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Identification of Groundwater Potential Zones using Remote Sensing and GIS of K-J Watershed, India

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ABSTRACT

Groundwater potential zone mapping has become easier with the inputs from Remote Sensing (RS) & Geographical Information System (GIS) techniques. Various thematic maps like geology, geomorphology, drainage density, slope, landuse/landcover etc can be easily generated through RS & GIS. The present study is aimed at generating groundwater potential map of Koshalya-Jhajhara (K-J) watershed by using integrated approach of RS & GIS. Various thematic layers have been generated and assigned weightages and ranks. These layers have been integrated in GIS software for generating Groundwater Potential Zone (GPZ) map of K-J watershed. The area falls into five categories of groundwater potential zones i.e. very good, good, moderate, poor and very Poor depending on the likelihood of availability of ground water. On the basis of this study it is found that only 5.83 km^2 and 4.91 km^2 area is under very good and good category of groundwater availability respectively. An area of 24.48 km^2 is found under moderate category whereas dominant portion of K-J watershed i.e. 61.83 km^2 and 37.87 km^2 area falls under poor and very poor category of availability of groundwater respectively.

INTRODUCTION

About 80% of drinking water requirement is fulfilled from groundwater. Groundwater is a crucial source of fresh water (Nandishkumar et al. 2014). With the passage of time due to nonscientific exploitation of groundwater for various purposes, the water table is continuously going down at a very fast rate. This phenomenon is specifically observed in areas having fresh groundwater (Chaudhary and Aggarwal, 2009). Hence it requires preparation of suitable plans for surface water management so that groundwater can be recharged more effectively. In present times, the RS & GIS is reliable, cost effective and time saving tool for water conservation and management.

Groundwater potential zone mapping can be easily done by employing RS & GIS techniques. Various thematic maps like geology, geomorphology, drainage density, slope, landuse/landcover (LU/LC) etc. can easily generated. Many researchers (Chaudhary et al., 1996; Mishra et al., 2010; Javed and Hussain, 2009; Narendra et al., 2013; Nandishkumar et al., 2014; Yeh et al., 2016) have used this technique for groundwater potential zone mapping.

The present study is aimed at generating groundwater potential map of K-J watershed. Various thematic maps like geology, geomorphology, LU/LC, slope, drainage density of K-J watershed have been generated. These maps have been integrated by using GIS software to prepare groundwater potential zone map of the area.

STUDY AREA

The Koshalya-Jhajhara watershed covers an area of 134.92 km^2 in districts of Solan (Himachal Pradesh) and Panchkula (Haryana). It is covered by SOI topographic sheets no. H43K13 and H43L1 on the scale of 1:50000 and bounded by 30°45' to 31°0' north latitudes and 76°45' to 77°15' east longitudes. The location map of study area is shown in Fig.1. The maximum and minimum elevations in the area are 399 m and 1810 m from mean sea level (MSL) respectively. The area is composed of hilly as well as plain terrain. Koshalya and Jhajhara are two tributaries of Ghaggar river. Geologically, the area falls in lesser Himalayas and also extends up to Siwalik hills on southwest side. Many thrusts like Jhajhara thrust, Barsar thrust, Koshalya thrust, Surajpur fault, Pinjore Garden fault (PGF) are present in the area. The main thrust which passes through the area is Himalayan frontal thrust (HFT) between Siwaliks and lesser Himalaya (Malik and Nakata, 2003; Singh and Tondon, 2009).

DATA USED AND METHODOLOGY

The following data have been used in the present study

1. SOI topographic sheets no. H43K13 and H43L1 on scale 1: 50000.
2. Landsat-8, Path-147, Row-39, Date-17-Oct-2015 and 22-Feb-2016.
3. ASTER DEM (30m).
4. Ancillary literature and published maps.

The following procedure has been adopted in the present study.

SOI topographic sheets were used for base map and drainage map preparation of K-J watershed. Drainage density is calculated by using spatial analyst tool. LU/LC map for year 2016 and geomorphological map were prepared by online digitization technique of satellite image and other ancillary data. Geological map has been updated using Khan and Prasad, 1998 as base information. Slope map have been prepared using Aster DEM (30m). All shape files of various layers in vector format were converted into raster format by using conversion tool for further analysis. All the thematic layers have been assigned weightages and ranks depending upon their influence on groundwater bearing capacity. By using Analytical Hierarchical Process (AHP) approach and by using raster calculator, all thematic layers were integrated to evaluate final GPZ map by using Arc GIS software. The detailed methodology is shown in Fig.2.

RESULT AND DISCUSSION

The description of various thematic maps generated for groundwater potential zone mapping is given below.

Geology of K-J Watershed

Geology of any area plays vital role in distribution and occurrence of groundwater. The rock type exposed at the surface significantly affects the ground water recharge (Yeh, 2016). In some studies lineament and drainage have been considered as secondary porosity but in the present study geological factor has also been taken in to consideration for ground water potential zone mapping. The K-J watershed is occupied by Siwalik range in SW part and lesser Himalaya in NE part. Lesser Himalaya corresponds to Subathu, Kasauli and Dagshai formations. The Siwaliks, Subathu and Kasauli-Dagshai geological formations falls in moderate and good categories of

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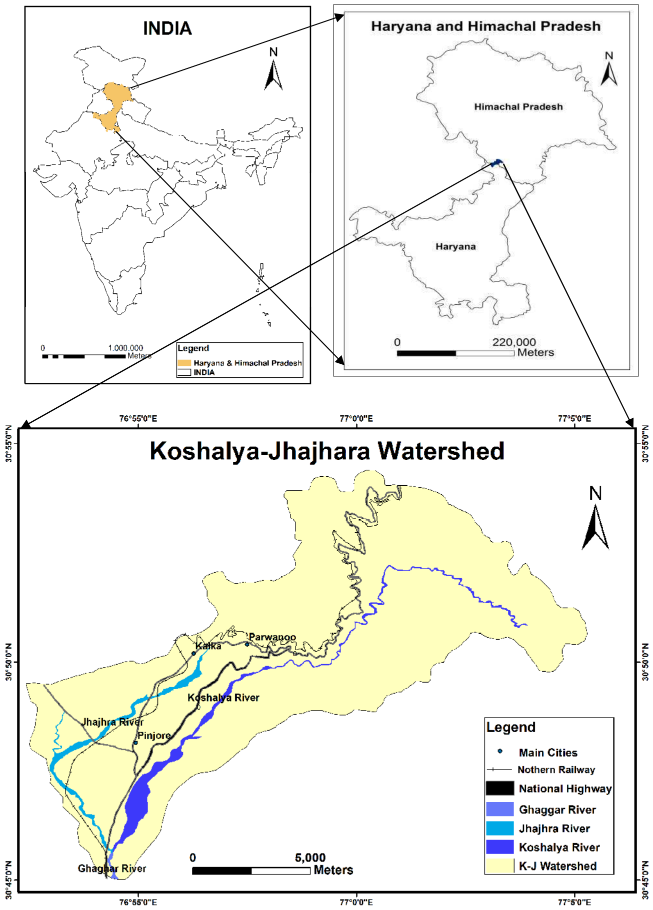

Fig.1. Location map of Koshalya-Jhajhara watershed.

groundwater potentiality respectively. The lithological description of K-J watershed is given in Table 1. The geological map of K-J watershed has been prepared after modifying the map of Khan and Prasad (1998). The final geological map of K-J watershed is shown in Fig.3.

Geomorphology of K-J Watershed

The K-J watershed is divided into two major geomorphic zones from north to south: (1) Highly and moderately dissected Hills, (2) intermontane valley.

Highly and Moderately Dissected Hills

The northern part of K-J watershed located in Kasauli, district Solan presents an intricate mosaic of high mountain ranges, hills and valleys with altitude ranging from 600 to 1800 m above MSL. The mountains are composed of Tertiary rocks of Dagshai and Kasauli formations and some patches of Subathu formation. There are seasonal streams in this area which carry water only in rainy season. Koshalya and Jhajhara are the two main tributaries of Ghaggar which originate from these mountains. Main geomorphic elements in this region are erosional features, fault, ridges, and valleys (Singh and Tandon, 2009). The altitude of the hill ranges is higher in northern parts, whereas south-western part of the watershed is covered by low denuded hill

Table 1. Lithological Description of K-J Watershed

Parameter	Formations	Lithology
Geology	Siwalik Formation	Conglomerate, Sandstone, Red Clay
	Subathu Formation	Shale, Green Mudstone
	Kasauli-Dagshai Formation	Coarse grain sandstone, Greyish Green Shale

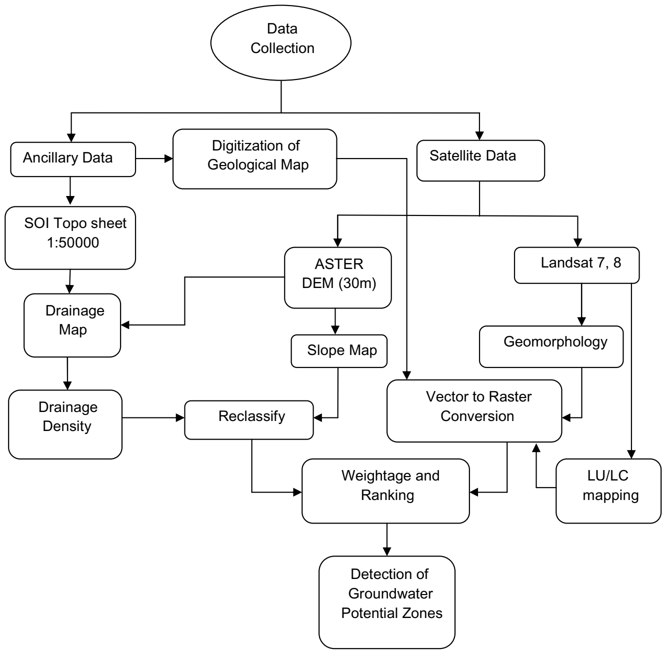

Fig.2. Flow chart of Methodology.

ranges. In the areas underlain by high hill ranges, the valleys are trending in NW-SE direction, narrow and deep with steep slopes. The terrain is moderate to highly dissected with steep slopes. Koshalya river flows towards south-west and enters Haryana at Kalka. Most of the rivers/streams/khads maintain base flow for major part of the year. In hilly terrain, the drainage density is high and fine, but it becomes coarse in foothills (Bhatia, 2013). As usual the drainage density is high in hilly region as compared to intermontane valley indicating more erosion in hilly region (Kumar and Chaudhary, 2016).

Intermontane Valley/Piedmont

An intermontane valley is located between tertiary sub-Himalayan and outermost Siwaliks which is also known as Pinjaur Dun which is a piggy back basin and divided into two parts (i) the wider north-western part and (ii) the narrower south-eastern part (Singh and Tondon, 2008). K-J watershed falls in south-eastern part. The drainage system of Sirsa River basin from Jhajhara river basin is divided within south-eastern part of Basudevpura which is an unusual geomorphic feature.

The geology, geomorphology and tectonic settings of Pinjaur dun and Dehra dun are slightly same (Malik and Nakata, 2003). According

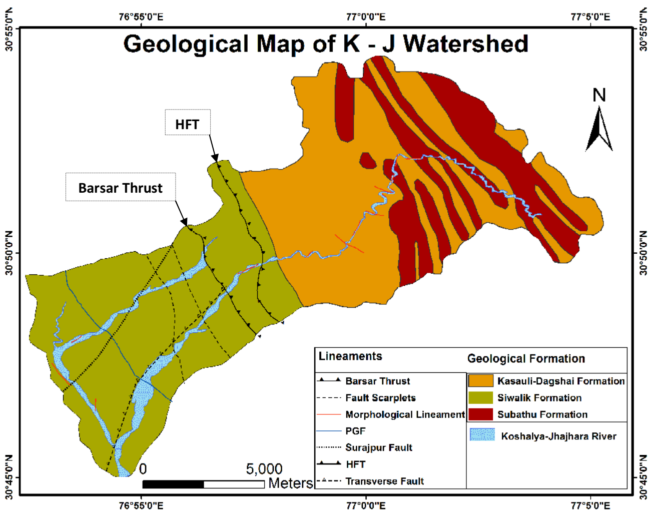

Fig.3. Geological Map of K-J Watershed (after Khan and Prasad, 1998).

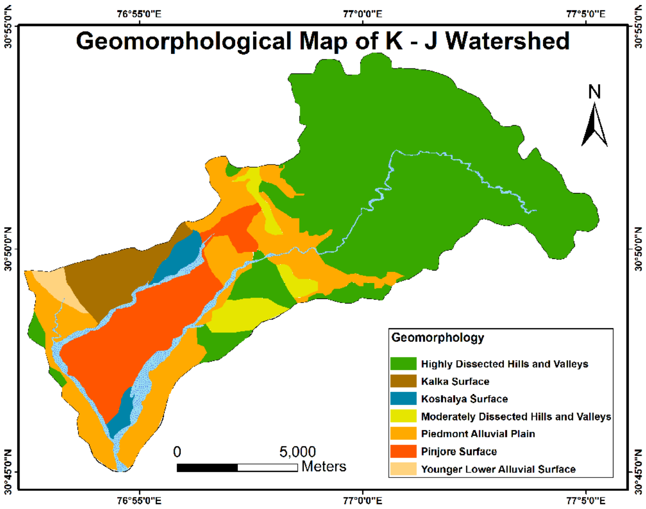

Fig.4. Geomorphological Map of K-J Watershed (after Malik and Nakata, 2003).

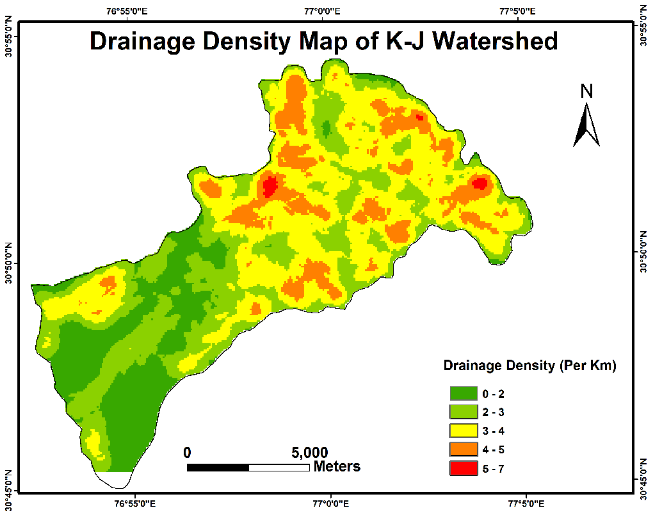

Fig.5. Drainage Density Map of K-J Watershed.

to Nakata (1972), Pinjore dun is made up of thick alluvial fill of late Pleistocene to Holocene age overlying the middle and lower Siwalik. Pinjaur dun is separated from lower Siwalik hills by Barsar thrust. The Pinjaur dun is having three major surfaces (i) Kalka surface, (ii) Pinjaur surface, (iii) Koshalya surface. These are composed of boulders, cobbles, pebbles and mud beds. The Kalka surface is located towards the north-east of Jhajhara river and the Pinjaur surface occurs on left bank of Jhajhara river and right bank of Koshalya river. Koshalya surface is present at right bank of Koshalya river. In the southwestern part of K-J watershed, a patch of younger lower alluvial surface is present along the Pinjore-Baddi highway. The geomorphological map of K-J watershed has been prepared after modifying the map of Malik and Nakata (2003). Figure 4 shows the geomorphology of K-J watershed and spatial distribution of various geomorphic features.

By taking into consideration geology and geomorphology, highly and moderately dissected hills are in very poor and poor category of groundwater potentiality, piedmont alluvial plain and younger lower alluvial surface are in moderate category, Kalka and Pinjore surfaces are in good category and Koshalya surface is in very good category.

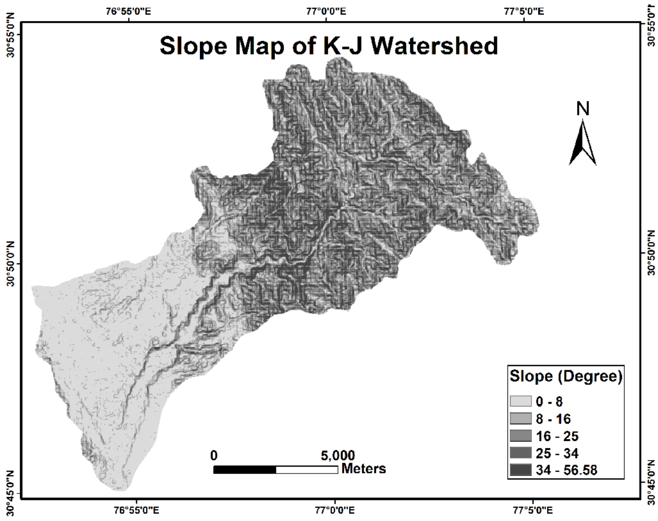

Fig.6. Slope Map of K-J Watershed.

Drainage Density

Drainage and drainage density are major factors which affect the ground water occurrence in the area. The surface water runoff is directly proportional to drainage density. If drainage density is higher, less will be the infiltration of water into the ground (Horton, 1945). The average drainage density of K-J watershed is 3.05 km^{-1} which is relatively high. It signifies that K-J watershed predominantly has impermeable surface materials (Kumar and Chaudhary, 2016). The drainage density map is shown in Fig.5. Based on drainage density, it is classified into five classes i.e. 0-2 km^{-1}, 2-3 km^{-1}, 3-4 km^{-1}, 4-5 km^{-1}, 5-7 km^{-1}. Accordingly these classes have been assigned very good, good, moderate, poor and very poor categories respectively.

Slope

In case of groundwater, the areas where the slope amount is low are capable of holding the rain water and allow percolation into the ground, which can recharge the groundwater. The slope varies from 0° to 56.58° in K-J watershed, higher slope is seen in NE part whereas low slope in SW part of K-J watershed (Kumar and Chaudhary, 2016). The area is divided into five classes i.e. 0-8°, 8°-16°, 16°-25°, 25°-34°, 34°-56.58°. Accordingly these classes have been assigned very good, good, moderate, poor and very poor categories respectively. Slope map of K-J watershed is shown in Fig.6.

Land Use/Land Cover

Land use/land cover feature affect the infiltration of water into ground. Present LU/LC is assessed for suitability for groundwater prospects. It includes the distribution of built up area, forest land, and agriculture land. LU/LC controls many hydrogeological processes like: evapotranspiration, runoff, and recharge of the groundwater system. LU/LC map shown in Fig.7 is generated using satellite data of year 2015-2016. LU/LC map shows that about 96.78 km^2 area of K-J watershed comes under forest category. Under this – dense forest covers an area of 82.45 km^2, open forest covers an area of 4.52 km^2 and scrub forest covers an area of 9.81 km^2. Agricultural land covers an area of 7.35 km^2. Built-up land covers an area of 24.84 km^2 which is further divided in to three categories – built-up compact covers an area of 14.80 km^2, built-up sparse covers an area of 9.02 km^2 and industries covers an area of 1.02 km^2 (Chaudhary and Kumar, 2017). LU/LC map of K-J watershed is shown in Fig.7.

Assigning Rank and Weight

To prepare groundwater potential zone map, it is necessary to integrate the maps thus prepared after assigning weights and ranks for these maps. By using spatial analysis tool (Raster Calculator) in GIS software after overlaying all thematic layers in terms of weighted overlay, the groundwater potential zones were calculated. Each

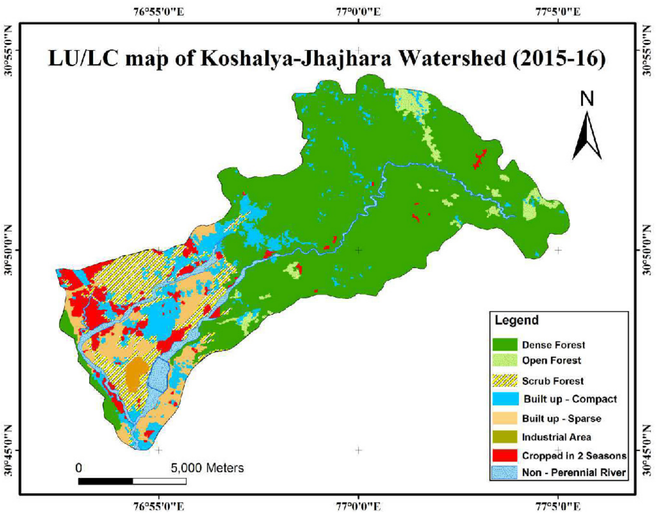

Fig.7. LU/LC map of K-J Watershed.

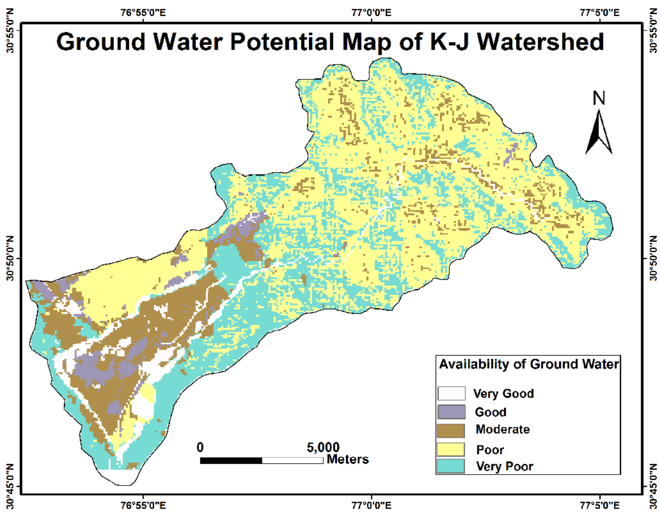

Fig.8. Groundwater Potential map of K-J Watershed.

Table 2. Weight and Rank for various parameters for groundwater potential zoning.

Parameter	Classes	Ground-water Prospect	Weight (%)	Rank
Geomorphology	Koshalya Surface	Very Good	40	5
	Pinjore Surface	Good		4
	Kalka Surface	Good		4
	Piedmont Alluvial Plain	Moderate		3
	Younger Lower Alluvial Surface	Moderate		3
	Moderately Dissected Hills and Valleys	Poor		1
	Highly Dissected Hills and Valleys	Very Poor		1
Slope (Degree)	0-8	Very Good	20	5
	8-16	Good		4
	16-25	Moderate		3
	25-34	Poor		1
	34-56.58	Very Poor		1
Drainage Density (Km/Km^2)	0-2	Very Good	15	5
	2-3	Good		4
	3-4	Moderate		3
	4-5	Poor		2
	5-7	Very Poor		1
Land use/ Land cover	Agriculture Land	Very Good	15	5
	Scrub Forest	Good		3
	Open Forest	Moderate		3
	Dense Forest	Poor		1
	Built-Up Land	Very Poor		1
Geology	Siwalik Formation	Moderate	10	4
	Subathu Formation	Moderate		3
	Kasauli-Dagshai Formation	Good		3

Table 3. Area under various Groundwater Potential Zones

Sr. No	Category	Area (Km^2)
1	Very Good	5.83
2	Good	4.91
3	Moderate	24.48
4	Poor	61.83
5	Very Poor	37.87

individual parameter was assigned weightage and ranks. Geomorphology and slope were assigned higher weight, whereas drainage density and LU/LC were assigned lower weight. After assigning weight to different parameters individual ranks are given to classes within those parameters. The maximum rank 5 is given to features with highest possibility/likelihood of presence of groundwater in it. The minimum rank 1 is given to feature with lowest potential of groundwater. The highest rank is assigned to Koshalya surface and lowest rank to highly dissected hills and valleys. In slope the highest rank is assigned to lower slope area and lowest rank is assigned to highest slope area. As far as the drainage density is concerned, the highest rank is assigned to lower drainage density and the lowest rank is assigned to highest drainage density portion. In LU/LC the highest rank is assigned to agriculture land and lowest rank is assigned to dense forest and built-up land. Table 2 shows the category wise description of rank and weightage. After assigning weight and rank to all parameters, the final groundwater potential zone map is prepared and is shown in Fig.8. The details of the category wise area are shown in Table 3.

CONCLUSION

The present study demonstrates the use of RS and GIS as a powerful and cost effective tool for GPZ zone mapping. The integration of geology, geomorphology, slope, drainage density and LU/LC gives prior information to planner and decision makers involved in the preparation of water resources development plans, so as to prepare economically viable plans. The study concludes that watershed is covered under five groundwater potential zones categories, ranging from very good, good, moderate, poor to very poor. The groundwater potential map of K-J Watershed shows that only 5.83 and 4.91 km^2 areas falls under very good and good category of groundwater availability whereas 24.48 km^2 area falls under moderate category, 61.83 and 37.87 km^2 area comes under poor and very poor category of groundwater availability. Most of the area in the southern portion of the watershed along the rivers falls under good to very good category. The farmers in the area will be highly benefited from such type of studies for further targeting sites under various zones for exploration of groundwater.

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