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Geo-Environmental and Geo-Hydrological Study of Rajghat Dam, Sagar (M. P.) using Remote Sensing Techniques

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Abstract— This study was conducted on the Rajghat dam situated in Sagar District of Madhya Pradesh, India; the remote sensing techniques have been proved to be very efficient in identification geo-hydrological and geo-environmental aspects of the study area. In the present paper IRS-P6 LISS-IV Mx (5.8 m) data has been used. The various thematic maps have been generated and integrated on 1:15,000 scale. Geology, geomorphology, hydro-geomorphology, geo-hydrology, structure, soils, erosion, and land use land cover helped in identification of the potential zones for development planning and forecasting limitations to their implementation with seasonal accuracy. Lineaments and their intersections appear to be potential sites for groundwater. Bewas drainage basin is suitable for surface reservoirs and check dams. The study shows that the integration of all attributes provide more accurate results in identification of geo-environmental and geo-hydrological characteristics.

Index Terms— Geo-environmental, geo-hydrological, hydro-geomorphology, and remote sensing

1 Introduction

Geo-environmental, geo-hydrology, and groundwater exploration means to identify and to locate the zone of occurrence and recharge of groundwater in a particular basin or a catchment. Geological set up is established for knowing about surface and subsurface nature of terrain. In other words, the composition of rock with its hydrological character is known. Topographic and surficial features are mapped in order to determine from highest to lowest area, where water from different higher places can move and accumulate. These particular zones are present in various terrains. The identification of such focal places from the entire area, are thus selected for groundwater exploration.

For integrated resources development and environmental management planning remote sensing is providing useful base line information, in conjunction with ground truths on soils, land use, vegetation, surface & groundwater, geology, landforms, topography, settlements, among others, in a regional perspective. Remote Sensing techniques are now being widely used for land resource surveys. Its importance of having fairly accurate, updated and timely information on natural resources for planning effective development cannot be over-emphasized. Data collection is costly and time consuming; hence, it is important that more efficient means of data collection be developed and utilized. In this regard, the utility of remote sensing technology in obtaining reliable, timely natural resources related information in a speedier manner for data base generation is well recognized. The technology is fast progressing.

In recent years many researchers such as [1], [2], [3], [4], [5], [6], [7], [8], [9], [10], [11], [12], [13], [14], [15], [16], [17], [18], [19], [20], etc., have shown the value of remote sensing technique for mapping of geo-environmental, and geo-hydrology aspect with geological studies. This paper attempts an overview of the application of remote sensing to geo-environmental and geo-hydrological studies of Rajghat dam, Sagar (M. P.).

2 Study Area

The catchment area of Bewas river at the dam site is 472 Sq. Kms is located between 23° 23' 36" N to 23° 46' 22" N latitude and 78° 30' 32" E to 78° 46' 42" E longitude. The Bewas River originates from the northeast part of Raisen district located at about 720 meter near the Pipalia Katan. The dam site is situated in three rivers i.e. Bewas River, Parkul River, and Jamunia River junction at Hinota village, Sagar (M. P.). Bewas River is 53.03 Kms, Parkul River is 33.93 Kms, and Jamunia River is 18.05 Kms long at the dam site. The study area falls in Survey of India (1:50,000) toposheets No. 55I/9, 55I/10, 55I/11, and 55I/14, fig. 1).

The dam is 1680.0 m long with 400.0 m masonry spillway, and remaining 1280.0 m is constructed from stone, and soil. The catchment area at dam site is 472 Sq. Kms with 1700-hectare submergence area. The total water capacity of dam is 96.0 million cubic meter with 80.0 live storage, and 16.0 dead storage. Bed level of river is 495.0, minimum sill level is 509.0 m, maximum water level is 518.0 m, and maximum bed level is 520.0 m at dam site.

The normal annual rainfall of the study area is 1234.8 mm about 90% of the annual rainfall takes place during the southwest monsoon period i.e. June to September only 5.5% of annual rainfall takes place during winter and about 4.5% of rainfall occurs during the summer months. January is the coldest months with the temperature falling as low as 11.6^{0}C and max up to 24.5^{0}C, and in the month of May, the temperature goes up to 40.7^{0}C.

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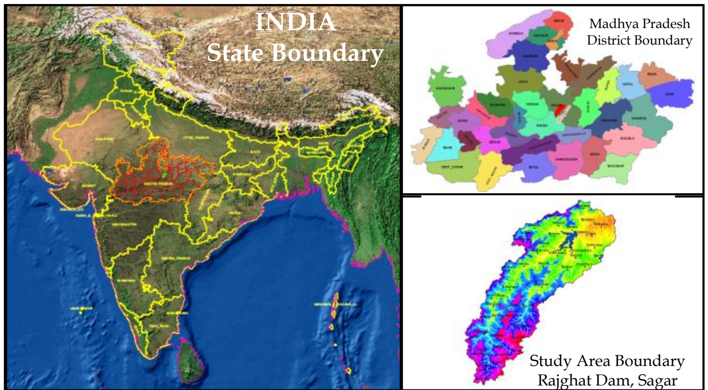

Fig. 1. Index Map of Rajghat Dam, Sagar (M. P.)

3 Data Used and Methodology

TABLE 1
DATA SOURCE AND METHODOLOGY

S. No.	Thematic Layer and Data Source
1.	Remote Sensing Data
	a. IRS-P6 LISS-IV Mx data (5.8 m), Dated: April 16, 2010
	b. LANDSAT-7 ETM+ Data (30 m), Dated: 02 December, 2009
	c. ASTER - DEM (30 m), Dated: 22 August, 2006
2.	Topographical Map
	a. :250,000 Scale - 55 I
	b. 1:50,000 Scale - 55I/9, 55I/10, 55I/11, and 55I/14
3.	Geological Map
	a. Sagar District Geological Map has been collected from Geological Survey of India, Bhopal, and updated through satellite remote sensing data i.e. IRS-P6 LISS-IV Mx, and LANDSAT-7 ETM+ Data with limited field check
4.	Drainage and Slope Map
	a. Drainage network has been generated in GIS environment using ASTER - DEM data and ArcHydro Tool in ESRI ArcGIS 9.3.1
	b. Slope map has been created using Spatial Analyst Extension in ArcGIS 9.3.1, and DEM data with 30 m spatial resolution
5.	Land Use and Land Cover Map
	a. Digitally land use and land cover map has been prepared using knowledge classification method in ERDAS IMAGINE 2010, and satellite remote sensing data i.e. IRS-P6 LISS-IV Mx, and LANDSAT-7 ETM+ Data, and it was also verified through limited field check

4 Results and Discussion

4.1 Drainage Network

Drainage network analysis is important for geo-environmental and geo-hydrological studies. Drainage density of a region depends on the climatic factors, landforms, slopes and stage of geomorphic cycle, lithology and its permeability etc. Hence, drainage density is an important index in geo-hydrological studies, and can be evaluated from aerial photographs. [21] have emphasized that permeability has a fundamental influence on drainage density. In bedrock areas, drainage textures and patterns depend, among others, on the lithological character of underlying rocks and their structural disposition. A drainage map of the study area has been prepared using the IRS-P6 LISS-IV Mx (5.8 m) on 1:50000, fig. 2. The drainage patterns depicted from the fig. 2 are dendritic pattern, rectangular pattern, and radial pattern.

Drainage density the stream length per unit area in region of drainage basin [22], [23], [24], [25], and [26] are another element of drainage analysis, which provides a better quantitative expression to the dissection and analysis of land form, although a function of climate, lithology and structures and relief history of the region etc. can ultimately be used as an indirect indicator to explain, those variables as well as the morphogenesis of landform. The drainage density of the catchment area is in the order of 3 to 6 km / km^2, fig. 3.

4.2 Slope Analysis

Slope is the most important and specific feature of the earth's surface form. Maximum slope line is well marked in the direction of a channel reaching downwards on the ground surface. In any region valley slopes, occupy most of the area of erosional relief in greater extent in comparison to flood plains, river terraces and other local depositional landforms. In geomorphology, the slope is combined effect of 'form' (Environmental conditions of slopes such as the geology, climate and vegetal cover) and 'process' (agents, such as soil creep, surface wash and the process of weathering). 'Form' and 'Processes' - both have existed right from the remote past. The sequence of the past forms prepares the way for the present ones, and this constitutes the evolution of a slope.

There are many contributions to slope-geomorphology and various methods of representing the slope, but the contributions made by [27], [28], [29], [30], [31], [32], [33], [34], [35], [36], and [37] are very important, fig. 4.

4.3 Lithology

In order to understand the groundwater conditions of the study area, a general lithological map has been prepared with the help of IRS-P6 LISS-IV Mx data and shown in Fig. 6. The important rock formations existing in the area are Upper Vindhyan Sandstone, Deccan Traps Basalt, and Alluvium.

In the Vindhyan sandstones, primary porosity varies from negligible to high depending on the degree of compaction. The storage and movement of ground water in these formation is controlled mainly by the secondary porosity and permeability created due to weathering jointing and fractured. Ground water occurrence is good along the lineaments and

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their in trisections and occurs under water table condition. Deccan traps are the most important formations in the study area due to their large aerial extent. The weathered jointed, fractured and vesicular units of basalts form moderately potential aquifers. The zeolitic basalt in weathered form also makes good aquifer. A common weathering product of the trap is a friable light greenish or yellowish green. Basalt Vindhyan contact is not a promising zone. The alluvial deposits are confined mostly to the area along the river courses and in the northeastern parts of the study area. It is composed of fine to medium sand, silt, clay and kankar, which are high potential aquifers.

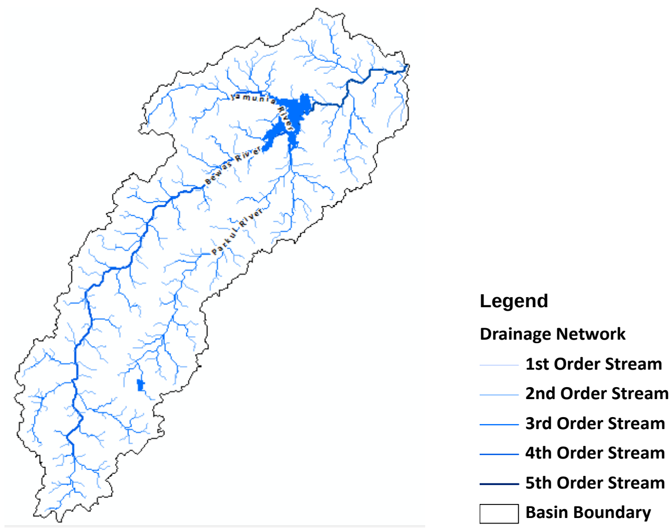

Fig. 2. Drainage Network Map

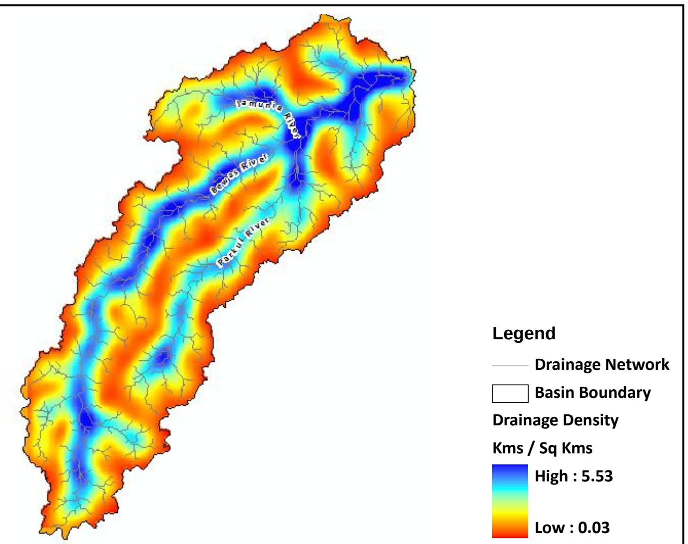

Fig. 3. Drainage Density Map

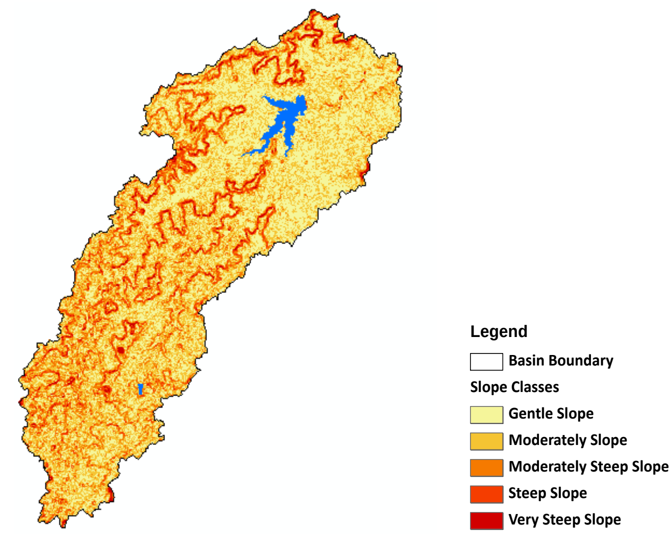

Fig. 4. Slope Map

4.4 Structure

Lineaments play significant role in groundwater exploration particularly in hard rocks. Water well yields often show a positive correlation with linear features or with the intersection of two features [38], and [39]. Therefore, groundwater prospecting based on mapping of landforms and lineaments (Hydro-geomorphological mapping) is now very common using remote sensing data [40], [41], and [42]. Lineaments are defined as linear features of geological significance extending in length over several kilometres. These linear features usually represent faults, fractures or shear zones and are identified on satellite images on the basis of tonal contrast, stream / river alignment, and differences in vegetation and knick-points in topography.
Lineament study of the area from remotely sensed imagery provides important information on sub-surface fractures that may control the movement and storage of groundwater [18]. Therefore, a lineament map of the study area has been prepared using IRS-P6 LISS-IV Mx data. A glance at this map shows that there are four predominant sets of lineaments present in the basalt. One set of lineament trend NE-SW whereas the other striking NW-SE. The fracture density is more in the Karaia, Bakswah, Bilehra, and Jasarathi Village, Fig. 7.

4.5 Hydro-Geomorphology

Application of remote sensing in geology and geomorphology for quick geo-hydrological evaluation has been proved to be very effective tool. [43] made an attempt to describe the hydro- geomorphological units coupled with geological parameters in Kotipally catchment area of Hyderabad. Similar studies on other river basins of India were also attempted such researchers as [44], [45], [46], [47], [48], [49], and [50].

A combined analysis of landforms (geomorphology), rocks as well as structures (geology) such as faults, folds, fractures etc. in relation to groundwater occurrence aspects with the help of remote sensing of ground truth is considered very useful in preparing integrated hydro-geomorphogeologic maps for

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targeting groundwater. According to [12], the factors which control the groundwater occurrence and movement are:

Geology	Lithology, and Structure
Geomorphology	Topography, drainage pattern, and density
Land Use & Land Cover	Vegetation, open/waste lands, agricultural lands
Soil and Erosion	Depth, type & moisture content, soil erosion

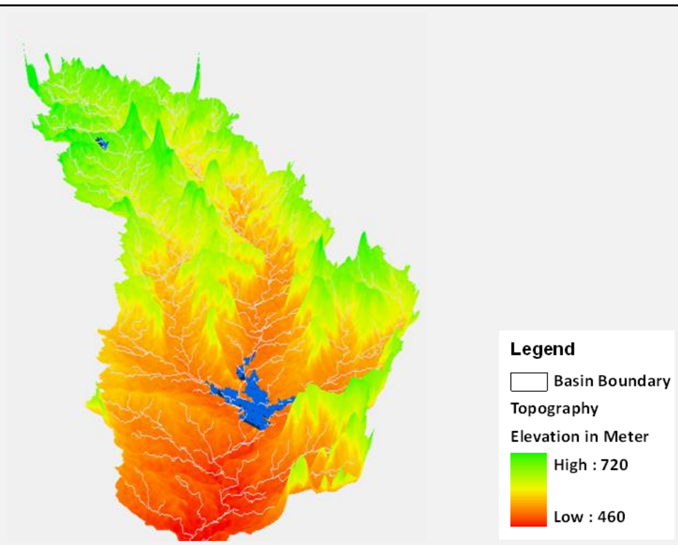

Fig. 5. 3D View of the Study Area

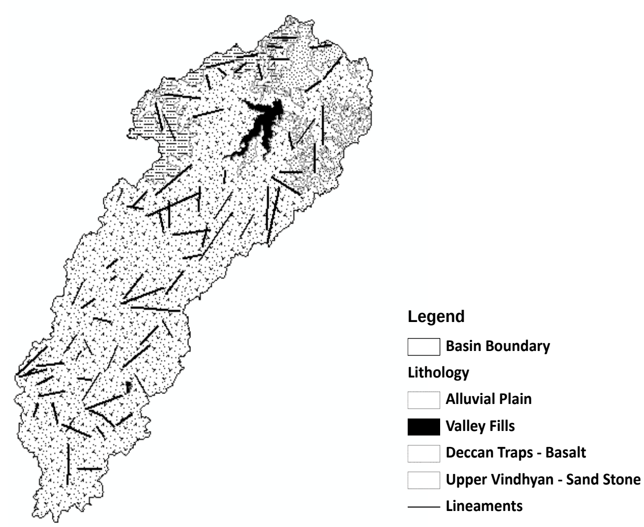

Fig. 6. Geological Map

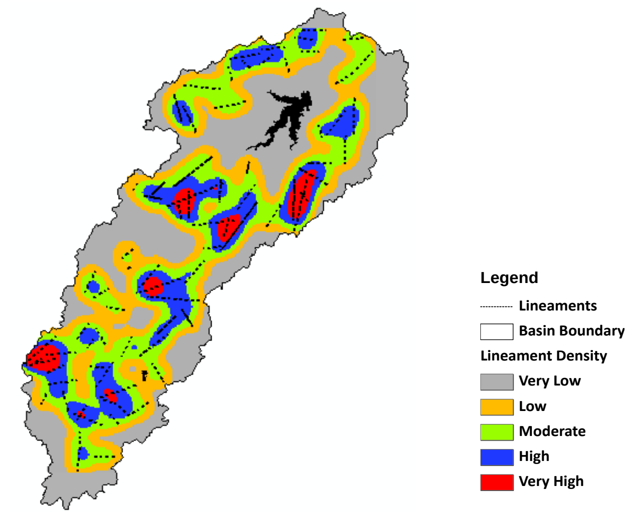

Fig. 7. Lineament Density Map

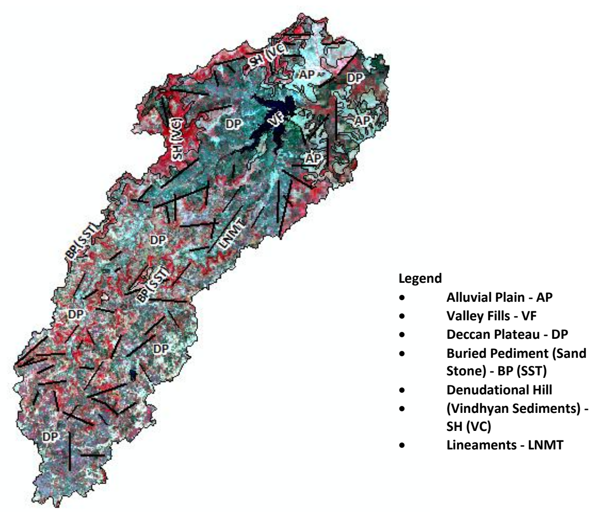

Fig. 8. Hydro-Geomorphological Map

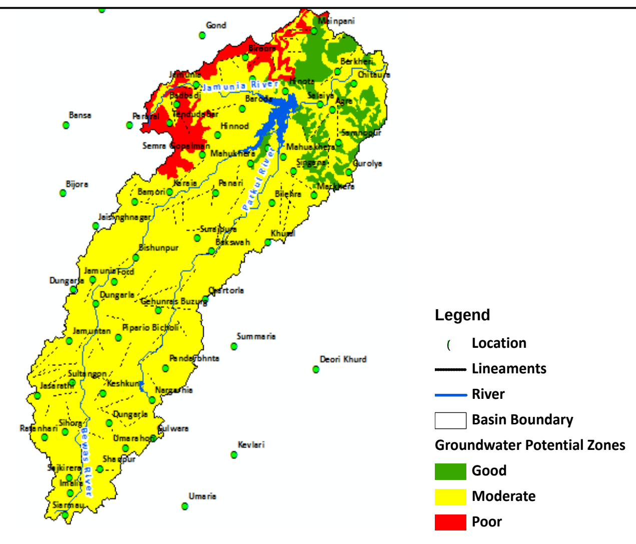

Fig. 9. Groundwater Potential Zones

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Hydro-geomorphological map of the study area was prepared using IRS-P6 LISS-IV Mx data; and following hydro-geomorphological units are delineated on the hydro-geomorphological map, Fig. 8.

a. Alluvial Plain - AP, Valley Fills – VF
b. Deccan Plateau - DP
c. Buried Pediment (Sand Stone) - BP (SST)
d. Structural Hills (Vindhyan Sediments) - SH (VC)
e. Dykes - DYK, Lineaments - LNMT

TABLE 2
HYDRO-GEOMORPHOLOGICAL UNITS OF RAJGHAT DAM

Map Symbol	Lithology	Structure	Description or Characteristics	Ground Water Occurrence
AP	Constitutes gravel, sand, silt, or clay sized unconsolidated material	-	A level or gently sloping tract or a slightly undulating land surface produced by deposition of alluvium	Good to excellent depending upon alluvium thickness
VF	Constitutes boulders, cobbles, pebbles, gravels, sand, silt, and clay sized grains of varying lithology	The Valleys sometimes fracture controlled	The unconsolidated sediment deposited so as to fill a valley. Sometime controlled by fracture forming linear depression	Good to excellent depending upon type of lithology and thickness of the material deposited
DP	Composed of basalt of Deccan traps	Jointed and fractured	Low relief undulating topography. Normally cultivated soil thickness varies from place to place	Moderate, good along lineaments weathered zone and depressions
BP(SST)	Vindhyan sand stone dominating the underlying lithology	-	Broad, gently sloping, erosional surface covered with detritus of sandstone and thin veneer of soil	Moderate
SH(VC)	Composed of sand stone, silt stone etc. of Vindhyan super group	Associated with folding, faulting etc.	Linear to actuate hills showing definite trend lines	Poor, moderate to good along linear inner hill valleys
DYK	Intrusive of quartz	-	Quartz intrusions that cut across the rock	Moderate to good on up gradient
LNMT	Cut across various lithology	Fault, fractures etc.	Fault line, fractures, joints, shear zone, contact zones, other linear features and straight stream courses	Good, excellent at inter section of lineament

Geomorphic Units ; AP = Alluvial Plain, VF = Valley Fills, DP = Deccan Plateau, BP(SST) = Buried Pediment (Sand Stone), SH(VC) = Structural Hills (Vindhyan Sediments), DYK = Dykes, LNMT = Lineaments

To find the fracture density of these hydro-geomorphic units, lineaments have been marked on the hydro-geomorphological map. It indicates that the alluvial plain (AP), valley fills (VF), Buried pediments (BP-SST), and lineaments (LNMT) are excellent hydro-geomorphic units from the view of occurrence and movement of groundwater. They are good groundwater potential zones of the study area. The description of different hydro-geomorphic units of Rajghat dam, Sagar has been given in Table-2 and depicted in Fig. 8.

4.6 Land Use and Land Cover

Land is the most important natural resource, which embodies soil, water and associated flora and fauna involving the total ecosystem. Comprehensive information on the spatial distribution of land use/land cover categories and the pattern of their change is a prerequisite for management and utilization of the land resources of the study area. The land use pattern of any terrain is a reflection of the complex physical processes acting upon the surface of the earth. These processes include impact of climate, geologic and topographic conditions on the distribution of soils, vegetation and occurrence of water. For better development and management of the catchment areas of reservoirs, it is necessary to have timely and reliable information on environmental status.

Keeping the above views in mind, the authors have prepared a land use/land cover map, Fig. 10 using IRS-P6 LISS-IV Mx data. This figure depicts that there are four units of land cover/land use pattern in the study area, which are given below and shown on the map.

Agricultural land: Fallow Land, Land with Shrub; Open Land; Forest: Deciduous Forest, Degraded Forest; Water Features

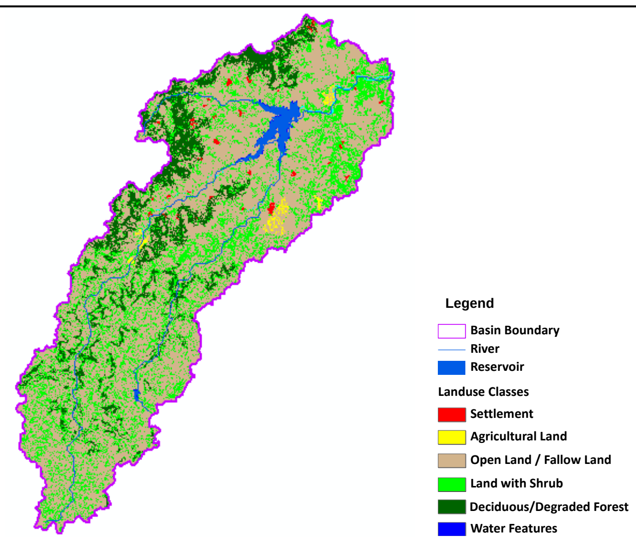

Fig. 10. Land Use / Land Cover Map - 2010

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4.7 Ground Water Scenario

The occurrence and movement of groundwater depend upon the rock formations present in the area. It also depends upon the topography, structure, and geomorphology, as well as hydro-geological properties of the water-bearing materials. The hydrogeological properties of water-bearing formation with a view to throw light on any possibility of inflow of ground waters from the hard rock as well as unconsolidated hydro-litho units into the aquifers of the study area.

Alluvium comprises of silt, sand, gravel, and clay particles, it is an excellent aquifer; basalt belongs to Deccan Traps, and sandstone belongs to Vindhyan Supergroup, it is a moderate aquifer in the study area. Depth to water level represents the position of water table with reference to ground surface, Fig. 11 - Groundwater 3D Model of the Study Area.

4.8 Groundwater Favourable Zone

A groundwater favourable zonation of the study area has been analyzed by the using of ModelBuilder Application in ESRI ArcGIS 9.3.1 with the lithological structural, lineament density, drainage density, land use, hydro-geomorphological elements, and the background of the survey of India topographical maps on 1:50,000 scale. On the basis of integration of these maps groundwater favourable zones of the study area were identified.

The groundwater favourable zones are shown in Fig. 12. On the above considerations, the various hydro-geomorphic units have then been classified into five categories of groundwater potentiality namely, very good, good, moderate, poor and very poor.

The hydro-geomorphological units such as Alluvial Plain, Valley Fills, Deccan Plateau, Buried Pediment (sand stone) are most favourable zones for groundwater exploration & development in the study. Hence, these areas are marked as good to very good favourable zones. These zones are distributed mostly in the north, and middle of the study area and only some few in the southern portion of the area. A glance at Fig. 12 reveals that the northern part and some of the southern part of the study area have excellent groundwater potential as compared to the upper middle basin and east-south-eastern part of the basin. These are also verified from field check. This information is very useful for the further groundwater development in the study area.

5 Conclusion

Remote sensing techniques with an emphasis on geology, geomorphology, physiography, hydro-geomorphology, structure, geo-hydrology, land use/land cover help in identification of the potential zones for developmental planning and predicting limitations to their implementation with reasonable accuracy. Lineaments particularly joints/fractures and their intersection appear to be potential sites for groundwater exploitation. The valley fills and burried pediments are good groundwater potential zones. From the drainage analysis, it is clear that the Bewas catchment is suitable for surface reservoir and check dams.

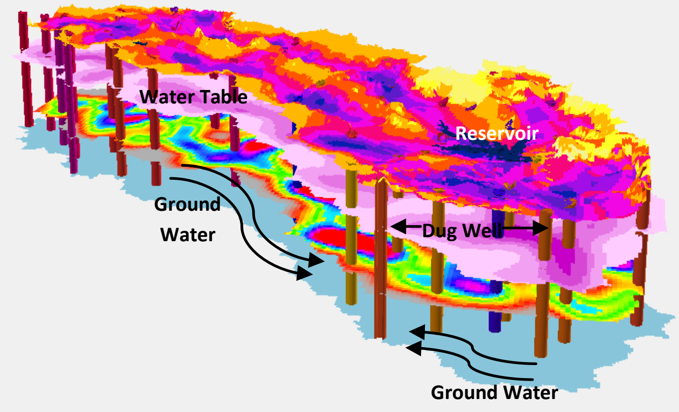

Fig. 11. Groundwater 3D Model of the Study Area

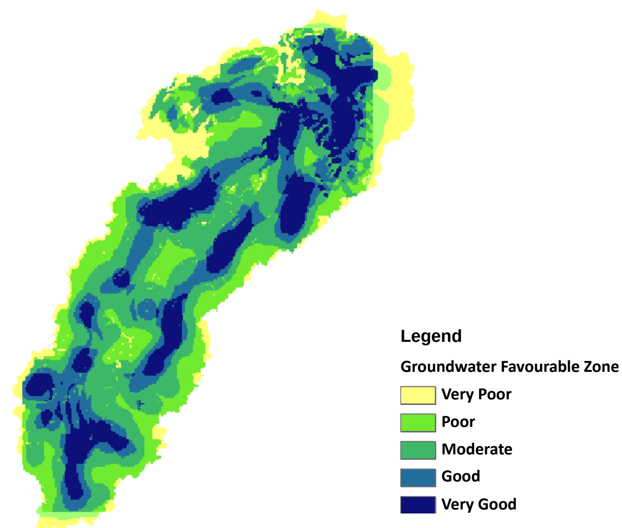

Fig. 12. Groundwater Favourable Zone Map of the Study Area

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