INTRODUCTION

Groundwater is a most important natural resource of the earth and is required for drinking, irrigation and industrialization. The resource can be optimally used and sustained only when quantity and quality of groundwater is assessed. It has been observed that lack of standardization of methodology in estimating the groundwater and improper tools for handling the same, leads to miscalculation of estimation of groundwater. It is essential to maintain a proper balance between the groundwater quantity and its exploitation. Otherwise it leads to large scale decline of groundwater levels, which ultimately cause a serious problem for sustainable agricultural production. A possible solution for such problems is micro level planning, and use of standard methodology for assessing the groundwater. In recent years micro level planning has gained acceptance, since it can be locally applied and readily managed by self-sufficient rural governance. Groundwater resources are dynamic in nature as they grow with the expansion of irrigation activities, industrialization, urbanization etc. As it is the largest available source of fresh water lying beneath the ground it has become crucial not only for targeting of groundwater potential zones, but also monitoring and conserving this important resource. The expenditure and labour incurred in developing surface water is much more compared to groundwater, hence more emphasis is placed on the utilization of groundwater which can be developed within a short time. Besides targeting groundwater potential zones it is also important to identify suitable sites for artificial recharge usage cycle. When the recharge rate cannot meet the demand for water, the balance is disturbed and hence calls for artificial recharge on a country wise basis (Sameena et al. 2000). With the increasing use of groundwater for agricultural, municipal and industrial needs, the annual extraction of groundwater is far in excess of net average recharge from natural resources. Consequently, groundwater is being withdrawn from storage and water levels are declining resulting in crop failures, seawater intrusion in coastal aquifers, land subsidence etc. Vagaries of monsoon and indiscriminate development of groundwater often result in declining trend of groundwater levels. There is an urgent need for artificial recharge of groundwater by augmenting the natural infiltration of precipitation into subsurface formation by some suitable method of recharge. Artificial recharge is one method of modifying the hydrological cycle and thereby providing groundwater in excess of that available by process. Advent of Satellite remote sensing and Geographical Information System (GIS) has opened new vistas for groundwater studies. This is due to the fact that earth observing devices, both on space craft as well as on aircraft provide most up-to-date, accurate, unbiased and detailed spectral, spatial and temporal information on conditions of natural resources.

This paper addresses the strategies for an integrated approach of remote sensing and GIS for groundwater targeting, management and conservation of groundwater resources that ensures optimum and judicious use of groundwater and in identification of artificial recharge sites.

REMOTE SENSING IN HYDROGEOLOGY

Remote sensing with its advantages of spatial, spectral and temporal availability of data covering large and inaccessible areas within short time has become a very handy tool in assessing, monitoring and conserving groundwater resources. Satellite data provides quick and useful baseline information on the parameters controlling the occurrence and movement of groundwater like lithology/structural, geomorphology, soils, landuse/landcover, lineaments etc. However all the controlling parameters have rarely been studied together because of non-availability of data, integrating tools and modeling techniques. Hence a systematic study of these factors leads to better delineation of prospective zones in an area which is then followed up on the ground through detailed hydro-geological and geophysical investigations. Visual interpretation has been the main tool for evaluation of groundwater prospective zones for over two decades. It has also been found that remote sensing besides helping in targeting potential zones for groundwater exploration provides inputs towards estimation of the total groundwater resources in an area, the selection of appropriate sites for artificial recharge and the depth of the weathering area. By combining the remote sensing information with adequate field data, particularly well inventory and yield data, it is possible to arrive at prognostic models to predict the ranges of depth, the yield, the success rate and the types of wells suited to various terrain under different hydro-geological domains. Based on the status of groundwater development and groundwater irrigated areas (though remote sensing), artificial recharge structures such as percolation tanks, check dams and subsurface dykes can be recommended upstream of groundwater irrigated areas to recharge the wells in the downstream areas so as to augment groundwater
resources.

Apart from visual interpretation, digital techniques are used by many researchers for deriving geological, structural and geomorphological details. The various thematic layers generated using remote sensing data like lithology/structural, geomorphology, landuse/landcover, lineaments etc. can be integrated with slope, drainage density and other collateral data in a Geographic Information system (GIS) framework and analysed using a model developed with logical conditions to derive at groundwater zones as well as artificial recharge sites. Digital enhancement techniques are found to be suitable since they improve the feature sharpness and contrast for simple interpretation.

The study of groundwater of a region has a direct bearing on geology of the area. It requires knowledge of the nature of rocks and materials occurring therein, their structural disposition and geomorphic set-up. Aquifer recharge occurs in nature by rainfall, seepage from canals and reservoirs and return flow from irrigation. The geomorphic features like alluvial fans buried pediments, old stream channels and the deep-seated interconnected fractures are the indicators of subsurface water accumulation (Mukherjee and Das, 1989). These features are the natural recharge sites due to their high permeability and water holding capacity, moreover it is clear that higher the permeability lower the drainage density and higher the drainage density higher the surface run off. The hydrogeologist usually infer subsurface hydrological condition through surface indicators, such as aerial geological features, linear structures. Most of the geological linear features are assumed to be the zone of fractured bed rocks and the position of porous and permeable state where enhanced well yields can be expected (Das, 1997). Scientists observed that yields of wells on lineaments are about 14 times than that of wells away from lineaments.

Observations from the satellite data must be complemented by field checks, and existing geologic maps. Topographical sheets are very much useful as supplementary data sources. Data integration and map overlay is performed through GIS technique (1:50,000 scale). Delineation of pertinent area (such as open deep-seated fractures, weathered residuum, alluvial fans, old channel courses etc.) in the composite map is one of the most desired task for groundwater development, for construction of artificial recharge structure and for surface water storage augmentation (Geomorphic depression with impermeable layer) by water impounding structure.

**CASE STUDY**

**OBJECTIVES**

- To prepare groundwater prospects map on 1:50,000 scale
- To suggest suitable recharge structures

**DESCRIPTION OF THE AREA**

Bhilwara is situated between 25°.00' to 27°.50' North Latitude and 74°.03' to 75°.25' East Longitude. It is situated 100 meters above the sea level. It is 270 km. away from Jaipur. Northern Border of the district touches district Ajmer, North-West Border touches district Rajsamand, South & South-East Border touches district Chittor and East & East-North Border touches district Bundi & Tonk. The study area comprises of parts of Bhilwara district and falls under the toposheet no. 45k11.

The area is almost entirely underlined by pre cambrian rocks. These consist of the BUNDELKHAND gneiss covering an extensive tract in the East, the Banded Genesis Complex occupying a large tract in the North South and the aravali schist and composite gneiss's predominant over the rest of the area where it is not occupied by out-crops of the numbers of the railo series and the Delhi's. Towards the Eastern parts of the district VINDHYAN formations, just by the
side of the great boundary fault are also exposed. However, there are some, exceptions of the recent and sub-recent soil forming the alluvial mantle of varying thickness that covers the solid geology of the plain in many places.

**DATA USED**

In this project both satellite data as well as extensive field data were used for preparation of various thematic maps. As far as satellite data is concerned IRS-1D LISS III image was used for the interpretation and analysis. In addition to the satellite imagery, the secondary data which was used includes rainfall, groundwater table, borehole data, SoI topographical maps, published geological maps and other literatures.

**OVERALL APPROACH**

This study was carried out for some parts of Bhilwara district, Rajasthan to explore the groundwater prospects of the area. All the hydro-geological themes was created by the interpretation of satellite data and subsequently verified by field check. Apart from this, a hydrological and base theme was also created in GIS. All the themes was integrated and analyzed to prepare the groundwater prospects maps. Based on the hydrogeology and drainage pattern, suitable site for recharge structures was suggested in the map. Various procedures adopted in this study are briefly explained below:

**METHODOLOGY**

The project was carried out in 3 steps, in which image interpretation, spatial database creation, ground truthing of the thematic maps and field work (for collection of well data, hydrological data from PHED etc.) was carried out in first 2 steps starting from pre-field to field work. The intregation and analysis was done in third step.

1. **Pre-field**

   - **Literature Survey and data collection:** Detailed literature survey was carried out to understand the methodology and analytical framework of the project. The satellite images, topographical maps, geological maps etc. was collected from NRSA and Survey of India.

   - **Image interpretation and creation of spatial database:** IRS-1D LISS-III image was interpreted to prepare various themes which mainly include Lithology, Geomorphology, structures, hydrology and groundwater irrigated area. Other secondary data like well yield, depth of water table was also projected on the base map. The SoI topographical maps and other maps were used for preparation of base maps. The thematic maps so prepared by interpretation were digitized in Arc Info and Arcview platform. This analog to digital conversion was done for overlay analysis of all the thematic maps.
Field Reconnaissance

**Ground truthing for spatial database:** The field checks and ground truthing of individual thematic maps was carried out by visiting the sample sites. The generated theme was taken for field verification.

**Finalisation of the spatial database:** After ground truthing and field validation all the thematic maps were modified by incorporating the field findings.

Field Work

A field work was done in order to collect the groundwater and well data from the State groundwater department and PHED etc. During the field work, all the wells were measured for the depth, water level. Also the yield of all the wells surveyed was obtained. In each village, interactions with community was also undertaken to know the water availability, sources of water and sites for recharge structures. On the basis of lithology, geomorphology and hydrology, suitable sites for recharge structures were marked on the map and cross-checked on the ground.

Spatial Analysis of Data

After finalizing the spatial database and collecting the relevant information, a detailed analysis was carried out to demarcate the groundwater prospects area. This was done by overlaying the lithology and geomorphology (Lith-geom) themes. This overlay of lithology and geomorphology is known as hydrogeomorphology. Further the well data and the hydrological details were transferred on this map. The entire overlay analysis was done in ARC Info.

Recommended recharge structures

After detailed analysis of the groundwater prospects map generated using GIS techniques, the various suitable recharge structures such as check dams, percolation ponds, recharge pits / shaft, subsurface dykes, nallah bund, contour trench etc., were suggested based on the field condition.

In most of the village area, check dam was suggested as the wells in those area were sump, dried up and they didn't give sufficient yield. The location where the check dam proposed falls under highly favorable zone with good potential of groundwater.

At some places recharge pit was also suggested to recharge the aquifer. The recharge pit is normally recommended where the soil is having poor infiltration rate. If the clay layer is present above the shallow aquifer, the clay will be removed by constructing small pits. These pits will be filled with pebble stone and sand. Whenever rain
occurs, the water seeps through the recharge pits and recharges the aquifer.

Similarly other recharge structures such as Nalla bund, desilting of tanks, were suggested wherever feasible.

CONCLUSION

Apart from direct benefits, space technology has clearly demonstrated its usefulness in understanding the factors responsible for maintaining the hydrological cycle; mainly the vegetal cover, surface water bodies, litho types and landform. The groundwater prospects maps form a very good database and help in identifying favorable zones (prospective zones) around the problem villages, thereby narrowing down the target areas. Then, by conducting detail ground hydro-geological and geophysical surveys within these zones, most appropriate sites can be selected for drilling. Recharge is the most important factor in groundwater studies. If sufficient recharge is not there, the most favorable aquifer zones will also become dry. It is true that satellite alone cannot provide information regarding confined aquifers, then geophysical and drilling data have to be consulted for acquiring subsurface information and decisions file shall be created through overlay by GIS technique. The groundwater prospects maps will serve the twin benefit of helping the field geologists to:

β Quickly identify the prospective groundwater zones for conducting site specific investigations
β Select the sites for planning recharge structures to improve sustainability of drinking water sources, wherever required.

REFERENCES

GIS application in hydrogeological studies, D. Das, Department of Environmental Science, University of Kalyani, W.B. - 741235, India