GROUND WATER PROSPECTS ZONATION USING REMOTE SENSING AND GIS - A CASE STUDY OF BATA WATERSHED, SIRMAUR DISTRICT, H.P.

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ABSTRACT:
The exploration, assessment and management of ground water resource has become one of the key issues as ground water forms an important component of the total water supply for drinking and irrigation purposes. Remote Sensing (RS) has been successfully used to locate prospective ground water. The present study has been undertaken in the Bata watershed falling in Sirmaur District of Himachal Pradesh (H.P.) State with a primary aim to map the prospective ground water zones. Towards this, RS data in conjunction with conventional methods have been used to characterize the terrain and aquifer parameters, followed by their integration using GIS for preparing the ground water prospects map. The synopticity, multispectral nature and high spatial resolution of PAN-sharpened LISS-III image of IRS-1D and Resourcesat-1 helped a great deal in terrain characterisation, i.e. in mapping the geomorphology, lithology, structures and land cover of the area. Geologically, the area comprises of the rocks of Subathu (Eocene), Lower and Upper Siwaliks (Middle Miocene to Early Pleistocene), and younger unconsolidated sediments (Late Pleistocene to Holocene) i.e. Doon gravels and alluvium. The main boundary thrust (MBT), Markanda thrust and Yamuna tear fault are the important geological structures/ discontinuities. A number of other lineaments have also been mapped. Active flood plains channel/ braid bars, river terraces, lower and upper piedmont, and residual, structural and denudational hills are the geomorphic units/ landforms mapped in this area. The terrain and aquifer parameters have been integrated using the weighted index overlay method in GIS domain to delineate the prospective ground water zones. The ground water prospects are mapped in five categories: excellent, good, moderate, low and runoff zone. Excellent and good ground water prospects zones occur in the flood plain, younger and older terraces, and lower piedmont. Moderate to low prospects zones occur in the upper piedmont. The denudational, structural and residual hills mainly act as runoff zones, wherein the ground water occurs in localised pockets, i.e. along narrow valleys, faults and fractures.

1. INTRODUCTION

Ground water is the major source of drinking water in both urban and rural India. Over the years, increasing population, urbanization and expansion in agriculture has led to the unscientific exploitation of this resource. It is an important source of water for the agricultural and the industrial sector. The demand for water has increased over the years and this has led to water scarcity in many parts of the world, especially in India. This alarming situation calls for a cost and time effective technique for proper evaluation of groundwater resources, management and planning. Interpreted remote sensing and GIS can provide the appropriate platform for convergent analysis of diverse data sets for decision making in ground water management and planning.

The remote sensing technology and GIS tools have opened new paths in water resources studies. Temporal data from remote sensing enables identification of groundwater aquifers and assessment of their changes, where as, geographical information system (GIS) enables user-specific management and integration of multi-thematic data. Remote Sensing and GIS applications have been used by numerous scientists in mapping of groundwater potential zones (venkatachalam et al., 1991; Ghosh, 1993; and Saraf & Choudhary, 1998).The Indian Remote Sensing programme is directed towards the realization of operational capabilities in space and ground segments of the technology for regular monitoring of earth resources and environment (Gupta and Roy, 2000). The spatio-temporal variations in rainfall and regional/ local differences in geology and geomorphology have led to an uneven distribution of ground water in different regions across the country. The poor prospects and over-exploitation in certain zones are the main reasons leading to scarcity of drinking water in many parts of the country (NRSA, 2000).

Apart from visual interpretation, many researchers for deriving geological, structural and geomorphological details use digital techniques. Commonly 1: 50,000 are a good scale for hydrogeological studies (Bartarya, 1995).

The main aim of the present study is to evaluate the ground water potential in the Bata watershed of Sirmaur district of H.P. In order to achieve this goal, to prepare the different thematic map which is a controlling a ground water parameters like as Geology, geomorphology, slope, water level/table and land use/ cover. Finally to prepare a ground water prospects map by integrating different controlling/indicative terrain and aquifer parameters in GIS environment.

2. STUDY AREA

The study area is lying between the latitude $30^0\ 20'\ 00''$ N to $30^0\ 35'\ 00''$ N and longitudes $77^0\ 20'\ 00''$ E to $77^0\ 45'\ 00''$ and covering an area of about 340 sq. km in Himachal Pradesh state. This area belongs to Paonta Block of Sirmaur district in H.P.State. Its headquarter is Nahan. The northeastern (NE), eastern and southeastern (SE) boundry of the area is drained by two major rivers, Giri and Yamuna.

3. METHODOLOGY

The different thematic maps like as geology, geomorphology, drainage and land cover have been prepared based on visual analysis of satellite data in conjunction with the available ancillary data and ground surveys. Aquifer

parameters has been done based on the available well data collected from different govt. dept., well inventory carried out during ground surveys. Subsequently, terrain and aquifer parameters have been integrated in GIS using Index Overlay Model for preparing ground water prospects map.

4. RESULTS AND DISCUSSION

4.1 Geology of the area

In the study area, based on previous literature and with the support of the satellite image interpretation coupled with ground surveys, following lithostratigraphic units have been mapped and shown in Figure-1:

- Alluvium (Recent)
- Younger Doon Gravel (Early Holocene to Sub-Recent)
- Older Doon Gravel (Late Pleistocene to Early Holocene)
- Upper Siwaliks (Upper Pliocene to Lower Pleistocene)
- Lower Siwaliks (Upper Miocene to Lower Pliocene)
- Subathus (Eocene)

The characteristic of both Lithology and structure are well reflected in the topographic expressions and were quite helpful during satellite image interpretation. A short description of each lithostratigraphic unit mapped in the study area is given here under.

4.1.1 Subathu Formation

It is composed of purple shale, sandstone and limestone pockets (Krishnan, 1968). These rocks are exposed in the NW part of the study area and extend in E-W direction. The lithology consists of thin succession of green, grey and red shales intercalated with thin lenticular bands of sandstone & impure limestone dipping northerly.

4.1.2 Lower Siwaliks

The Lower Siwaliks comprise of hard, compact, massive, dark grey colored, fine to medium grained sandstone interbedded with minor siltstone and red, grey, green clay. Sandstones are rather well bedded, jointed and show few primary sedimentary features (Devi & Wankhede., 1995). The Lower Siwaliks are exposed between MBT and Markanda fault (Bata river) in Dhaula kuan to Baila road section in the northern part of the study area. The sandstone beds dip 20^{o} to 50^{o} towards NE with strike trend in NW-SE direction. On the image, these rocks show dark tone and moderate dissection and flat-iron geometry.

4.1.3 Upper Siwaliks

It conformably overlies the Middle Siwaliks. It consists of coarse clastics and occurs in the southern part of the study area (south of Bata river) (Dey and Naitnani., 1988). The beds dip 15^{o} to 45^{o} towards NE. The general trend is NW-SE to NNW-SSE. Doon fan gravels cover the upper Siwalik beds along the Bata river. The boulders, pebbles, cobbles of Upper Siwaliks are of quartzite, shale, slate and limestone derived from erosion of the Lesser and Higher Himalaya. On the image, Upper Siwaliks show dark red color and high dissection. The unconsolidated valley fill deposits are termed as Doon Gravels or Doon Fan Gravels. Doon Gravels consist of an admixture of boulder, cobble, pebble, gravel, sand, silt and clay and are divided into two units like as Older Doon Gravel and Younger Doon Gravel. The isolated hillocks of older Doon Gravels are characterized by thick vegetative cover mostly of sal trees as observed around Garibnath Ka Tilla and Gorakhpur Reserved Forest in the NE part of the study area. Younger Doon Gravel shows horizontal nature, imbrication of platy material, inclination and alternate beds of clay and boulder in the river section. The boulders (sub-rounded to sub-angular) are of quartzites, schist, gneisses and the finer material is of slates, phyllites, and shales derived from Pre-Tertiary rocks zones. These materials are also seen at higher elevation than the present river courses.

4.1.4 Alluvium

These are the youngest deposits and are exposed along the river beds of Bata, Yamuna and Giri river associated with terraces and flood plains. The central region parallel to the NW-SE flowing Bata river and flanking its both sides are mostly covered with recent alluvium.

In this area, there are three thrusts have been identified and some structural features have also been present in the form of lineaments, faults, folds etc. In this area MBT (Main Boundary Thrust), Nahan Thrust and Markanda Thrust have been seen. Some micro faults have also seen in this area.

4.2 Geomorphology of the area

Geomorphic set up of the area has considerably influenced the ground water occurrences. Considering the regional condition, image characteristics and field information, the study area has been divided into the following geomorphic units and landforms on the basis of structure, degree of dissection, rate of denudation and lithology (Nossin, 1971). The detailed geomorphological map is shown in Figure-2.

4.2.1 Active Flood Plain

It is youngest geomorphologic unit in the area. It is composed primarily of unconsolidated river-borne sediments such as pebbles, cobbles, sand, silt and clay. The major rivers like Yamuna, Giri, and Bata form wide flood plains (1/2 to 1 km wide), and mainly show braided nature (Jugran, 2003).

4.2.2 Braid/Channel Bar

The braid bars are formed by the interlacing of the streams, and are chiefly characteristic of braided streams. The braid/channel bars are found in tributaries of the Giri river, Bata river and Yamuna river. They have variable shape and size, and are easily identifiable on the satellite imagery. Some of the braid bars are very old and stablised due to development of soil; vegetation also occurs on them.

4.2.3 River Terraces

The fluvial terraces are vestiges of former flood plains and occur on either side of river. They are composed of unconsolidated and poorly stratified boulders, pebbles, sand, silt and clay. They are identified on the satellite image by light to medium grey tone, internal drainage, step like arrangement parallel to riverbanks and cultivation practices.

4.2.4 Intermontane Piedmont Plain

This intermontane piedmont plain occurs in the central part of the study area on either side of the Bata river. It is associated with moderate to very low slopes merging with the flood plains. The piedmont area along the Bata river can

be divided into two sub division. The upper most area associated with coarse material is generally covered by forest area. Major portion of this sub-unit is covered under forest and is less cultivated. It is made up of mainly boulder, cobble and pebble within sandy and silty matrix. This is mainly known as Upper Piedmont. This unit is developed in between upper piedmont and terraces. The lower most regions associated with finer materials. The slope of the terrain becomes very gentle almost like an alluvial plain (0-2°). The loose material that comes from Upper piedmont zone spreads in a fan shape in poorly sorted or assorted manner, as the condition arises. This zone is mainly used for cultivation and habitations. It is mainly known as lower piedmont zone.

4.2.5 Residual Hill

It consists of Older Doon Gravels. In the study area, one isolated hill of moderate dimension is seen in the southern facing piedmont section known as Garibnath Tilla at Rajban area. This unit shows thick vegetation, deeper dissection and steep to moderate sloping topography. It is composed of big boulders and pebbles of quartzite, quartzitic sandstone, sand and clay.

4.2.6 Structural Hill

The structural configuration is well exhibited in the hills of Lower and Upper Siwalik formations. It displays various structures such as strike ridges, fold, faults, bedding planes and associated landforms such as Hogbacks and cuestas. Based on dissection, these structural hills have been further classified and mapped as Highly Dissected Structural Hill and Low Dissected Structural Hill. The main rock types in this region are sandstone, clay beds, boulder beds etc.

4.2.7 Denudational Hill

This geomorphic unit is situated north of the MBT in the Subathus and shows relatively higher relief and steeper slope. The rock fall and landslides are common in this unit. Drainage pattern in the whole area is dendritic to sub-dendritic but occasional structurally controlled drainage is also found.

5. LAND USE /COVER MAP

RESOURCESAT-1 LISS-III and IRS, 1-D PAN merge data has been visually interpreted to demarcate the land use/ land cover features in the study area. The identified land cover features are agriculture, settlement, degraded forest/scrub land, open forest, dense forest and river bed. It has been found that forest is maximum land cover in this area. This is about 71.2 sq. km. The second main land cover is agriculture (71.2 sq. km.). For ground water prospects point of view agriculture is main suitable recharge part. Land use/cover map is shown in Figure no-3.

6. CHARACTERISTICS OF AQUIFER

In the study area, groundwater is being extracted from the unconfined and semi-confined to confined aquifers through dug wells and tube wells. Maximum groundwater development has taken place in the valley part (or central piedmont part) of the area. Most of the dug wells and tube wells (private and Govt.) exist in the lower piedmont and river terraces catering the domestic and irrigation water requirement. Most of these dug wells are used for drinking and irrigation purpose; however, some dug wells are unused and require cleaning. Based on the collected data during field work, depth of water table maps have been prepared. These maps are shown in Figures no-4 and 5. As seen in these maps, the depth to water table in this area ranges from less than 5m from ground level to more than 35m in the pre and post monsoon periods in unconfined aquifers condition. On the basis of these water table maps and ground truth checking, it is observed that the water table is very deep from the ground level in the NE part of the area. The water table represents the groundwater reservoir level and changes in its level represent changes in the ground water storage. Hence the overall groundwater movement is from west to east, i.e. towards Yamuna river.

In confined to semi confined aquifers the depth to static water table varies from less than 10m to more than 55m from the ground level. In the NE part, ground water moves from north to south and finally it follows the topography. Overall its movement is towards the Yamuna river.

7. GIS BASED ANALYSIS FOR GROUNDWATER PROSPECTS MAPPING

The groundwater prospects mapping involves identification and mapping of prospective groundwater zones. The ground water prospect zones for ground water exploration were identified and delineated after integrating the all information on geology, geomorphology, land use/ cover, slope, drainage density and recharge conditions in unconfined to semi confined aquifers of the terrain like as discharge, drawdown, specific capacity maps. During the present study, an index overlay method has been adopted for combining the multiple thematic maps. In this model, the map classes occurring in each input map are assigned some different scores, in addition to the maps themselves receiving weights. The average score is then defined by:

$$S = \sum Sij*Wi / \sum Wi$$

Where S is the score for an area object, Wi is the weight for the ith input map, and Sij is the rating score for the jth class of the ith map. The value of J depends upon the class actually occurring at the current location. The groundwater prospects map prepared based on GIS based analysis is shown in Figure No-6. In weighted index overlay, the individual thematic layers and also their classes are assigned weightages on the basis of their relative contribution towards the output. The weights to different themes and scores to different classes of each theme are assigned from 1 to 10, and are given in Table no-1. The final ground water Prospects are represented in terms of the following zones: Excellent, good, moderate, low and runoff zone.

Excellent potential zones are associated with the younger terraces and flood plains of Bata river, Giri river and Yamuna river and part of lower piedmont area where the aquifer thickness is high and depth to water table is shallow. The area near Bata Mandi, Byankuana, Patilion, Bahral etc. belong to this zone. Good ground water potential zones are associated with the part of lower piedmont area. This zone has shallow water table and higher aquifer thickness. The area near Tokion, Surajpur, Kartarpur, Majra, etc. belong to this zone. Moderate ground water potential zones fall in the lower part of the upper piedmont unit where aquifer thickness is moderate to good. The area near Kolar, Jhanki, Dhaula kuan, Rampur Banjaran, Surajpur, etc belongs to moderate potential zone. The low potential zones are associated with in the upper part of piedmont units, adjacent to structural hills. The area near Akalgarh, Nihalgarh,

Nawada, Bhungarni, etc. belong to this zone. In this area all the hills like as residual hills, denudational hills, and structural hills belong to runoff zone. Here water table occurs in perched conditions and ground water prospects are limited to narrow valleys along the faults, fracture and lineaments.

8. CONCLUSIONS

The study has focused on the utility of remote sensing and GIS in the identification of ground water potential zones. Satellite imagery proved to be highly useful in terrain characterization, i.e. in mapping of different groundwater controlling parameters for the occurrence and movement of groundwater such as geology, geomorphology, landuse/cover drainage, etc. The groundwater prospects map has been prepared by integrating the Geology, Geomorphology, landuse and depth to water table maps using Index Overlay Model in the GIS domain. The groundwater prospects are depicted in five categories excellent, good, moderate, low and runoff zone. Excellent and good groundwater prospects zones mainly fall in the flood plain, younger and older terraces and lower piedmont; moderate to low prospects zones mainly fall in the upper piedmont. The denudational hills, structural hills and residual hills mainly act as runoff zones. But in hilly terrain, prospect of groundwater availability is more along structurally weak planes such as lineaments, faults, fractures, joints and narrow valleys.

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Evidential Themes	Class	Class Weight	Evidential Weight
Geology	Recent Alluvium	10	**10**
	Younger Doon Gravel	8	
	Older Doon Gravel	5	
	Upper Siwalik	4	
	Lower Siwalik	1	
	Subathu	1	
Geomorphology	Braided/channel Bar	10	**8**
	Active Flood Plain (T0)	10	
	River Terrace (T1)	9	
	River Terrace (T2)	8	
	River Terrace (T3)	7	
	Lower Piedmont	6	
	Upper Piedmont	4	
	Dissected Upper Piedmont	3	
	Residual Hill	1	
	Highly Dissected Structural Hill	1	
	Low Dissected Structural Hill	1	
	Denudational Hill	1	
Land use/cover	Agriculture	8	**4**
	Settlement	4	
	Degraded Forest	5	
	Dense Forest	7	
	Open Forest	6	
	River Bed/water body	10	
Depth to Water Table (Unconfined condition)	<5 mt.	10	**5**
	5-10 mt.	8	
	10-15 mt.	7	
	15-20 mt.	6	
	20-25 mt.	5	
	25-30 mt.	4	
	30-35 mt	3	
	35-40 mt	2	
	>40 mt	1	
	Hilly Area	1	
Depth to water table (Semi to confined condition)	<10 mt	10	6
	10-15 mt	9	
	15-20 mt	8	
	20-25 mt	7	
	25-30 mt	6	
	30-35 mt	5	
	35-40 mt	4	
	40-45 mt	3	
	45-50 mt	2	
	50-55 mt	1	
	>55 mt	1	
	Hilly Area	1	

Table No-1.

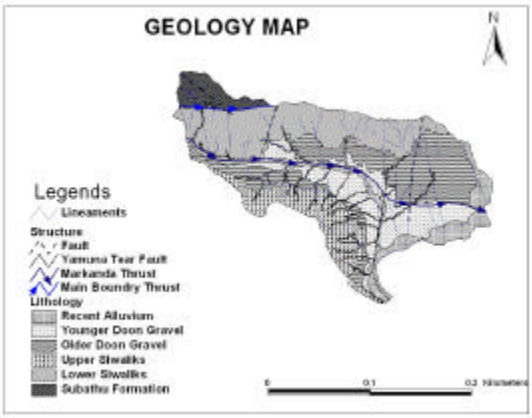

Figure No-1 Geology Map of the study area.

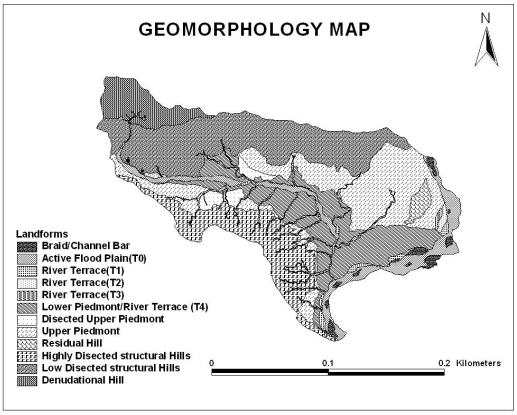

Figure No-2 Geomorphology Map of the study area.

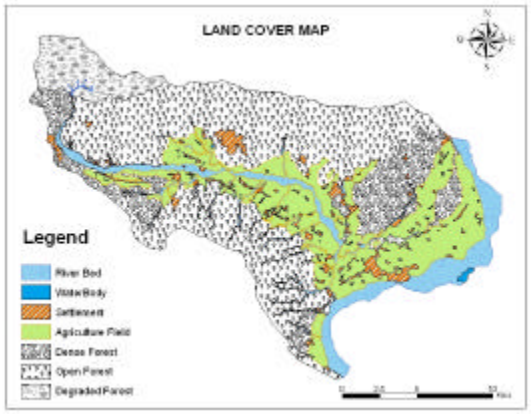

Figure No-3 Land use/cover Map of the study area.

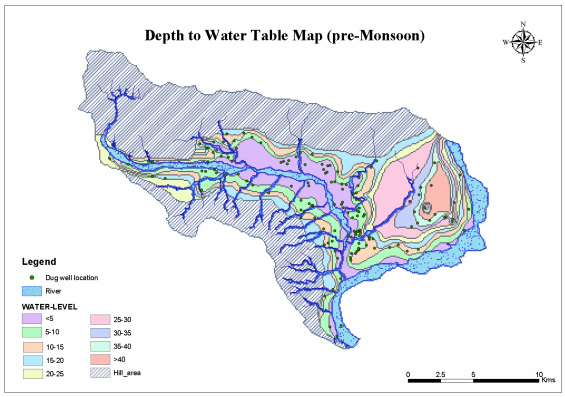

Figure No-4 Ground Water Table map in unconfined conditions.

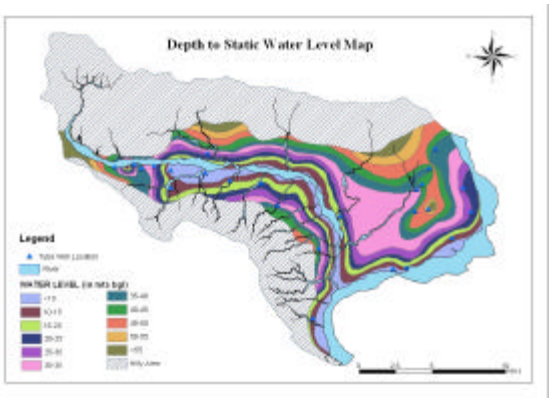

Figure No-5 Ground water Table Map in Semi to confined conditions.

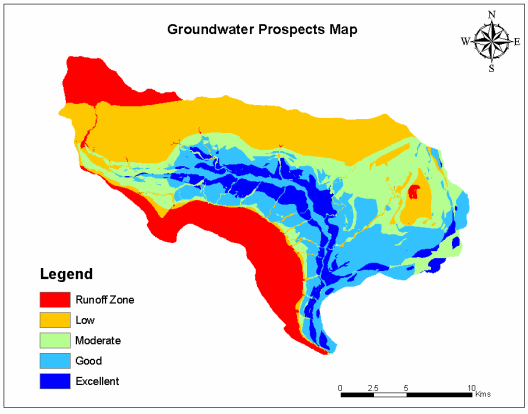

Figure No-6 Ground water Prospects Map of the study area.