INTEGRATED GROUNDWATER RESOURCE DEVELOPMENT IN HARD ROCK AREA AND ITS MANAGEMENT - A CASE STUDY

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ABSTRACT

Increasing population growth worldwide is putting increasing pressure on water resources. In arid and semi area pressure goes to groundwater. Keeping in view havoc capability of remote sensing and GIS, a study for the integrated groundwater development has been under taken in part of Lalitpur district, Uttar Pradesh. The Satellite data of IRS -IC and ID have been used to prepare the hydrogeomorphology, lineament, landuse map. Overburden thickness map was prepared by conducting vertical electrical sounding (VES) using Schlumberger configuration in the study area. All the thematic maps were digitally prepared in GIS environment. The integration of multigeodata technique using arc/info has been applied to have a composite groundwater potential map with the use of four themes i.e. hydrogeomorphology, lineament, overburden thickness and slope. Integrated potential map comprises of four potential classes viz. excellent, good, moderate and poor according to their groundwater potentiality. The integrated groundwater potential map has been overlaid with the landuse map and disparities related to the landuse practices at the study area were studied.

1.0 INTRODUCTION

The available water resources are inadequate to cater to the needs of water requirement for various purposes owing to increase in population growth. The demand for water has increased over years, which needs the development of quantity and quality of water. In arid and semiarid areas, surface water is limited in extent and hence pressure on groundwater utilisation. Development of groundwater and its proper management is necessary specially in hard rock areas. The interpretation of satellite data in conjunction with sufficient ground truth information makes it possible to identify and outline various ground features (such as geological structures, geomorphic features and their hydraulic characters), that may serve as direct or indirect indicators of the presence of ground water. The geomorphological conditions are essential prerequisite in understanding water bearing characteristics of hard rooks. Sufficiently thick weathered zone forms groundwater storage in hard rock areas but often may not provide regular supply of groundwater. Remote Sensing and GIS (Geographic Information System) techniques permit rapid and cost effective natural resource survey and management. Moreover, the integrated GIS analysis serves as vital tool in generating water resources development plan of an area (Sharaf et al 1998). In view of above potentiality of remote sensing, GIS and resistivity survey, which helps in detecting quality and quantity of water, a study has been under taken in part of Lalitpur district, Uttar Pradesh, India .The objective of this study is to derive integrated groundwater potential map and its validation with water well yield. The overlay analysis of landuse map with the groundwater potential map may help in highlighting the disparities related to the landuse practices in the area.

2.0 STUDY AREA

The area under investigation is located within district Lalitpur, which is a part of Bundelkhand area of Uttar Pradesh. Physiographically, the district is characterised by a highly undulating terrain dotted with small hillocks, mound inselberg etc. Geologically, the area consists mainly of granites, gneiss and younger alluvium. Black cotton soil covers major part of the area between Lalitpur town and the southern Vindhyan range. Shahzad River, having a general flow direction from SW to NE passes over the area. The climate of the region is semi-arid. Lalitpur district is a drought prone and backward region of the state of U. P. Source of income of the area is mainly agriculture.

3.0 DATA USED

(i) IRS–1C and IRS–1D LISS III FCC's on 1:50,000 scale

(ii) Survey of India (SOI) toposheet no. 54L/6 (1:50,000 scale)

(iii) Available literature of the study area

4.0 METHODOLOGY

The methodology adopted for the present study comprises of three parts (i) generation of resource map using satellite data (ii) derivation of integrated groundwater prospect map based on the integration hydrogeomorphology, lineament, slope and overburden thickness maps and (iii) overlay analysis of integrated groundwater prospect map along with existing landuse practice map and to observe the discrepancy over the area. GIS (ARC/INFO) has been used to demarcate the integrated groundwater potential zones by using above mentioned thematic maps.

4.1 HYDROGEOMORPHOLOGY

The hydrogeomorphological map is very useful in delineating groundwater prospect zone. Based on visual interpretation of IRS–1C LISS III (dated 01.03.2000) FCC's macro-landforms were delineated and hydrogeomorphological map has been prepared. The mapping envisaged delineation of rock types, geological structures, geomorphic units and landform for identification of potential groundwater zones. The groundwater prospect of geomorphic units is evaluated using available hydrologic characterise and aquifer parameters. The thematic map has been finalised after field checks at selected locations. The salient characteristics of various geomorphic units with their groundwater potentiality are studied.

4.2 LINEAMENT MAP

The structural trends on the basis of soil tone characteristics, microrelief of linearity, vegetation alignment and moisture rhythmicity have been interpreted from remotely sensed data. The area is traversed by numerous fractures of both mega and mesoscopic scale. The lineaments are traced from the satellite images along with the geological map and structural configuration of that basin. There are two prominent azimuth direction (a) NW-SE (Conjugate to shear axis) (b) NE-SW (azimuthal to shear fractures). The shear fractures are conduit for movement of groundwater (A.L. Haldar et.al. 2000). The length of lineaments varying from 1.2km to 3.5km represents macro fractures. Bore wells located in BPP-D and VF zone and close to NW-SE lineaments are highly successful

4.3 LANDUSE MAP

Landuse/landcover is one of the important resource maps since it suggests the developmental activity of any area. The present use and spatial distribution of the land is the prerequisite task. The preparation of landuse/landcover maps from the satellite image has been considered as original information in the sense that are generated by first hand examination of direct evidence of landuse patterns rather than by compilation from secondary sources, such as census data and topographic maps.

The landuse /landcover map of the study area has been prepared with the help of IRS -1C (dated 01.03.2000) and IRS - 1D LISS III (dated 28.10.1998) FCC image of two different seasons especially for agricultural landuse along with the Survey of India toposheet The land use/land cover map has been interpreted by using the techniques of visual interpretation. Different category includes in the map are agricultural land, barren land, water bodies, builtup land etc. Large amount of land in the study area (Fig. 4), is used for agricultural purposes. About 188.98 sq.km. area is found under agricultural use, which is about 76.1 % of the total geographical area of the present study. The agricultural land is further classified into - rabi (137.2 sq.km), kharif (28.6 sq.km.) double cropped (23.17 sq.km) and fallow land (13.85 sq.km.

4.4 SLOPE MAP

The study area is having almost flat topography except very limited patches where undulations do exist. The slope map shows the variation of slope of the study area.

4.5 OVERBURDEN THICKNESS MAP

Vertical Electrical Sounding (VES) were conducted to prepare the overburden thickness map of the study area. The main objective of conducting Vertical Electrical Sounding (VES) in the field is to transform the field data in terms of subsurface geology/ hydrogeology so that suitable maps can be drawn for different parameters of interest. To achieve this, one has to collect VES data cautiously and analyse the results after interpreting suitably. In the present study, 120 nos. VES have been conducted in the central parts of Lalitpur district. To delineate suitable aquifers, the layer parameters are translated into lithological formations. The lithology of various boreholes drilled on VES sites have been correlated with geoelectrical layer parameters. The subsurface of this area has been classified as 4 main lithological layers depending upon the resistivity of the formation.

Depth to bedrock map gives at a glance the variation of different substratum with depth in addition to the configuration of massive rock. In general the study area shows that thickness of overburden increases from north to south (Fig. 1) and varies in between 5m and 25m. in the study area except the SE part, where the overburden exists upto 40m. This part of the area is having moderate to good thickness of aquifer, which is indicative of the presence of aquifer and was confirmed from the bore holes drilled on the basis of geophysical recommendations. The reported well discharge in this part varies from 30 to 600 litre/minute (lpm).

5.0 INTEGRATION OF MULTIGEODATA

One of the important aim of GIS application is to integrate the various thematic information and its analysis, which will provide useful information about spatial and nonspatial data. The same technique is applied for groundwater exploration study in the granitic terrain of Lalitpur district. The integration has been made with four no. of coverages viz., hydrogeomorphology, lineament, overburden thickness and slope through Arc/Info GIS with the use of 'union' technique, to have a composite groundwater potential map. Each theme has different categories of attributes and they have been assigned relative weightages as per their importance to the relevant potentiality of groundwater in that area. The relative weightages are shown in Table 1

At the composite map there have been number of polygons created and the weightages values of each polygon have been summed up. Sum of the weightages of these polygons have been reclassified into four distinct classes viz. excellent, good, moderate and poor according to their groundwater potentiality. The decision rule has been prepared depending on the sum-

Table 1 Assigned weightages for the themes

Theme	Attribute	Weightages
Hydrogeomorphology		
	Valley Fill	120
	BPP-D	90
	BPP-M	60
	BPP-S/PP	30
Overburden thickness		
	>25 m.	140
	15-25m.	105
	05-15 m.	70
	<5 m.	35
Lineament		
	NW-SE orientation	20
	NE-SW orientation	10
Slope		
	0-1 %	10
	1-3 %	05

weightages of the attributes. After reclassifying the composite coverage the integrated groundwater potential map has been prepared.

5.1 CLASSIFICATION

Depending on the attributes of four GIS coverages and the general properties pertaining to the groundwater criteria, decision rule has been prepared. The probable groundwater potential zones has been classified from all the polygons in the composite coverage. Then the polygons have been reclassified according to the weightages. Sum-weightages 200- 290 has been considered for 'Class-4', which is 'excellent' groundwater potential zone, Sum-weightages 140-200 has been considered for 'Class-3', which is 'Good' groundwater potential zone, Sum-weightages 110-140 has been considered for 'Class-2', which is 'moderate' groundwater potential zone and Sum-weightages upto 110 has been considered for 'Class-1', which is 'poor' groundwater potential zone. Fig. 6 shows the probable groundwater potential zones constitutes four classes with overlay of landuse/land cover map.

5.2 GROUNDWATER POTENTIAL MAP AND ITS VALIDATION

Integrated groundwater potential map (Fig. 2) derived through GIS shows excellent groundwater potential zones near villages Mirchwara, Jijiawan, north of Satarwans, extreme south of Govind Sagar Dam, south of Pipriabansa etc. Similarly, good groundwater potential zones are oriented towards outer pheriphery of above mentioned villages and medium groundwater potential zones exist near villages Pipriabansa, Merthikalan, south of Seoni Khurd etc. Drilling results have confirmed that villages Mirchwara and Jijiawan and surrounding yields 600-1000 lpm. which are falling in excellent and good zones as per GIS derived map and the well discharge reported near village Pipriabansa and Merthikalan are appx. 300-500 lpm and they are lying in moderate groundwater potential zone at the GIS derived map. These results prove the correlation of GIS derived map and actual availability of groundwater within various zones.

5.3 OVERLAY ANALYSIS

Various classes of groundwater potential zones can respond to specified management practices for the purposes of optimisation of the available resources. The integrated groundwater potential map overlaid with the landuse map reveals the disparities regarding landuse practices in area vis-à-vis proper suggestion for management of land could be made. The salient observations are: (i) near the village Mirchwara very limited area is used for double crop, whereas a big patch has emerged as 'excellent' groundwater zone which can support for double crop. (ii) near village Pipria Bansa and southern part of Govind Sagar Dam patches of 'excellent' groundwater are delineated, which can be used for double crop. (iii) in the area of 'good' groundwater potential zone near Jijiawan (double crop is existed) but the cropping pattern should be changed to single crop (either rabi or kharif) keeping in view excess exploitation of groundwater leading to stress on aquifers. (iv) some of the existing double crop areas are lying in the 'poor' groundwater potential zone viz., near the villages Mailwara khurd, Raghunathpur, Berwara and northern side of Govind Sagar Dam, where surface water irrigation facilities exist and must be used accordingly.

6.0 CONCLUSIONS

The study has shown that preparation of integrated groundwater prospect map using remote sensing, GIS and resistivity survey leads to precise identification and may help in planning for optimum utilisation of water resources especially in hard rock area. Drilling results show relatively higher yields in the excellent groundwater potential zone as compared to the medium potential zone within the study area. Anomalous areas where despite moderate groundwater availability, the intensive/double cropping is being practiced could also be delineated. Proper management of land and water for crop cultivation depending on the groundwater availability is possible through the above approach.

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DEPTH TO BASEMENT CONTOUR MAP OF GOVIND SAGAR DAM ENVIRONS DISTRICT LALITPUR

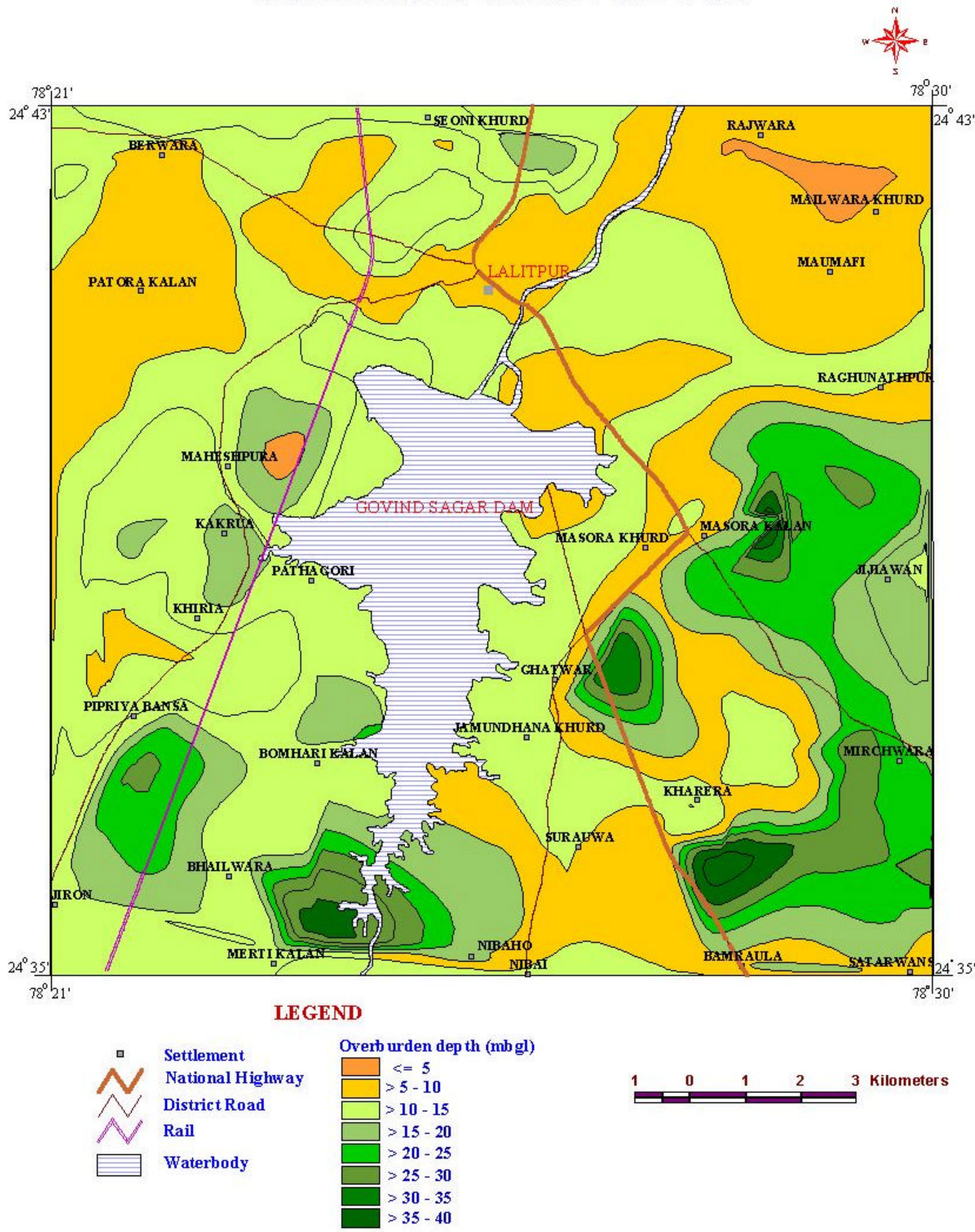

Fig. 1

INTEGRATED GROUNDWATER POTENTIAL MAP WITH OVERLAY OF LANDUSE MAP
GOVIND SAGAR DAM ENVIRONS DISTRICT LALITPUR

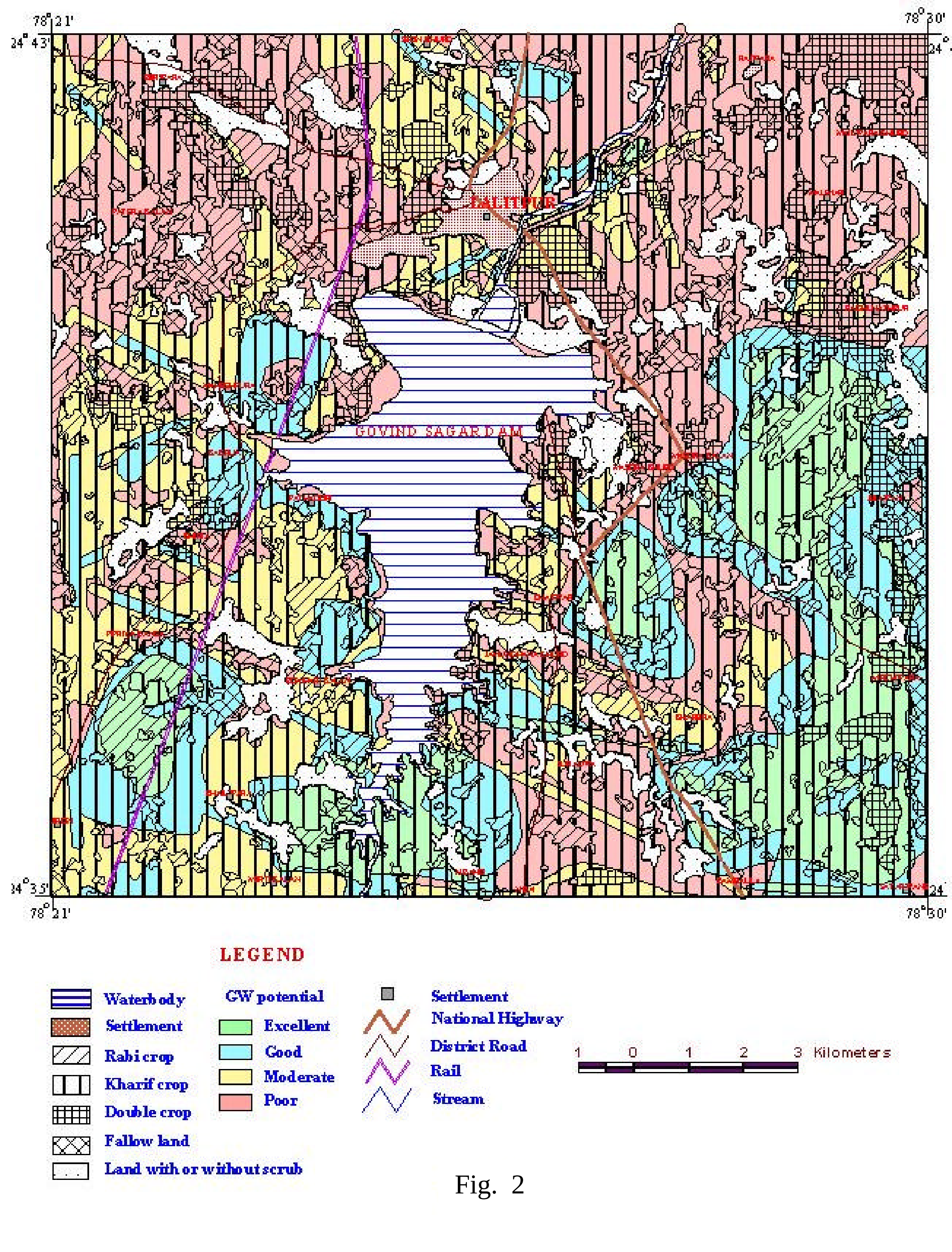

Fig. 2