanks, springs/seepages, canal commands, groundwater irrigated areas, etcetera. Based on visual interpretation all the information can be derived and mapped from the satellite image. The hydrological information derived from satellite imagery in conjunction with collateral data has shown on a separate map overlay in a classified with appropriate symbols. For the preparation of hydrological map overlay, the following sources of information are required: (i) interpretation of satellite imagery, (ii) field visits/surveys, and (iii) meteorological data. Moreover the following details have to be shown in hydrological map overlay: (i) canal/tank commands, (ii) groundwater irrigated areas, and (iii) rain gauge stations indicating average annual rainfall. Average annual rainfall in the unit of mm has to be given in the legend. This source of rainfall data was obtained from Indian Meteorological Department. Initially, a pre-field hydrological map overlay has to be prepared by visually interpreting the satellite image and taking the help of toposheet. Subsequently, during the field surveys,

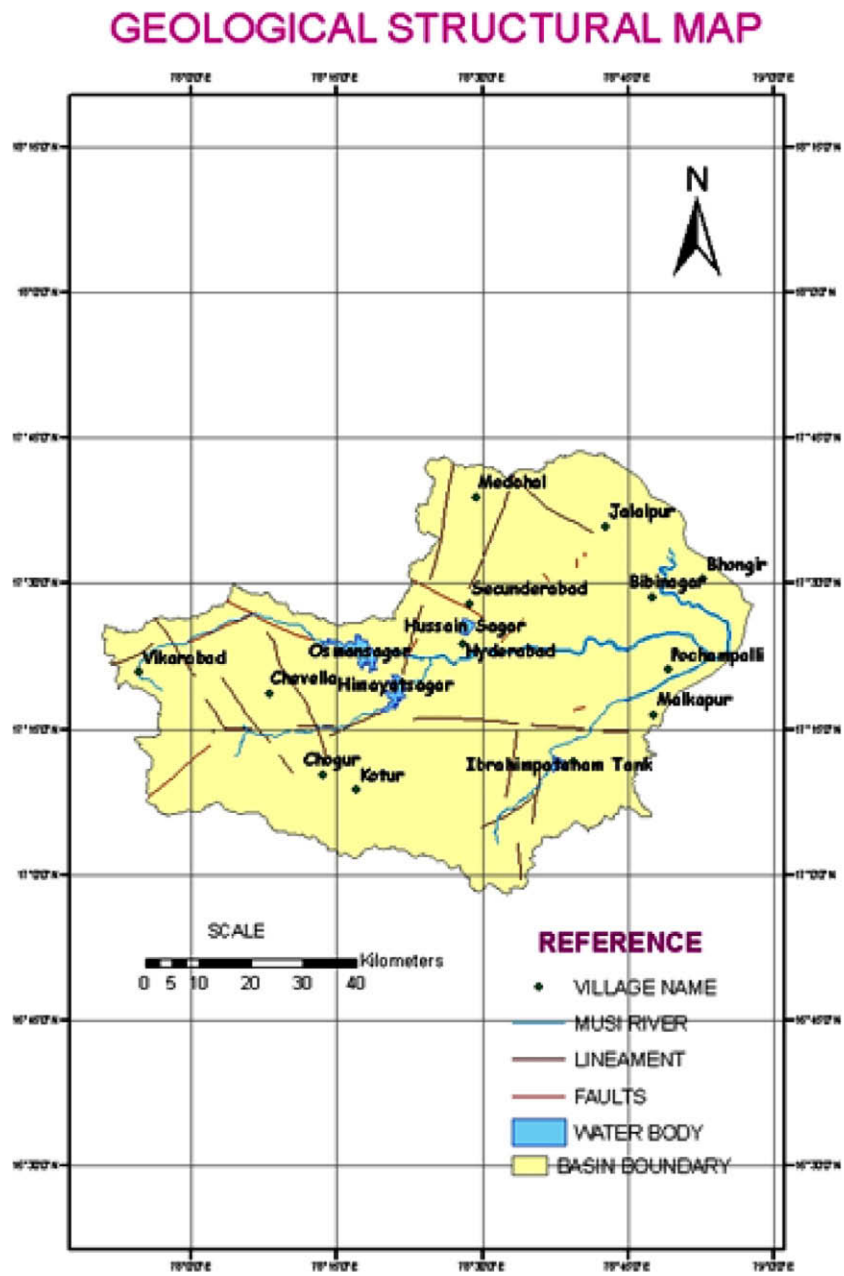

Fig. 9. Geological structural map of Musi sub-basin.

necessary information on the surface and groundwater irrigated areas, cropping pattern, command areas, existing wells, etc have to be collected and incorporated for preparing the hydrological map overlay.

3.7. Preparation of land use/land cover classification

Land use/land cover map was prepared for Kharif (south-west monsoon season) using Land Sat Thematic Mapper Remote Sensing Data with special emphasis on irrigated areas in the Musi basin. Geocoded Land sat TM data was digitally classified in ERDAS Software package using supervised classification technique along with limited ground truth for mapping the broad categories. A hierarchical classification system based on the modified Anderson classification scheme with the ten criteria [1] was adopted for the present study. The parallelepiped supervised classification technique was applied as it has been widely used decision rule which is based on simple boolean -and/or- logic. Training data in n spectral bands are used in performing the classification. Brightness values from each pixel of the multispectral imager are used to produce an n-dimensional mean vector, $M_c = (\mu_c^1, \mu_c^2, \mu_c^3 \ldots \mu_c^n)$, with μ_c^k being the mean value of the training data obtained for class c in band k out of m possible classes.

Ground truth was conducted during October 2004 to coincide with the peak *Kharif* crop growing conditions. The sampling was stratified by road network or even by footpath access where possible and randomized by locating sites. Class labels were assigned in the field. Classes have the flexibility to merge to a higher class or break into a distinct class based on the land cover percentages

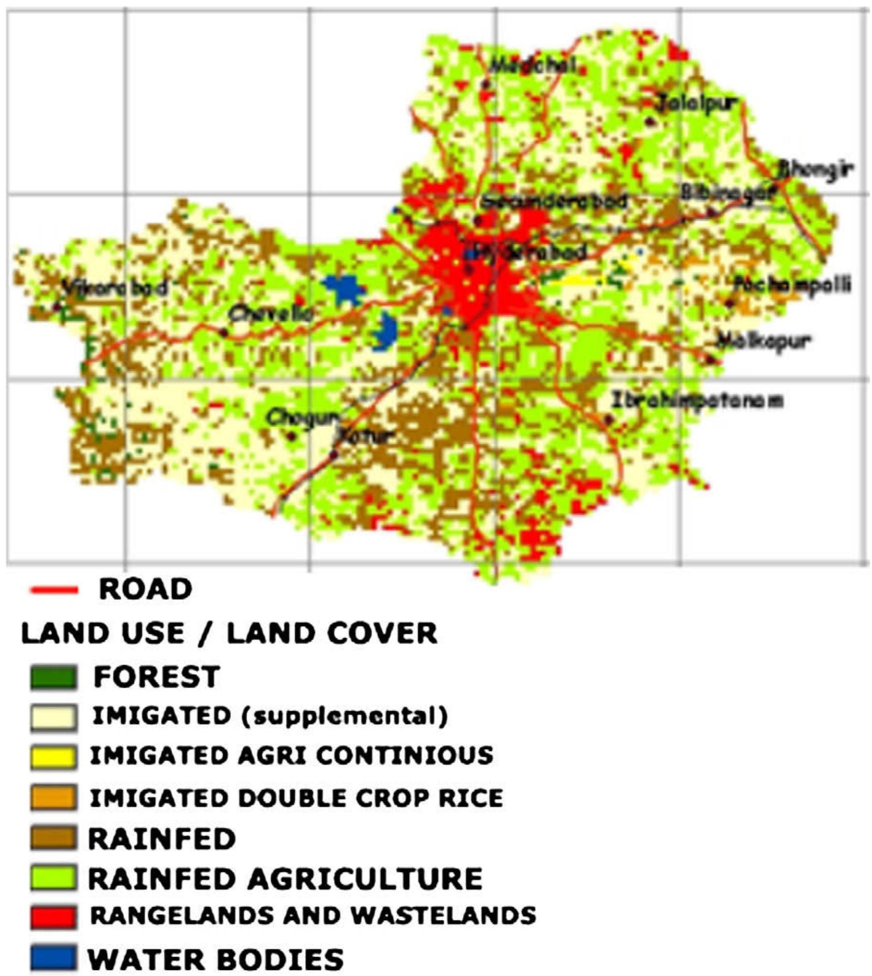

Fig. 10. Land use/land cover map of Musi sub-basin.

Table 1
Land use/land cover classes of Musi River basin.

Sl. no.	Land use/land cover class	Area in percentage of total area (%)	Area in km^2
1.	Forests, dense and contiguous	0.9	50.72
2.	Irrigated supplemental	34.7	1955.41
3.	Irrigated agriculture continuous	0.2	11.27
4.	Irrigated agriculture double crop rice	1.0	56.35
5.	Rainfed + supplemental	22.7	1279.19
6.	Rainfed agriculture	33.3	1876.52
7.	Rangeland and wasteland	6.6	371.92
8.	Water bodies	0.6	33.811

taken at each location. The precise locations of the samples were recorded by a Garmin Global Positioning System (GPS) Unit in Universal Transverse Mercator (UTM) and latitude/longitude coordinate system with common datum of WGS84. About 8–37 samples per class were obtained in this study.

At each location the following data were recorded:

(i) Land use/land cover (LU/LC) classes (level I, II, III Anderson approach).
(ii) Land cover types (percentage) (trees, shrubs, grasses, built-up, water, fallow lands, weeds, different crops, sand, snow rock and fallow farms).
(iii) Crop types (for *Kharif*, *Rabi* and Summer seasons).
(iv) Cropping pattern (for *Kharif*, *Rabi* and Summer seasons).
(v) Cropping calendar (for *Kharif*, *Rabi* and Summer seasons).
(vi) Irrigated, rainfed, supplemental irrigation (at each location).

A total of eight LULC classes were mapped for *Kharif* (main monsoon rainy season; June-October) season particularly to identify the irrigated area of the Musi basin (Fig. 10). The total areal extent being irrigated through the groundwater (supplemental), rain, canals and tanks is of the order of 5070.9 km^2. The different classes that have been mapped and their area in Square Km are shown

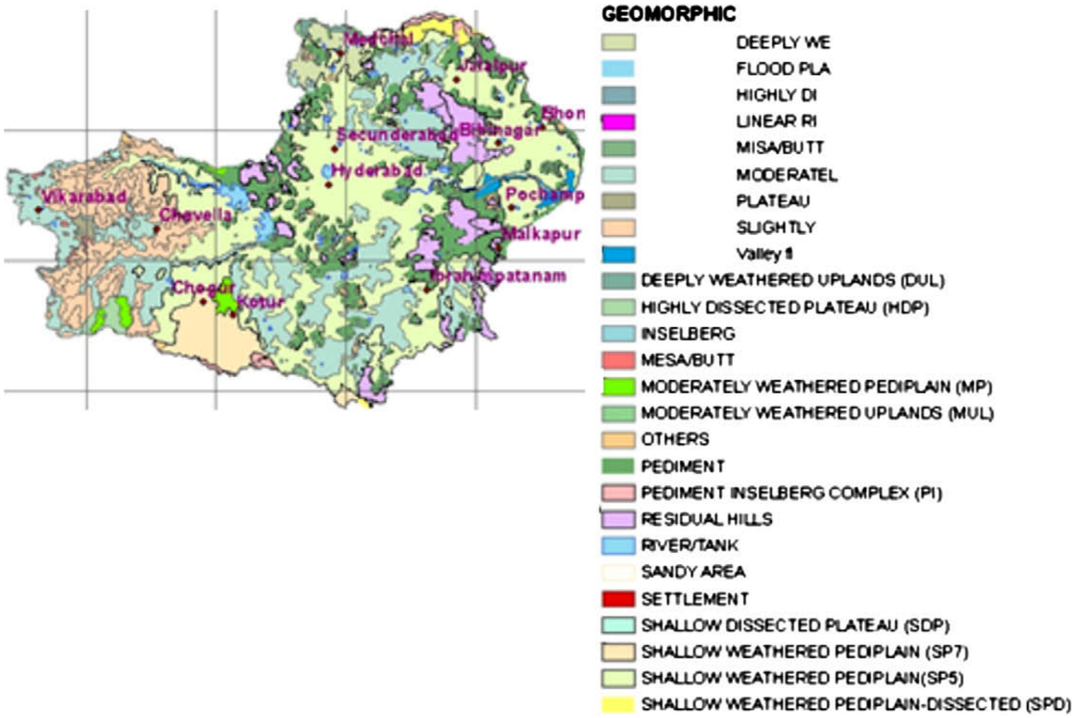

Fig. 11. Hydrogeomorphology map of the Musi basin.

in the Table 1. The irrigated classes have rice as main crop during *Kharif* season.

3.8. Preparation of hydrogeomorphology

Hydrogeomorphically the area is divided into the following hydrogeomorphological units: flood plain, in filled valley, buried pediplain, piedmont plain, linear ridges, residual hills, pediment, plateau, pediment-inselbergs complex, deeply weathered pediplain, moderately weathered pediplain, shallow weathered pediplain, shallow weathered pediplain-dissected, deeply weathered uplands, moderately weathered uplands, Misa/butt, shallow dissected plateau, highly dissected plateau, sandy area, and inselbergs. On the basis of weathering, buried pediplain can be further sub divided into deeply, moderately and shallow weathered pediments. Linear ridges are represented by quartz reefs. The area consists of inselbergs and dykes. The older alluvial plain, deeply buried pediplain and valley fill have good groundwater potential in the area Fig. 11.

3.9. Preparation of groundwater prospects map

For preparing the groundwater prospects map (Fig. 12) the following procedure has to be followed. First a groundwater prospects map has to be prepared by integrating the information from lithological, structural, geomorphological and hydrological maps in ArcGIS as indicated below steps.

Step 1: Create a fresh layer in ArcGIS software and transfer the integrated lithological – geomorphic units by superimposing the lithological and geomorphological map overlays. These integrated lithologic–geomorphic units result in the hydrogeomorphic units and have to be annotated with alphanumeric codes (e.g., PPS-71, PPD- 81, etc.) wherein the alphabetic code represents the geomorphic unit and the numeric code stands for the lithologic unit.

Step 2: Transfer the geological structures from the structural map overlay on to the integrated lithologic-landform map. The geological structures that act as conduits and barriers for groundwater movement should be drawn in blue and red colors.

Step 3: Transfer the hydrologic information including all the drainages and water bodies from the hydrological map on to the integrated lithologic-landform-structure map. In addition to above, some of the rivers/streams, major water bodies and metalled roads have also to be transferred on the integrated map for control. To avoid confusion in identifying features, the rivers/streams and water bodies have to be drawn in different color. However, while preparing the final groundwater prospects map prepared digitally, all the rivers/stream and water bodies and entire road network and other details available in hydrology and base layers have to be shown.

All the hydrogeomorphic units occurring in the area have to be listed in the legend following the geological sequence. Then, the groundwater prospects of each hydrogeomorphic unit have to be evaluated by considering the lithological, structural, geomorphological and hydrological information. The groundwater prospects information has to be furnished in a tabular manner in the map legend.

The groundwater potential zones deduced after the integration of hydrogeomorphological and structural maps is shown in the groundwater potential zones map. Various hydrogeomorphic units are grouped into potential zones, moderately potential zones and poor zones. In general older alluvial plain, floodplain, deeply buried pediplain and unfilled valley are covered by thick alluvium and weathered material. Hence, these areas are marked as good to very good prospect zones for groundwater exploration. The moderately deep buried pediplain, shallow buried pediplain and lineaments are grouped as moderate to good zones and lineaments are grouped as moderate to good zones. The piedmont plain, denudational hills, linear ridge and inselbergs are grouped as poor zones.

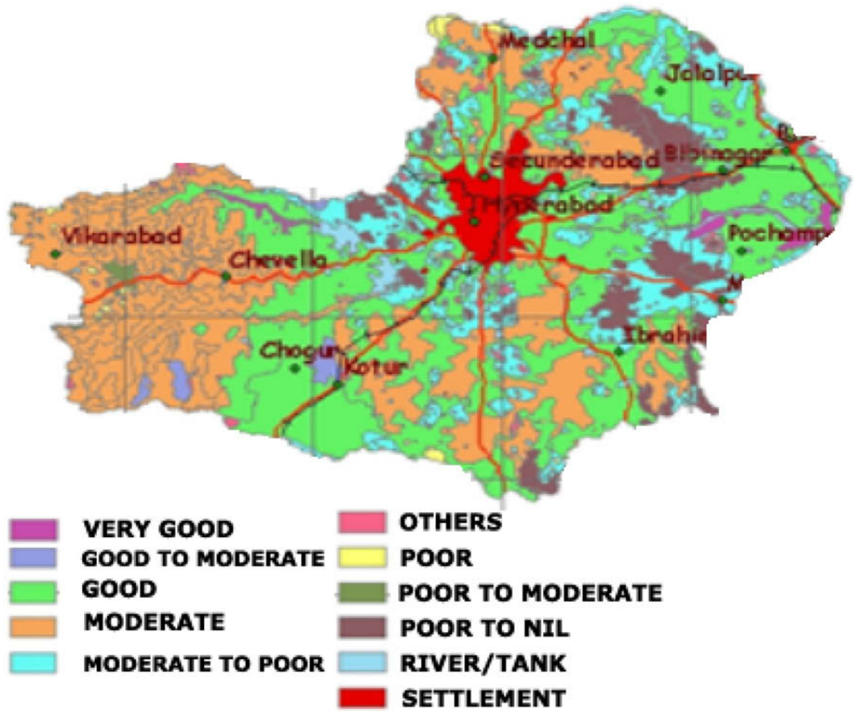

Fig. 12. Groundwater prospect zones map of Musi sub-basin.

4. Conclusions

Mapping of groundwater resources have been increasingly implemented in recent years because of increased demand for water. The data most commonly available for groundwater study are geological, geomorphological and hydrological information. In this study we attempted to identify groundwater potential zones using remote sensing and geographic information system techniques in the Musi basin.

To demarcate the groundwater availability of the Musi basin, various thematic maps such as, base map, lithological map, geological structural map, geomorphology map and hydrological map were prepared from remote sensing data, topographic maps, geology maps and hydrogeomorphology maps using Arc GIS and ERDAS software and these maps are integrated for preparing groundwater prospects map.

The hydrogeomorphological units such as flood plain, valley fill and deeply buried pediplain are prospective zones for groundwater exploration and development in the study area. Presence of faults and lineaments in the area enhance the potential of these units.

References

[1] Anderson JR, Hardy EE, et al. A land use and land cover classification system for use with remote sensor data 1976.

[2] Das P, Bahara SC, et al. Hydrogeomorphological mapping in ground water exploration using remotely sensed data – a case study in Keunjhar District, Orissa. J Ind Soc Remote Sens 1997;25(4):247–60.

[3] Gustafsson P. High resolution satellite data and GIS as a tool for assessment of groundwater potential of semi arid area. In: IXth thematic conference on geologic remote sensing, vol. 1. Pasadena, CA; 1993. p. 609–619.

[4] Jain PK. Remote sensing techniques to locate ground water potential zones in upper Urmil River basin, district Chatarpur-central India. J Ind Soc Remote Sens 1998;26(3):135–47.

[5] Krishnamurthy J, Venkatesesa KN, et al. An approach to demarcate ground water potential maps through remote sensing and GIS. Int J Remote Sens 1996;7:1867–84.

[6] Martinez J-M, Le Toan T. Mapping of flood dynamics and spatial distribution of vegetation in the Amazon floodplain using multitemporal SAR data. Remote Sens Environ 2007;108(3):209–23.

[7] Minor T, Carter J, et al. The use of GIS and remote sensing in groundwater exploration for developing countries. In: Proceedings of the tenth thematic conference on geologic remote sensing. San Antonio, Texas, USA, Environmental Research Institute of Michigan, Ann Arbor, MI; 1994.

[8] Rao CG, Reddy BR. Application of remote sensing for mapping of irrigated areas using treated water in the Hyderabad and environs. J Assoc Environ Geochem 1998;1(1):91–2.

[9] Reinartz P, Lehne M, et al. First results on accuracy analysis for DEM and orthoimages derived from SPOT HRS stereo data over Bavaria 2003.

[10] Richards C, Roaza HP, et al. Applying GIS to groundwater assessments. In: Proceedings of AWRA symposium on GIS and water resources held in Ft.Lauderdala, Florida. USA: Florida Ft. Lauderdale; 1996.

[11] Sander P. Water well siting in hard rock areas: identifying promising targets using a probabilistic approach. Hydrogeol J 1997;5(3):32–43.

[12] Sikdar PK, Chakraborty S, et al. Land use/land cover changes and groundwater potential zoning in and around Raniganji coal mining area, Bardhaman District, West Bengal – a GIS and remote sensing approach. J Spatial Hydrol 2004;4(2):1–24.

[13] Singh AK, Prakash SR. An integrated approach of remote sensing, geophysics and GIS to evaluation of groundwater potentiality of Ojhala subwatershed, Mirzapur district, UP, India. Map India conference; 2003.

[14] Subramanian KSS, Sing A, et al. Evaluation of digital models created from different satellite images; 2003. <http://www.gisdevelopment.nt/technology/r/mio3079.htm>.

[15] Teevw RM. Groundwater exploration using remote sensing and a low cost GIS. Hydrogeol J 1999;3(3):21–30.

[16] Todd KD. Ground water hydrology. 2nd ed. New York: John Wiley and Sons; 1980.