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GROUND WATER POTENTIAL ZONE DELINEATION USING GEOSPATIAL TECHNIQUE : A CASE STUDY OF BIKANER BLOCK, RAJASTHAN, INDIA

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ABSTRACT

One of the most precious natural resources, groundwater is crucial for socioeconomic, ecological, and environmental processes. Through the use of remote sensing and geographic information systems, the current study was done at Bikaner Block of Rajasthan, India during 2021-2022. This study seeks to define the groundwater potential of the Bikaner block of Rajasthan, India. In a GIS setting, a number of groundwater-influencing elements are mapped during this year, including geology, geomorphology, and water table level. Later, these variables were graded according to how much of an impact they had on a region's potential for groundwater. After that, a groundwater potential map of the Bikaner Block was created by combining all these parameters in a GIS context. Applying the influencing factor, it is found that 21%, 50%, and 29% of the lands, respectively, fall into the high, moderate, and low groundwater potential zones. Zones with moderate to extremely high groundwater potential were situated in the south-eastern, south-western, north-eastern, and central regions of the study region. The politicians, administrative organisations, and engineers who are responsible for managing groundwater and creating sustainable water resource plans in the Bikaner Block will find the current study to be of great value. Overall, this study provides a convenient approach of delineating the potential of groundwater availability which ultimately will aid in better planning and managing of groundwater resources. The current report will also aid in developing a plan for artificial groundwater recharge in the research area.

(Key words : Remote sensing, GIS, ground water, geomorphology)

INTRODUCTION

Groundwater accounts for 0.61% of the world's total water resources. An alarming drop in water availability in India is expected to take place between 2001 and 2050 (Shekhar and Pandey, 2015). Water shortages in India have been exacerbated by the widespread use of water pumps and tubewells for agricultural purposes. Groundwater is the primary source of water supply in Rajasthan because there are no reliable surface water sources in most of the state's areas. Over-exploitation of groundwater and arid and sub-humid climatic conditions has had a severe impact on the quality and quantity of groundwater (Jadhav *et al.*, 2011). The aim of the study was groundwater exploration and their management in Bikaner Block, Rajasthan. For the same location, we were also discussed the demarcation of groundwater potential zones. Therefore, in order to maximise the use of groundwater, it is important to conduct studies on the petro physical features of the water-bearing materials, water balancing, hydro-chemical analysis, and so forth.

Groundwater dynamics monitoring at the regional or district level was almost impossible due to time, effort and financial investment constraints, despite national and state efforts to do so. In addition, such regional efforts become fruitless because they do not contribute to the formulation of national and state groundwater management strategies and policies. Agro climatic zones, for example, are already defined by government organisations, thus groundwater potential and use should be assessed at that level. The complicated agro climatic zone of Rajasthan necessitates a groundwater potential evaluation and demarcation in order to increase the groundwater resource urgently. Because these management projects align with the government-declared key zones, they can be used to assist formulate new regulations. In the words of Jamel (2002) economic and social development in Rajasthan, a dry region with little rainfall has heavily reliant on groundwater. Groundwater supply was important for many

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water-related tasks, such as irrigation and getting drinking water to people. As a matter of fact, 71% of the irrigation and 90% of the drinkable water supply were dependent on groundwater.

To maintain quality and quantity of groundwater while coping with the high pressure of groundwater exploitation by both governmental and private users remains a concern. The scarcity of safe drinking water could be worsened if groundwater is used in an uncontrolled and haphazard manner. In a survey conducted in 2001, 20.8% of groundwater zones were found to be safe, whereas 36.4% were found to be over-exploited.

According to the same assessment, 33.9% of groundwater zones were categorised as critical (Pradhan, 2009; Avtar *et al.,* 2010; Singh *et al.,* 2011; Singh *et al.,* 2009; Acharya, *et al*., 2019). Many factors contribute to groundwater depletion and pollution, including an increase in population, economic growth, and other factors. Furthermore, climate and human-caused declines in groundwater recharge are still important. An overabundance of groundwater resources can be caused by the erroneous installation of a wide variety of groundwater extraction devices, including tube wells and hand pumps. Over-pumping of groundwater has been made worse in recent years by the introduction of new pumping methods. More than a dozen studies have found that those with autism spectrum disorder (ASD) are more likely to be diagnosed with the disorder than those without it. 10.4% of the land area and 5.67% of the people make up Rajasthan, the largest state in India, according to the Office of the Registrar General and Census Commissioner, India. The state can be divided into four distinct physiographic zones and 10 distinct agro-climatic zones, which can be further subdivided. Western desert; Aravalli hills; Eastern Plains and South-Eastern plateau are the four distinct physiographic zones. In the Western Desert, you'll find dry hills, stony plains, and sand-covered plains. South-west to northeast, the Aravalli hills are located in Gujarat (Delhi). Plains of alluvial soils in the eastern region consisting of Chambal Basin, Bahras Plain and the Middle Mahi Plain (Selvam *et al.,* 2015; Jasrotia *et al.,* 2016). By taking into account characteristics like temperature and rainfall as well as geographical location and natural vegetation and soils, the state of Rajasthan has been divided into 10 agricultural zones. The state's agro-climatic conditions range from humid and warm in the south-east to dry and cool in the west. The hyper-arid desert region of Rajasthan is home to the municipality of Nokha, which is located in the district of Bikaner.

Study area

A total area of 30247.90 square kilometers may be found inside the boundaries of Rajasthan's Bikaner district, which is situated in the northwest corner of the state. It lies between north latitudes 27°11' and 29°03' and east longitudes 71°52' to 74°15'. Figure 1 shows the location map of the study area.

MATERIALS AND METHODS

The main goal of this study was to use a geographic information system (GIS) to keep track of and work with many theme layers. We have used Arc GIS 9.3.1 to carry out the required GIS activities. All of these geographic tasks and many more could be done with the help of ArcGIS desktop software solutions. The researchers in this study have used geographic information system (GIS) and remote sensing (RS) technology to create thematic layers of several parameters that affect the presence of groundwater. Figure 2 shows the methodology flow chart of this study.

Collection of thematic layers

Since it was believed that all thematic qualities had some influence on the occurrence of groundwater, a broad variety of thematic maps, including the combined use of RS and GIS techniques, were used to define groundwater favourability zones in earlier studies (Jha *et al*., 2010; Razandi *et al.,* 2015). Eight thematic layers—geomorphology, soil, slope, topographic elevation, land use/land cover, post-monsoon groundwater depth, recharge, and transmissivity—were taken into account while determining the groundwater potential zones in the current study.

Generation of thematic layers

Eight thematic maps were made using remote sensing and conventional data to assess the groundwater potential in the study area. Geomorphology, slope, topographic elevation, land use/cover, post-monsoon groundwater depth, recharge, and transmissivity were all shown on these maps. Topographic elevation and slope maps were produced using ASTER data, and the remaining thematic maps were produced using conventional data. Arc GIS was used to create this set of thematic maps.

Geomorphology map

In this study, we have used the Arc GIS software to scan, fix, and digitise SOI topo sheets in order to generate a geomorphology-focused thematic layer. Following the identification of various geomorphology classes, each was given a relative relevance score based on how important it was to the research's focus on groundwater occurrence or recharge.

Soil map

The residue left behind after physical, chemical, and biological processes have finished acting on and changing a particular material is referred to as soil. How frequently groundwater is present is mostly determined by the soil's capacity to retain water or by its texture. A particular soil's percentage of silt, sand, and clay provides a reliable indication of its texture. Clay soil causes greater runoff and less infiltration than sand, which has wider pores and so allows more water to seep through it, decreasing the groundwater level. 1:250,000 scale soil data for the study area were obtained from the National Bureau of Soil Survey and Land Use Planning (NBSS&LUP).

Slope and Topographic elevation map

Groundwater study relies on slope since it affects water accumulation time. Slope gradient controls runoff infiltration. Less runoff and more infiltration and recharge increase groundwater resources on flatter slopes. A study area slope map was constructed using digital elevation model data (DEM).

This study emphasis on a topographical elevation map as topography (land surface height) affects groundwater potential. Groundwater availability decreases with topographic height (Krishnamurthy *et al*., 1996; Singh *et al*., 2010; Jha *et al*., 2007; Machiwal *et al*., 2011; Shekhar and Pandey, 2015). This project creates a landscape elevation model using USGS topographic data. ASTER's near-global elevation data provided the world's most complete high-resolution digital topographic database. Space Shuttle Endeavour carried the ASTER radar equipment for 11 days in February 2000. Topographic data recorded as 30 m-pixel Geo TIFF raster files.

Land use land cover map

A thematic map of the region's land usage and land cover was made using satellite photos. A land use/ land cover thematic map was made using IRS-1D LISS-III data at a spatial resolution of 23.5 m. The raw satellite images were subjected to digital image processing techniques like geometric rectification, image enhancement, image interpretation, and multispectral classification. Supervised image classification was also used to classify different land uses.

Post monsoon groundwater depth map

After the monsoon season had passed, a map of the depth of the groundwater in the research area was made using Arc GIS data from 60 monitoring points. The generated map was categorised and weighted appropriately from the standpoint of groundwater.

Groundwater recharge map

Any water that enters an aquifer is considered a recharge, whether direct, localised, or indirect. Localized recharge refers to regional recharge from surface topographic depressions such as streams and lakes, whereas direct recharge refers to widespread recharge caused by precipitation or irrigation. Aquatic table at 60 locations in the research region, fluctuation was utilised to calculate the net recharge. A map of the research area's recharging points was created using this data. Graph displaying the radiation's transmissivity the transmissivity of the aquifer, a key element, regulates the pace of groundwater movement and recharge.

Delineation of groundwater potential zones

The Thematic layers on geomorphology, soil, slope, topographic elevation, land use/land cover, post-monsoon groundwater depth, recharge, and transmissivity were used to delineate groundwater potential zones. In order to demarcate the likely zones, weights were assigned to each of these thematic layers before they were integrated using Arc GIS. The relative importance of each landmark on the themed map was determined by expert judgement and knowledge of the terrain. The weights of the various themes ranged from 1 to 5, depending on their potential effect on groundwater levels. Groundwater potential was taken into account, and different facets of each topic were given weights ranging from 1 to 9. Using this scale, we assigned the following ratings to various facets of the theme: poor, fair, good, very good, or excellent. The amount that each theme and feature contributed to groundwater potential was calculated using expert opinion, information, and local knowledge. Eight thematic layers in Arc GIS were given weights, and the layers were then combined (overlaid) to produce groundwater potential zones. By resolving the following equation, the importance of each polygon in the integrated layer was calculated (Bele *et al*., 2021). A dimensionless index called the Groundwater Potential Assess (GWPI) was used to identify locations with high groundwater potential. Polygons with GWPIs in neighbouring zones were grouped together after GWPI values were divided into four equal groups, or "zones," for convenience. As a result, we were able to qualitatively divide the entire research region into four unique groundwater potential zones using Arc GIS software.

RESULTS AND DISCUSSION

Varieties of thematic maps and their distinctive characteristics geomorphology, soil, slope, topographic elevation, land use/land cover, post monsoon groundwater depth, recharge, and transmissivity were the eight theme layers that were developed.

Topography

In the district of Bikaner, one can immediately see vast sand plains and a marked lack of hills. Eolian dunes and undulations in the landscape are distinctive features. The highest point in the district is located in Nokha Block, where Tertiary sandstone outcrops, at 349.1 metres above mean sea level (amsl), while the lowest point is located in Kolayat Block at 103.7 metres amsl. The slope of the ground is generally southeast to northwest. Figure 3 shows the topographical map of Bikaner block.

Rainfall

Unpredictable rain falls, and it pours lightly. The monsoon season receives over 90% of the yearly precipitation, with the remaining months receiving practically little precipitation at all. The annual rainfall averages for all of the blocks were calculated to be 458.2 mm, with the Dungargarh block having the highest average at 595.4 mm. Every year, the Khajuwal block received the least quantity of rainfall. The Lunkaransar area got the greatest annual average rainfall of 781.2 mm.

Geology

In the Bikaner district, alluvial and eolian sand makes up about 80% of the land area. The most prevalent type of eolian sand was found in sand dunes of various heights. Rocks in the region, on the other hand, ranged in age from the Palaeosoic to the Recent. Sandstone formations with various grain sizes are a part of the Tertiary group of rocks, which comes after eolian and alluvial sand. Equally susceptible to these were the region near Kolayat and Bikaner. The Nagaur Sandstones and Bilara Limestone, which make up the Marwar Super Group, were found in the district's southeast. Figure 4 shows the geological map of the study area and Figure 5 shows the geomorphological map of the Bikaner block, Rajasthan.

Aquifers

The aquifers in the Bikaner region are composed of several different types of rock. Only approximately 8% of the district's aquifers contain fresh water in alluvial aquifers, even though older alluvium makes up the most widespread aquifer material. Because they cover around 31% of the district area, of which about 24% is fresh water aquifer, tertiary sandstones are also very good aquifers in terms of both spatial distribution and ground water quality within them. The Nagaur and Jodhpur sandstones, as well as the Jodhpur limestone and a portion of the Bilara limestone, are also significant to maintain the aquifers in the region. Figure 6 shows total Aquifers present in the study area and Figure 7 shows Map of unconfined Aquifer of Bikaner block.

Location of exploratory and ground water monitoring wells

Both the Regional Ground Water Department (RGWD; 145 wells) and the Central Ground Water Board (CGWB); 444 monitoring stations) are spread out across the Bikaner district (49 and 106 respectively). The data from exploration wells was used to sketch out a three-dimensional picture of the aquifer system under the ground. Studies of benchmarking and optimization reveals that the ground water level monitoring network had enough nodes to ensure adequate monitoring, but that an extra 148 wells spread across several blocks would improve water quality monitoring. Figure 8 shows the location of exploratory wells map in Bikaner block, Rajasthan.

Depth to water level (pre-monsoon – 2010)

Water can be found anywhere from less than 10 metres underground to around 120 metres underground. Water has been found at depths up to 120 metres below ground in the hard rock sections of the south east, within Sandstone aquifers, while alluvial aquifers in the west have revealed a shallower ground water occurrence, i.e., up to 30 metres from ground level. Figure 9 shows the depth of the water level in Bikaner block.

Water table elevation (pre-monsoon – 2010)

The water table is highest in the Dungargarh and Nokha blocks in the district's southeastern margin, at an elevation of up to 280 m above sea level. Towards the northwest, the water table gradually decreased, with the lowest point being in the Kolayat block, which is the westernmost area of the district. There is a common water table elevation of 120 m to 160 m above mean sea level over most of the district's middle section. Figure 10 shows the water table elevation map of the Bikaner block.

Water level fluctuation (pre- to post-monsoon – 2010)

A rise in water level of up to two metres was observed in the central region of the district after the monsoons. Water levels in the rest of the district had dropped by 2 metres since the beginning of the monsoon season, which is quite concerning. Even while the water table dropped by more than 6 metres in one area of Block Nokha (near Nokha city), it was raise by the same amount in an adjacent area. Figure 11 shows the water level fluctuation map.

Ground water electrical conductivity distribution

Electrical conductivity distribution map shown in Figure 12. As a general rule, the electrical conductivity of ground water is lower than 2000 S cm^{-1} at 25° C, but it can be as high as 10,000 S/cm at that temperature. Hard rock aquifers in the Dungargarh, southeastern Bikaner, and northern Nokha blocks provide considerable quantities of potable water (2000 S/cm). A significant region in the northwest of the Bikaner block, as well as parts of the neighbouring Khajuwal and Lunkaransar blocks, had low EC since its aquifer created in earlier alluvium. Many areas, including the entire Kolayat block and a sizeable area near Lunkaransar, was affected by the salty brine. The northwest edge and the very south of the Nokha block both contained areas of high salinity. Average EC values from the pre-monsoon seasons of 2005-2009 were used in this investigation.

Ground water chloride distribution

The southwest and northeastern areas of the district showed red zones, indicating very high chloride concentration (>1000 mg). Most of the Kolayat block has a chloride content that was over 1000 mg. The chloride concentration of ground water was moderately high in the Khajuwal, Nokha, and Dungargarh blocks. The areas with the lowest chloride concentration were near the intersection of the Dungargarh, Bikaner, and Nokha blocks and the Lunkaransar, Bikaner border. Figure 13 shows the ground water chloride distribution of Bikaner block.

Ground water fluoride distribution

The highest fluoride concentration greater than 3.0 mg l^{-1} was found in three large, NW–SE-oriented patches: the western section of the Kolayat block, the Khajuwal–Bikaner region, and the area north of Lunkaransar. The concentration of fluoride in the remaining land was mostly moderately high. Fluoride distribution map of Bikaner have been shown in Figure 14.

Ground water nitrate distribution

Low ground water Nitrate concentration (<50 mg) locations were located in the southwest and northwest of Nokha-Kolayat-Bikaner-Lunkaransar region and a broad patch in the western section of the district falling under Khajuwal and parts of Bikaner and Kolayat blocks. Rest of the district had high Nitrate concentration i.e., above 100 mg. Hard rock areas weathered, fractured and jointed rock formations occurred at shallower depths make suitable unconfined aquifers. Such zone spans in thickness from less than 10 metre to roughly 50 metre throughout the middle and southern section of the district. Southernmost part of the district in Nokha block had thickest zone of weathered/ fractured hard rock thickness and the Bikaner –Kolayat-Nokha region had moderate thickness of up to 30 metre. Figure 15 shows the nitrate distribution in Bikaner block of Rajasthan.

Depth to bedrock

Bedrock of varying ages and litho logies lies beneath the thick alluvial deposits. The variation in bedrock depth above ground was seen in Plate XVI. Top of bedrock was conceptualised as beginning at huge bedrock. Sandstones and limestones are the most common igneous rocks in the area. Alluvial deposits of sand, clay, silt, and mixing of these, in varying amounts and thicknesses, lie above these rocks. In the east, the bedrock surface was very undulating, as seen by the depth to bedrock in metres below ground level map, whereas in the northwest, it was reasonably even. A range of 60–260 metres above sea level was possible. Bedrock was thin in the north-eastern corner of the Lunkaransar and Kolayat blocks and in the southernmost half of the Nokha block. The areas of Dungargarh and Lunkaransar, east of Bikaner city, and Kolayat and Nokha, southwest of the city, had the deepest occurrence of bedrock (indicating significant alluvial thickness). Bedrock in the western regions was about 200 metres deep.

The present study demonstrates the utility of remotely sensed satellite image data to identify geological landforms, lineament features, topographical and hydro geomorphological landforms. The integration and analysis of thematic maps and satellite images were adequate for the delineation of groundwater potential zones as well. Groundwater potential zones with moderate to extremely high, were situated in the south-eastern, south-western, north-eastern and central areas of the study region. This study estimated that 21%, 50%, and 29% of the land, respectively, fall into the high, moderate, and low groundwater potential zones. Results also exhibited that the Khajuwal block had the highest rainfall at 781.2 mm. The most prevalent type of landform is eolian sand dunes were found at various heights across the study region. It was also found that the areas of Dungargarh and Lunkaransar, east of Bikaner city, and Kolayat and Nokha, southwest of the city, had the deepest occurrence of bedrock (indicating significant alluvial thickness). The result also exhibited that 24% of aquifers were freshwater aquifers across the district. Groundwater had been found at 120 m depth in the hard rock terrain in the southeast region contained within sandstone aquifers. In alluvial aquifers, groundwater levels were up to 30 metres found in the western region. Bikaner, Khajuwal, and Lunkaransar blocks showed low electrical conductivity since their aquifer was created in earlier alluvium. It was also assessed that the concentration of chloride, fluoride, and nitrate in the Bikaner block was high.

Ground water is continuously polluted due to improperly treated industrial effluents and municipal sewage. To overcome this problem, remedial measures have been applied by placing limits on companies and municipalities for adequate treatment of effluents and wastes as per the WHO and ISI requirements for reducing the sources of the pollution. It is also helpful for the public to understand that water quality is a valuable instrument in many ways in water quality management. The study's findings support that remote sensing is a superior independent technique for mapping groundwater potential zones. Any region's land use and cover can be mapped using satellite imagery. The study is helpful for the government and planners to get rid of the water scarcity problem by designing policies and monitoring the groundwater level.

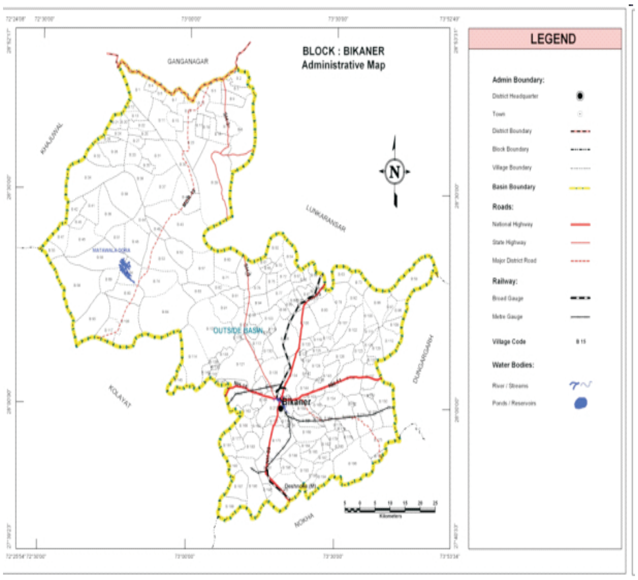

Figure 1. Location Map

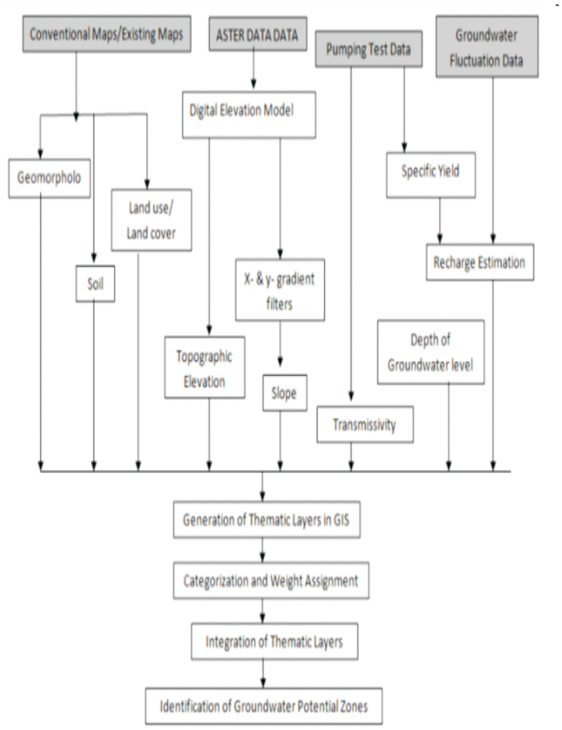

Figure 2. Methodology flow chart

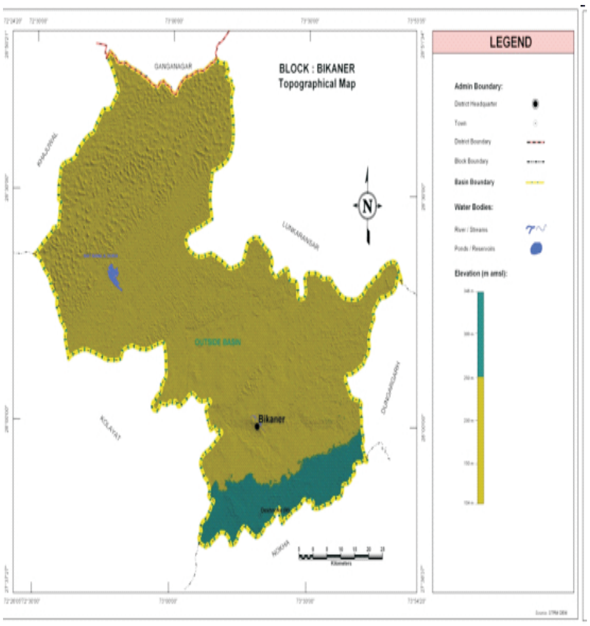

Figure 3. Topographical map

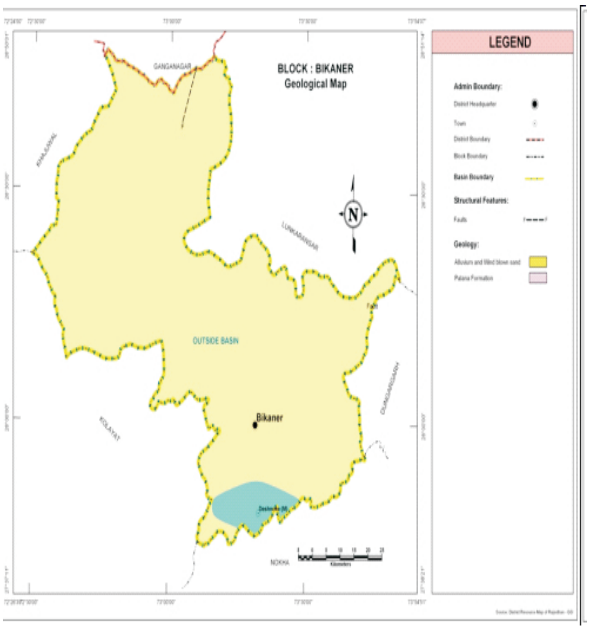

Figure 4. Geological Map

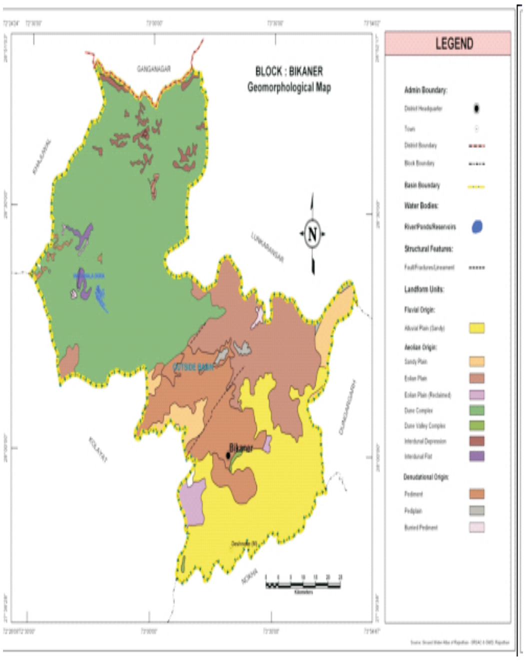

Figure 5. Geomorphological map

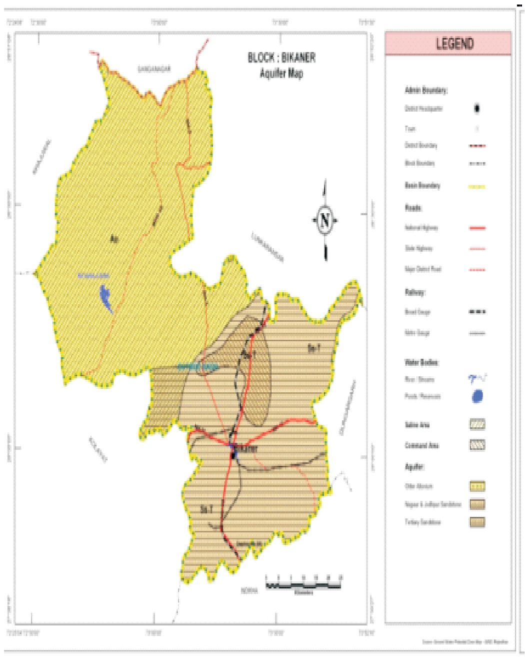

Figure 6. Aquifer map

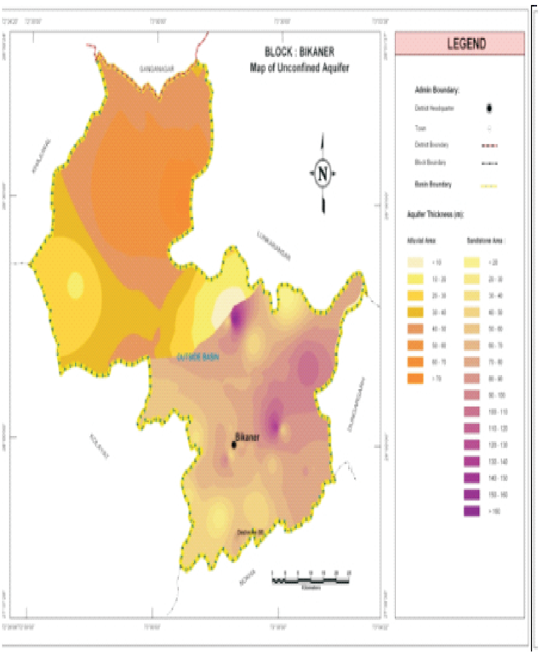

Figure 7. Unconfined aquifer map

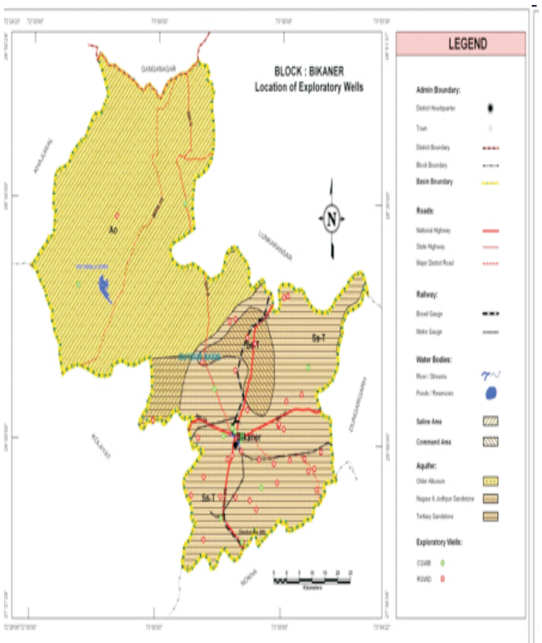

Figure 8. Exploratory wells map

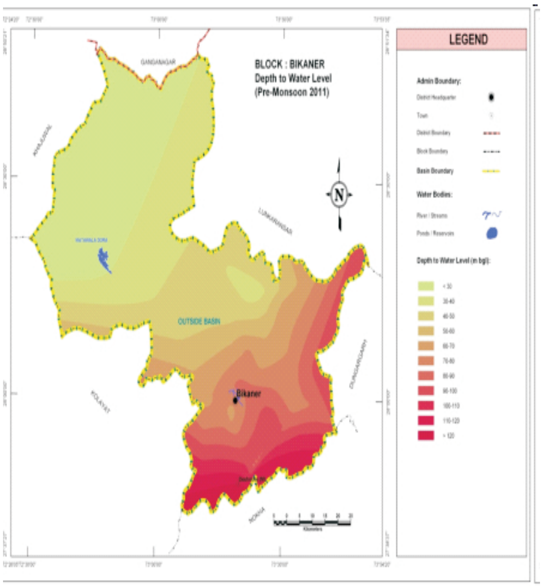

Figure 9. Depth to water level map

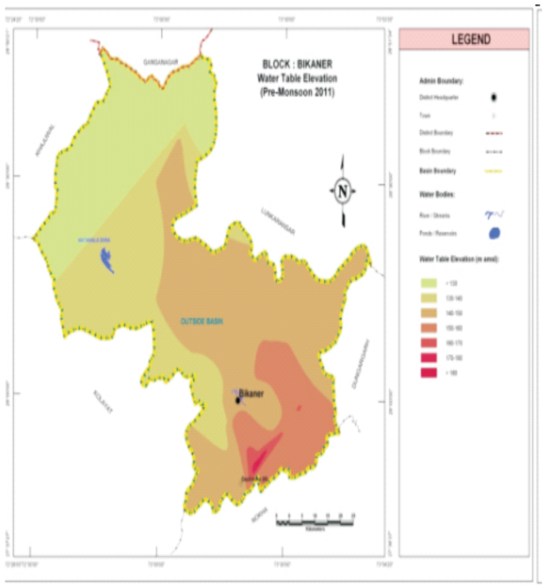

Figure 10. Water table elemation map

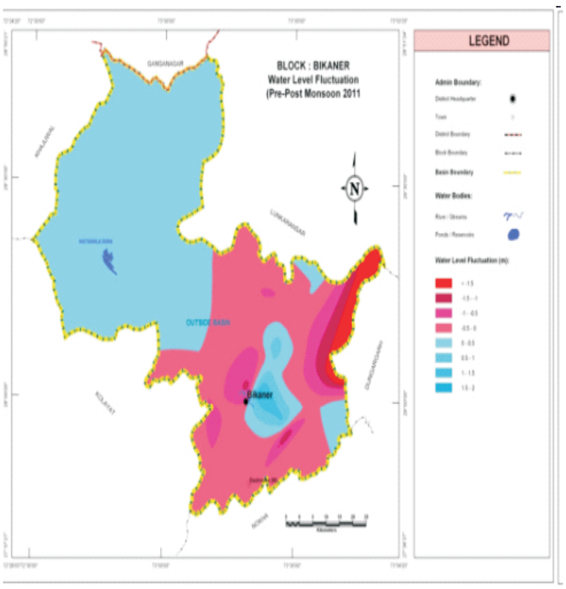

Figure 11. Water level fluctuation map

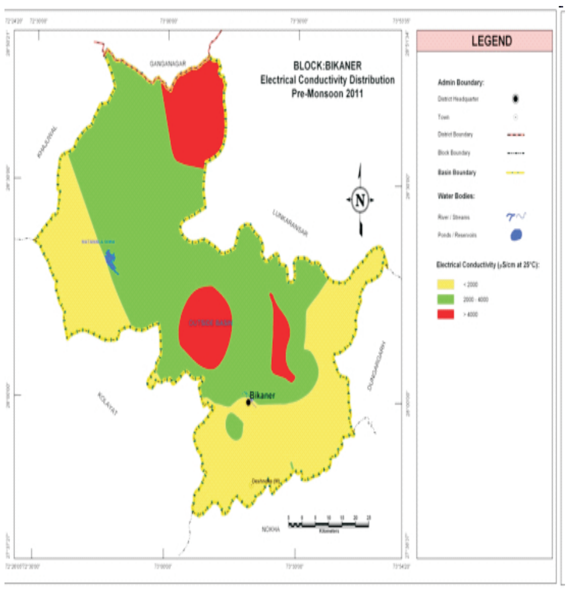

Figure 12. Electical conductivity distribution map

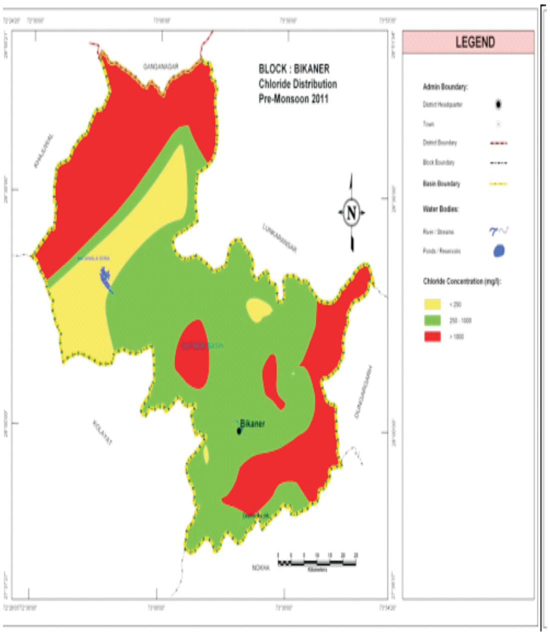

Figure 13. Chloride distribution map

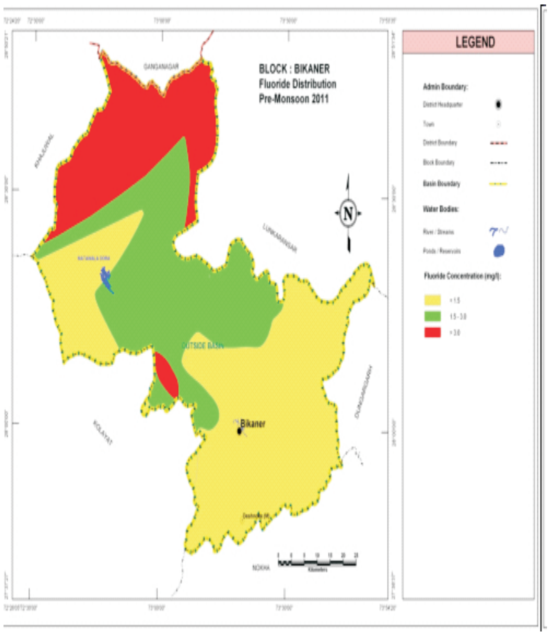

Figure 14. Fluoride distribution map

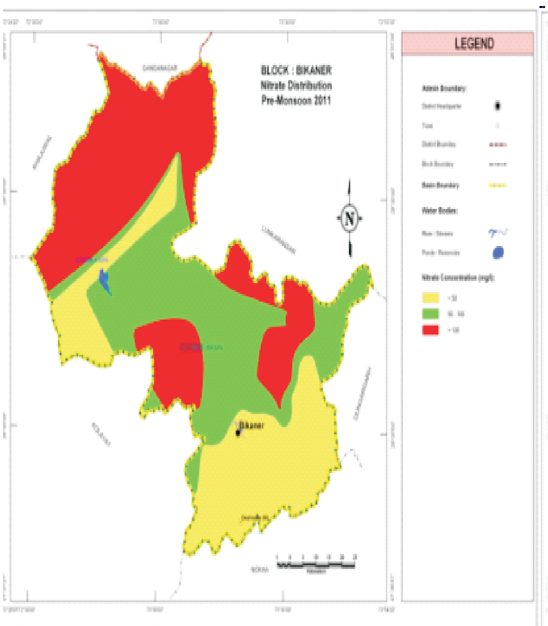

Figure 15. Nitrate distribution map

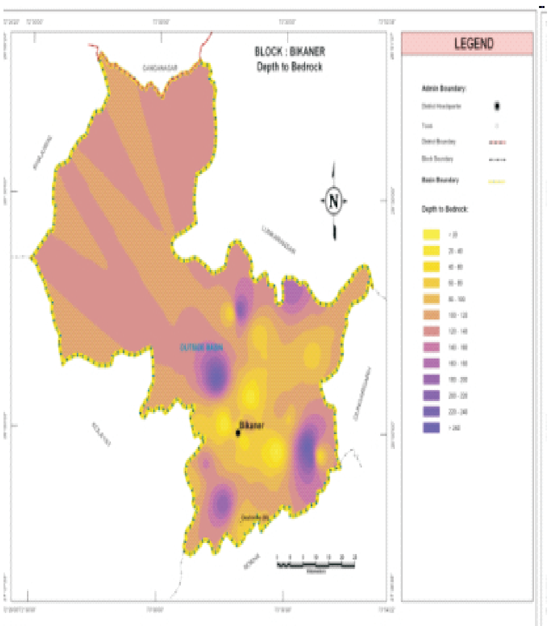

Figure 16. Depth to bedrock map

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