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Delineation of Prospecting Zones of Groundwater Using Remote Sensing and Geographic Information System (GIS): A case Study of Solani River Basin

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Abstract

Initial delineation of prospecting zones of groundwater was conducted in the present study using remote sensing and geographic information system (GIS) techniques. It has been preparing an integrated geographic database of spatial and non-spatial data for the study area. The spatial data were generated by using image processing software (Erdas 8.3) and GIS software (Arc view 3.3) enhanced by real frequent field visits of the study area. These data include: surface features which give a direct and indirect indicators of the existence of groundwater and affect to the groundwater movement such as hydrogeomorphological, drainage density, slope, landuse and soil maps. The non spatial data were derived primarily from real views during field visits to the study area and from the existing writing or previous studies. All the data generated were saved in the GIS databank for the purpose of digitization, computational and generate the best possible output results to determine the extent of possible areas where the water that exists for the purpose of prospecting. Results showed that more areas could be have very good categories of prospect zones are the southern parts of the study area, which covers about 375 Km^2 while the northern areas, which covers about 164 Km^2 of the study area are grouped as runoff zone. Accordingly the possibilities of the presence of groundwater are poor to negligible in this zone. The current study demonstrated that a remote sensing and GIS technique are very effective tools that can give the initial predictions on the presence or probability of the presence of ground water in areas which have the same considered geological deposits for the study area.

Keywords: Groundwater, Remote Sensing, GIS, Solani River, India

Introduction

In recent years, there has been a very rapid growth of the population, as well as agricultural and industrial activities, which leads to an increase in fresh water demand or to look for other sources of fresh water [1]. For this and for other reasons, including excessive use of fresh water which was generate a lot of pressure on fresh water and lead to the reduction of groundwater table. The residents of the area that will be studied in this research are totally dependent on groundwater and the main source of groundwater recharge in the study area is rainfall as well as some seasonal rivers coming from Siwalik Hills. Accordingly, most of the water resources are threatened access in this area caused the deterioration of agricultural land, so prospecting for additional groundwater in these areas is must and requires use of suitable techniques for the best results. Remote sensing and geographic information systems (GIS) techniques were use in the current study for this purpose. These techniques applied a lot

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in many studies to delineate of groundwater prospect zones [2], [3], [4] and [5] [6] [7] [8] [9] [10] and [11]. The appearance of remote sensing has opened up new vistas in the mapping of geomorphological, geological, structural research, study and exploration of groundwater in many parts of the world. Also the aerial photographs and satellite images provided integrated information on different terrain that control the groundwater system factors [1].

Purpose of the study

The following are the main objectives of the current study:

1- Identify the geographic surface features including hydro geomorphological, drainage density, slope, land use and soil features that could give indications to the presence of groundwater.
2- Save the entire surface feature in the GIS data bank for the purpose of digitization, calculations and generate the best results.
3- Create thematic maps of hydro geomorphology, drainage density, slope, landuse and soil.
4- Integrate of all above thematic maps to delineate the prospect zones of groundwater in the study area

Description of the study area

Solani River is a sub watershed of the main Ganges River. It lies between Longitude 77° 43' 19" to 78° 04' 21" East and latitudes 29° 49' 00" to 30° 17' 21" North and it is belongs to state of Uttaranchal in northern part of India **Fig.1**. The northern part of the study area is a hilly and presence of protected forest and Siwalik rocks group are exposed therefore it is not possible to carry out detailed examination, due to inaccessibility. Siwalik rocks and alluvial deposits are the major geological deposits in the study area **Fig.2.** The alluvial fan deposits of recent age are made up of assorted sands and gravels with occasional clays [12] **Fig.3.** These geological deposits were mapped by "GIS" software after field visit and historical information derived from the relevant literature [13], [14], [15], [16] and [17] **Fig.2**.

Data Used and Methodology

In the current study various data were used including Survey of India (SOI) topsheet, Indian Remote Sensing Satellite Linear Imaging Self- Scanning System (IRS-1D LISS-III) digital data, real field checking and existing literatures [12], [13] and [14]. IRS-1D LISS-III data were collected by National Remote Sensing Agency, Hyderabad (24th January, 2006) in digital form. SOI published by Survey of India on scale 1:50,000 and used for Geometric correction for "IRS-1D LISS-III" digital data using Erdas 8.3 software [18]. Various geographic surface features were recognized using digital image processing interpretation techniques and its mapping by "Arc View 3.3 GIS" software [19]. These features derived from remote sensing and topographic data were verified by fieldwork and available 10 tubewells located in the different location in the study area. Representative lithological tube well located in the southern part of the study area indicates that the unconsolidated Quaternary is the main sediments that consist of sand clay with pebble at the upper layer underlain by sand with boulder **Fig.3**.

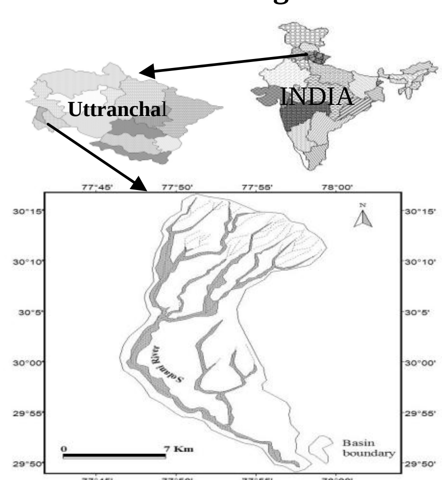

Figure.1. Location map of the study area

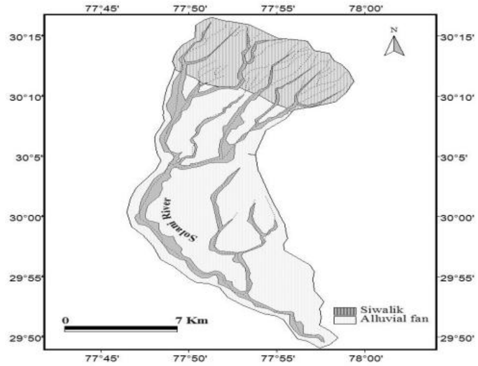

Figure.2. Geological map

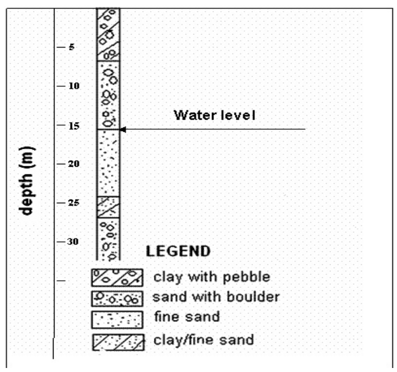

Figure.3. Lithological data at selected site

Result and Discussion

The initial delineation of groundwater prospecting areas requires study the features of surface and near the surface, such as hydrogeomorphology, drainage density, slope, landuse and soil. These features resulting from the total multi-spectral coverage of the terrain and it is very important for the purpose of determining and definition of the presence of the various groundwater sites that could serve as direct and indirect indicators of the presence of groundwater. All these data were prepared by integrating topographic maps, remote sensing data, truth ground checking and available previous studies for the region [12] [13] and [20] .

1- Hydrgeomorphological map

Hydro geomorphological units affected by the nature of the various human activities include the expansion of cultivated and irrigated land, industrialization, urbanization and other so they need constant monitoring and mapping [15]. On the basis of differential erosion processes and hydrogeomorphological characteristics the geomorphic features were classified in the study area into four classes under fluvial, denudational and structural origin. These geomorphic classes have been digitized using "Arc View GIS" software to create hydrogeomorphological map which is presented in **Fig.4**. The various geomorpological classes and their groundwater prospects are discuses as follow:

1.2- Flood Plain, Young and Old Terrace

It is characterized by a fluvial origin and composed of silt, sand, silt, clay and gravel. It is present along the riverbeds acting as drainage and recharge areas at the same time.

1.3- Lower Piedmont

It is characterized by denudational origin and composing of a mixture of gravel, sand, silt and clay gravel. It has a gentle to a moderately slop occurring along the eastern margin and in the southern part of the study area. The soil-surface moisture is high in these areas due to presence of spring water and it has dark red tones and fine texture on infrared images. This is cover about 88 km^2 in the region, followed by the upper piedmont unit everywhere in the study area and separated by spring's line.

1.4- Upper Piedmont

The origin of this feature is denudational consisting of gravel and a moderately to steeply slope. It serves as the recharge areas and the prospecting of groundwater is moderate to good. In some pleases occurs at higher levels with more clay percentage resulting in dendritic high density drainage and increase the surface runoff in these areas.

1.5- Siwalik Hill

is constituted of interbedded mudstones, sandstones, conglomerates and subordinate marls. Due to their high rises rocky topography, this geomorphic unit mainly serves as runoff zones where drainage density is very high and steeply sloping accordingly groundwater prospecting in this area is poor to negligible.

2- Drainage density map

Create a map of drainage density requires the firs draw a map of a drainage pattern which has generated using IRS-1D (LISS-III data) and survey of India toposheets as a reference. It shows that a dendritic type of drainage occurs in steeply sloping areas while a subdendritic type occurs in gently sloping areas which indicate that the materials covering these areas is homogeneous and it is controlling by secondary structures. Based on drainage network map the drainage density has been created which is ranging between 0 to1.4 km/km^2 **Fig.5**. It should be noted that the drainage density is high in the northern part of the study area and this leads to a reduction of infiltration and increase surface water runoff.

3- Slope map

The slope percent map computed from elevation data set shown in **Fig.6**. It is noted that 23% of the study area, which represents the northern part has a steep slope, and 40% of the total area, which represents the southern part of the study area has a gentle slope. Genital sloping areas are the most promising areas for the development of groundwater due to a reduction of the surface water runoff and allow it to infiltrate into groundwater.

4- Landuse map

Monitoring and mapping of land use is very important in determining the presence of groundwater sites because it is affected by many human activities including urbanization and industrialization as well as the expansion of cultivated land [15]. In the study area six main types of landuse were identified **Fig.7**. The most important of these land uses are a dense and scattered forests, agriculture, seasonal river, scrub and fallow land. In hilly area dense and scattered forests cover around 27 % of the total area while in the flat areas the dominant landuse type are agriculture and covering more than 36 % of the total area. Cultivated land type is the most promising areas for prospect of the groundwater because it helps to increased infiltration and reduces the runoff of the surface water

5- Soil map

The main types of soils in the study area are loam, sandy loam, sand clay and sandy as shown in **Fig.8.** [12] [20]. The northern part of the study area, which consists of high mountainous areas contained sandy loam soil, whiles the southern part, which consists of flat areas dominated by clay and sandy soil. Sandy soil is the most soil promising groundwater prospecting because of it has high permeability allowing water to infiltrate to the groundwater in large quantities

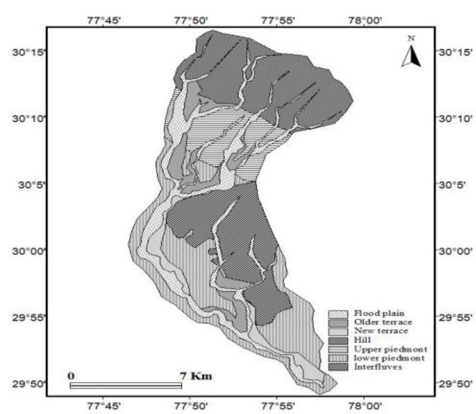

Figure. 4. Hydrogeomorphological map

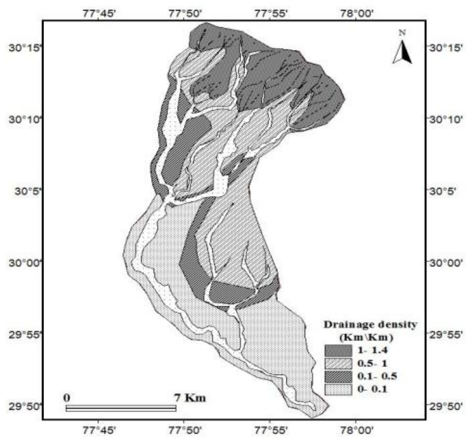

Figure.5. Drainage density map

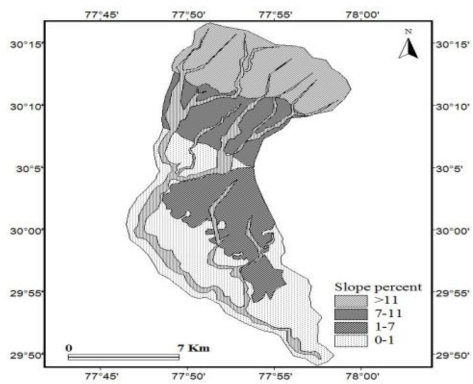

Fig.6. Slope map

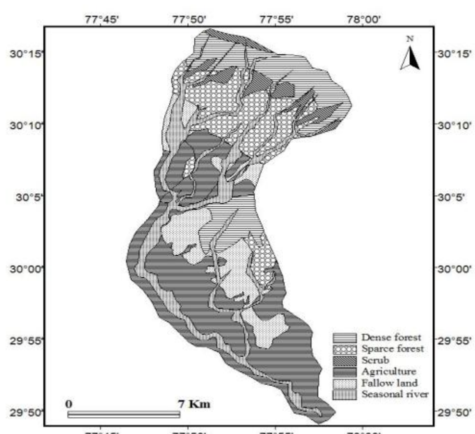

Fig.7. Landuse map

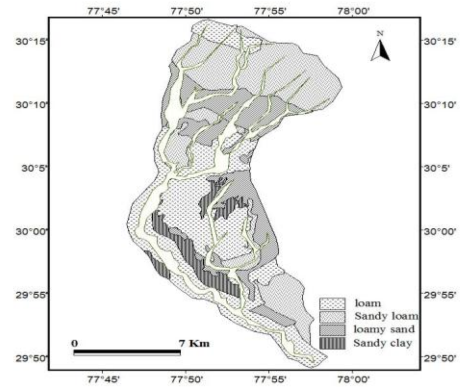

Figure.8. Soil map [12]

initial delineation prospecting zones of groundwater through GIS

Quantitative analysis of the hydrogeological surface features that discuss above has been done in GIS environment to delineate the initial prospecting zones of groundwater in the area of study. For quantitative analysis each surface features have been assigned appropriate weight depending on its role in detecting the occurrence of groundwater **(Table 1).** Hydrogeomorphological features play an important role in prospecting of groundwater than other features confirmed by many researchers [21], [22] and [23], hence given highest weight. In each surface feature there are different classes shown in **Table 1.** These classes were assigned different rank on the basis of their relative significance with reference to their groundwater prospecting. Ranks one, two, three and four denotes poor favorable, moderately favorable, good favorable and very good zone respectively for groundwater prospect. The final score of each class is the product of multiplied rank by weight. On the basis of total score of various classes the relative prospecting of groundwater for each zone has been defined. Score more than 10 is indicate a very good groundwater prospect zone and the zone having a score of less than 4 is considered a poor to very poor groundwater prospect. Accordingly the prospecting of groundwater in hilly area is poor to very poor covers 162 km^2 of the total area because having high drainage densities and very steep slopes. These features do not allow the water to infiltrate into the groundwater but increasing the runoff. In the southern part of the study area which represents the lower flat terrain covers about 124 km^2 of area has good prospecting of groundwater and 242 km^2 has very good because of very low drainage density and gentling slope **(Table 1)**. The validity of the results was checked against the yield data obtained from 10 tubewells located in the different groundwater prospect zones in the study area. These data show that a good water yield was ranging from 121-257 m^3/h in the very good prospective zone and ranging from 63-225 m^3/h in the good prospective zone. It is also been observed from these data that the yields from locations close to a gentle slope and low drainage density in the piedmont geomorphic are comparatively higher than other locations. It may be mentioned here that the area in the extreme north (Siwalik hill) is not accessible and no subsurface data is available for this area.

Table 1: Rank, weight and scores for attributes for various themes with respect to groundwaterprospective

Parameters or Attributes	Weight	Classes	Rank	Score	Groundwater Prospect zones
Hydrogeomorphology	5	Flood Plain, Young and old Terrace	4	20	Very Good
		Lower piedmont	3	15	Good
		Upper piedmont	2	10	Moderate
		Hill	1	5	Poor
Slope	4	<1	4	16	Very Good
		1-7	3	12	Good
		7-11	2	8	Moderate
		>11	1	4	Poor
Drainage density	3	0- 0.1	4	12	Very Good
		0.1- 0.5	3	9	Good
		0.5- 1	2	6	Moderate
		1- 1.4	1	3	Poor
Landuse	2	Scrub & fallow land	4	8	Very good
		Seasonal river	3	6	Good
		Agriculture	2	4	Moderate
		Dense & scattered forests	1	2	Poor
Soil	2	Sandy	4	8	Very good
		Sandy loam	3	6	Good
		Sand clay	2	4	Moderate
		Loam	1	2	Poor

Conclusion

The above study results have demonstrated that GIS integration geographic database derived from remote sensing and topographic data with various indicators of groundwater availability can decrease the uncertainty in delineating preliminary prospecting of groundwater in the same considered geological deposits for further detailed subsurface investigations. The results of this study show that the southern part of the study area has prospect of groundwater is very good that is possible to meet the demand for water while the northern part of the study area, which represents a severe area of regression, the prospect of groundwater is very poor to negligible.

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ترسيم مناطق تواجد المياه الجوفية عن طريق الاستشعار عن بعد ونظم المعلومات الجغرافية: دراسة حالة حوض نهر "سولاني"

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الخلاصة

في هذه الدراسة تم القيام برسم وتخطيط للمناطق المحتملة لتواجد المياه الجوفية باستخدام الاستشعار عن بعد ونظم المعلومات الجغرافية (GIS). وقد تم ذلك بانشاء قاعدة بيانات جغرافية متكاملة من "البيانات المكانية والبيانات غير المكانية" لمنطقة الدراسة . إنشئت البيانات المكانية باستخدام برنامج "Erdas,8.3 " معالج صور الاقمار الصناعية والارك فيو "Arc View" برنامج نظم المعلومات الجغرافية وشملت خرائط "الانحدار، والتربة، واستخدام الأراضي وكثافة البزل والهيدروجيومورفولجيا" والتي تعطي مؤشرات مباشرة وغير مباشرة على وجود أو عدم وجود المياه الجوفية. انشئت البيانات غير المكانية أساسا من الزيارات الميدانية الفعلية لمنطقة الدراسة ومن الكتابات والدراسات السابقة عن منطقة الدراسة. جمعت كل البيانات التي تم إنشاؤها وخزنت في بنك بيانات نظم المعلومات الجغرافية لغرض اجراء التحاليل والحسابات عليها واظهار النتائج المثالية لتحديد الاماكن المحتملة لتواجد المياه لغرض التنقيب عنها. اظهرت النتائج أن أكثر المناطق يمكن ان تمتلك فئات ممتازة من احتمال تواجد المياه الجوفية هي الأجزاء الجنوبية من منطقة الدراسة، والتي تغطي حوالي 375 كم^2 في حين صنفت المناطق الشمالية، والتي تغطي حوالي 164 كم^2 من منطقة الدراسة كمنطقة الجريان السطحي وبالتالي فان إمكانية وجود مياه جوفية فيها يكون ضعيف الى معدوم .أظهرت هذه الدراسة كذلك أن تقنيات الاستشعار عن بعد ونظم المعلومات الجغرافية ادوات فعالة جدا يمكن أن تعطي التوقعات الأولية على وجود أو احتمال وجود المياه الجوفية في المناطق التي لديها نفس التكوينات الجيولوجية لمنطقة الدراسة.

الكلمات الدالة: المياه الجوفية, استشعار عن بعد , نظم المعلومات الجغرافية , حوض سولاني , الهند.