Artificial Groundwater Recharge Planning in Northern Uttar Pradesh Using Remote Sensing and GIS

Moumita Roy[1], H.C. Sharma[2] and Ambrish Kumar[3]

[1]Ex-student, M.Tech., [2]Professor & Head, Department of Irrigation and Drainage Engineering
College of Technology, G.B.Pant University of Agriculture & Technology
Pantnagar, Uttaranchal
[3]Senior Scientist (SWC Engg.), Central Soil & Water Conservation Research & Training Institute
Dehradun, Uttaranchal

Abstract: The over-exploitation of ground water has become an acute problem in the agriculturally important states e.g. Punjab, Haryana, Gujarat, Maharashtra, Rajasthan, Uttar Pradesh and Tamil Nadu. Over-exploitation of ground water leads to progressive lowering of water table and consequent decline in well yield due to increase in suction lift, drying of springs and dug wells etc. If attempts are not made to protect the future degradation of water table, the situation will be more critical in near future. Keeping it in view, the present study was conducted in Bijnore district of northern Uttar Pradesh, where the groundwater table is gradually declining. The contour map of the study area, prepared for variation of pre-monsoon water table during 20 years' period (1983-2002), showed that water declined by about 2 to 9 m in Haldaur, Nahtaur, Dhampur, Kotwali, Jaleelpur and Noorpur blocks of Bijnor district. In some parts of Nazibabad, Seohara and Noorpur blocks water table declined below 1 m. Post-monsoon water table depth variation during above mentioned 20 years' period was found to vary in the range of 2 to 4 m in Noorpur, Kotwali, Haldaur, Jaleelpur and Kiratpur blocks.

On the basis of remote sensing data and GIS application, the study area was classified into four geomorphic units—Piedmont Plain (Upper Piedmont Plain P1, Lower Piedmont Plain P2 and Piedmont Plain P3), Young Flood Plain (YFP), Old Flood Plain (OFP-1, OFP-2 and OFP-3) and Fluvial Landforms. A number of geomorphic fluvial features such as palaeo-channels, natural levees, back swamp and channel scars were delineated which are potential sites for groundwater recharge. Recharge capability of each landform has been discussed in the paper in detail and accordingly an artificial groundwater recharge plan for the construction of different recharge structures for the study area has been prepared and discussed so that the declining water table in Bijnor district can be arrested at the desired level.

INTRODUCTION

The haphazard development of this renewable resource has resulted in over-exploitation of ground water causing rapid depletion of water levels. Competitions for the available resources have brought

awareness about its management. Proper planning and management of this important resource requires the quantitative assessment with all possible segments and apprising of the relative merits of various alternatives. It is, therefore, an important need of the time that this natural resource should be judiciously developed and utilized in planned and scientific manner. In this context it is important that water resources should be conserved as best as possible and every drop of it should be put to achieve optimum benefits.

Assessment of groundwater potential is very important before taking up the massive development of groundwater basin, especially for the areas facing the problem of lowering of water levels. The problem of lowering of water table has been encountered in many districts of western Uttar Pradesh (Bijnor, Moradabad, Budaun, Bulandshahar, Meerut, Saharanpur, Etah, Etawah, Agra), and Bundelkhand and hill regions. The rate of fall in groundwater level varies widely with time and space depending upon extent of groundwater exploitation, recharge and aquifer characteristics. Over-exploitation, poor recharge and poor yield of aquifers favours speedy decline of groundwater levels.

All the above mentioned observations of the area reveal that to fulfil the groundwater requirement of increased area under high water demanding crops and irrigated area by tube wells, the over-exploitation of ground water is taking place. Further, the increase in human population is also creating pressure on ground water, which is a main source for human consumption. Canal irrigated area which is one of the sources of groundwater recharge has decreased. Due to some of the reasons mentioned above, the groundwater exploitation is increasing rapidly and resulting in continuous decline in water table at an alarming rate. Situation will further deteriorate due to introduction of new cash crops like mentha, summer vegetables etc., decreasing canal supply, poor water management practices and decreasing net recharge area due to construction of building structures and other uses etc.

Different areas in Bijnor district, since the last decade, are showing continuous decline in the phreatic surface causing an alarming situation amongst the farmers. Different agencies have also reported similar type of groundwater problems of the area. Keeping it in view, the present study was taken up to delineate different geomorphic units in the area and to assess the recharge capability of different geomorphic units. On the basis of remote sensing data and G.I.S. application the study area was classified into different geomorphic units. A number of geomorphic fluvial features such as palaeo channels, natural levees, back swamp and channel scars were delineated which are potential sites for groundwater recharge. Recharge capability of each landform has been discussed in the paper in detail and accordingly an artificial groundwater recharge plan for the construction of different recharge structures for the study area has been prepared and discussed so that the declining water table in Bijnor district can be arrested at the desired level.

GENERAL DESCRIPTION OF THE STUDY AREA

Location

Bijnor occupies the north-west corner of the Moradabad division, and it is a roughly triangular stretch of the country with its apex to the north. The western boundary is formed throughout by the deep stream of the river Ganges, beyond which lie the four districts of Dehradun, Saharanpur, Muzaffarnagar and Meerut. In the east the Phika river for the greater part of its course constitutes the boundary, separating the district from Nainital, Udham Singh Nagar and Moradabad district; and to the south lie the Thakurdwara, Amroha and Hasanpur tehsils of Moradabad district and Jyotiba Phule Nagar district, the boundary being conventional and undetermined by natural features. The district lies

between latitudes of 29° 2′ and 29° 58′N and of east longitude of 78° 0′ and 78° 57′E. The total area of the district is liable to change slightly from time to time by reason of the erratic action of the rivers Ganges and Ramganga. There are five tehsils (Bijnor, Dhampur, Nagina, Nazibabad and Chandpur) and 11 development blocks in the district namely: Nazibabad, Kiratpur, Mohammodpur Deomol, Haldaur, Kotwali, Afzalgarh, Dhampur, Seohara, Nahataur, Jaleelpur and Noorpur. Index map of the district is shown in Fig. 1.

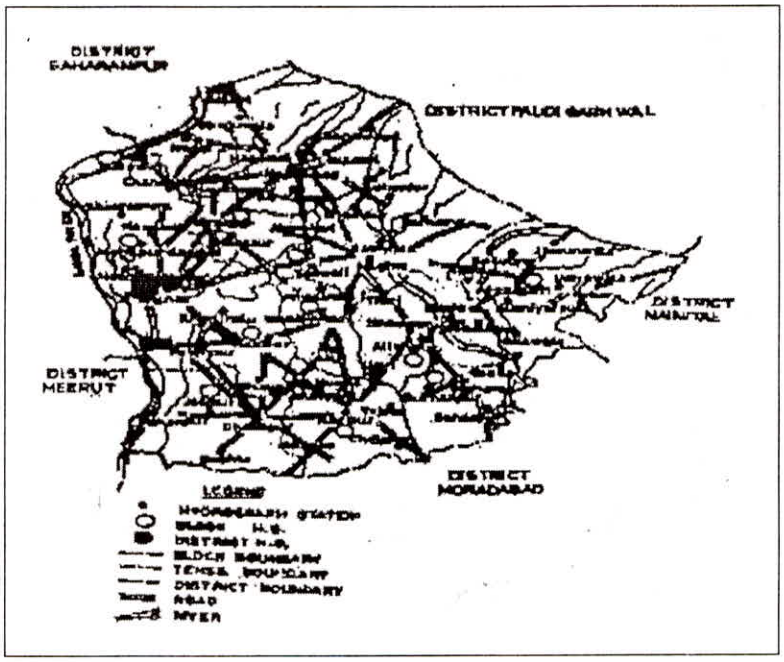

Fig. 1. Block wise detailed map of the study area.

Topography

The land is level or nearly level. The gradient is up to one per cent. In general, alluvial belt is flat with very gentle undulations. These regions are made from the flood deposition. There remains the low fringe of *khadir* along the Ganges to the west. This generally resembles the lowlands that skirt the rivers of the interior, the low flats which adjoin the stream itself being purely alluvial in character while above them rises a terrace of higher ground lying immediately under the *bhangar* cliff. Being a part of Gangetic plain, the study area has no sharp topography except some small pockets in the north-west part of district.

Geology

The study area is a part of alluvial region of Indo-Gangetic plain. The soil characteristics are affected by sub-humid climate. The geology of the area expresses nothing but the ordinary Gangetic alluvium, which consists mostly of gravel, sand, silt, clay and *kankar* (nodular limestone). Its deposition commenced in the Pleistocene period after the final upheaval of the Himalayas and it is still in progress. In the north-west area of Nazibabad block existence of perched aquifers are expected. In the

study area, topmost alluvial cover consists of soil having mixed sand and tiny mica flakes. Almost everywhere massive structure is found a few metres below the surface.

Climate

The climate of the area can be classified as subtropical with three well-defined seasons i.e. winter (November to March), summer (April to mid-June) and rainy season (mid-June to September). The average annual rainfall in the area is about 901 mm. Most of the rainfall occurs from southwest monsoon, starting from middle June and extending till the end of September. About 75 to 80% of the annual total precipitation is received during four months (June to September) and the rest of the precipitation is distributed over eight months, of which the largest precipitation is received in December to January. The annual mean daily temperature is about 22.71°C. The mean summer temperature is 28.05°C and the mean winter temperature is 14.21°C. The mean monthly minimum temperature is observed in December (4.08°C). The mean relative humidity remains more than 90% in July to February. From March onward it decreases to about 55% till mid June and steadily rises till August.

INPUT GENERATION

The IRS–1 D satellite data of the study area were analysed for their characterization of various land forms and its geomorphology with the help of G.I.S. software Geo_Media. The satellite data were of 5th May, 2003 and imageries were of the scale of 1:250,000. Base maps were prepared using Survey of India (SOI) topo sheets 53 L, 53 K, 54 M, 53 P and 54 I of 1:250,000. Base maps for river boundary, drainage network, district and block boundaries prepared by digitizing topo sheets, and other ancillary maps were prepared using Geo_Media software with polygonic projection.

RESULTS AND DISCUSSION

Delineation of Various Landforms using Remote Sensing and G.I.S.

Different types of landforms were delineated for hydro-morphological study of Bijnor district. Figure 2 depicts the entire Bijnor district in false colour composite (FCC). The upstream areas like upper and lower piedmont areas, lying in the upper part of the district, are also shown in the FCC image because the geo-hydrology is directly linked with northern parts of the study area and fluvial action of rivers. The image is well superimposed with block and district boundaries of the study area. The textural and tonal differences can easily be seen by visual interpretation of the image varying from one block to another. Thematic map, for different land forms, showing various colour schemes, of the study area was prepared (Fig. 3). Fifteen landforms were identified in the study area. The geomorphic details of these landforms are described as below.

Piedmont Plain (P)

This is the transition zone lying at the junction of Siwalik hill and plain of the study area. The landform is divided into three geomorphologic units as given below:

Upper Piedmont (P1): This geomorphologic unit is located in upper most zone of the study area, extending from north-east to north-west of the district under Najibabad and Kotwali blocks (Fig. 3). Unconsolidated sediments with variable runoff and infiltration characterize it. Depth to water table is

also varying from shallow to deep. In upper and lower piedmont zones, a number of buried and abandoned channels are found due to regular and frequent changing of flow direction of different rivulets. The groundwater prospect is high along buried and abandoned channels.

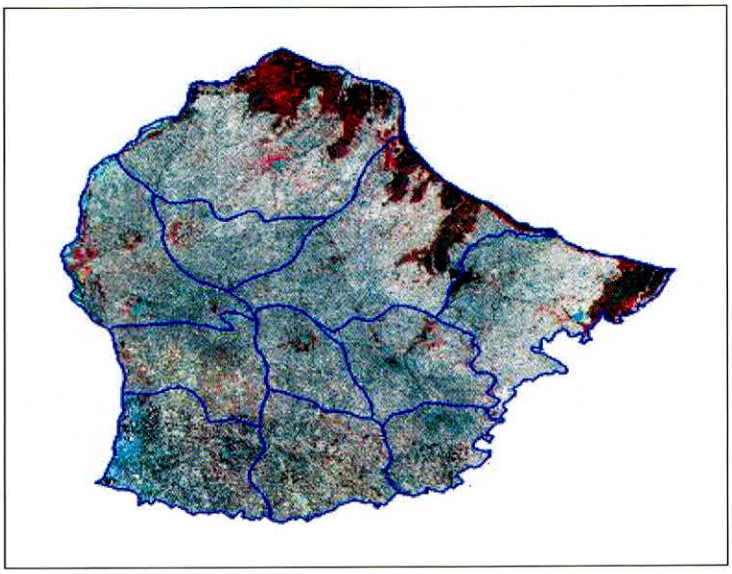

Fig. 2. Bijnor district in False Colour Composite (FCC).

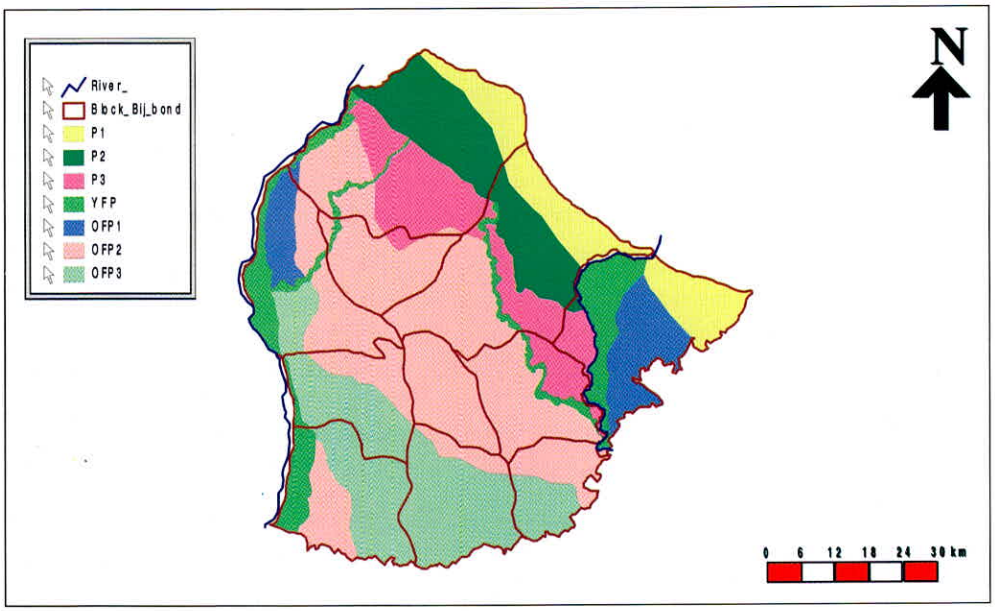

Fig. 3. Geo-morphological map of the study area.

Lower Piedmont (P2): It is also located in Najibabad and Kotwali blocks of Bijnor district just south of upper piedmont zone lying in northern region of the study area. The geomorphologic characteristics of the unit are by and large similar to upper piedmont landform except altitude and slope, which is relatively low. The zone has equal groundwater prospects varying from shallow to deep.

Piedmont Flood Plain (P3): It is also known as transitional plain between piedmont and flood plain lying mostly under Nazibabad block of Bijnor district. This unit is frequently visited by flood from upland runoff during monsoon season. The geomorphologic feature is similar to other flood plains. The prospect of ground water is very high; somewhere the depth to water table in the unit is quite shallow.

Young Flood Plain (YFP)

The young flood plain has been identified at either sides of river courses which is frequently visited by floods, and the sand content and depth of sand layer in the area are comparatively medium to high (Fig. 3). The study area has been divided into two parts:

Mixed sand and silt dominated (YFP-1): This type of landform is concentrated in small patches along the riverlets flowing in upper piedmont, lower piedmont and transitional plains in Nazibabad, Afzalgarh, Dhampur, Mohd. Pur Deomal, Haldaur, Jaleelpur and Seohara blocks of Bijnor district. The percentage of sand and silt contents varied from one patch to another.

Sand dominated (YFP-2): This is sand dominated landform. It is found in Najibabad block of Bijnor district, along Ganga river. The depth and width of the layer varied from place to place. The width of the landform along river Ramganga is narrow. Small patches of this flood plain are also found either side of both main rivers. The groundwater prospects of this landform are very high because of high percentage of sand content in upper layer of the geomorphic unit which provides sufficient opportunity of groundwater recharge, if the surface of the landform is modified to store water.

Old Flood Plain

These types of geomorphic units are known as older upper alluvial plain because such plains do not come under active flood plain. A larger area between Ganga and Ramganga rivers is under category of old alluvial plain. This landform has been classified into three geomorphic units as follows:

Sand dominated (OFP-1): This is sand dominated geomorphic unit of old alluvial landform. Figure 3 shows the geomorphic unit having dominating sand content after young flood plain. This unit is concentrated in small patches along the river Ganga in Mohd. Pur Deomal block and along the river Ramganga in Afzalgarh block. Such geomorphic unit is second phase formation of young flood plain; therefore, the sand materials are dominating in the unit. This is not under active flood plain, is the only difference from young flood plain. The prospect of ground water is sufficient but the unit is better to correlate the underlying hydro-geological strata.

Silt dominated (OFP-2): This is a geomorphic unit of old upper alluvial landform having high silt proportion in surface textural morphology. Such type of landform exits in upland portion of the interbasin in Bijnor district. It is spread over Najibabad, Mohd. Pur Deomal, Keeratpur, lower part of Kotwali, Haldaur, Nahtaur, Dhampur and Noorpur blocks of Bijnor district. Such landform needs attention for developing recharge structures to sustain the prospect of groundwater in future.

Mixed sand and silt (OFP-3): Geomorphic unit of this category is spread over every part of the study area from north-west to south-east. Although, the main constituent of the unit is sand and silt, the proportion of the sand and silt varies from one part to another. This landform prevails in the Mohd. Pur Deomal, parts of Haldaur, Jaleelpur, Noorpur and Seohara blocks.

Fluvial Landforms

Various kinds of geomorphic features, formed either sides of river by fluvial action of rivers, are known as fluvial landforms e.g. channel bar, channel island, point bar, river terrace, natural levee, back swamp, cut-off meander, abandoned channel, ox-bow lake, palaeochannel and buried channel. Out of these geomorphic features, palaeochannels, natural lavees, back swamp and channel scare/cut-offs were delineated in the study area. Palaeochannels are remnant of streams/rivers and appear as buried or abandoned channels. They are found in Keeratpur, Kotawali and Dhampur blocks of Bijnor district. These features possess a good promising zone for shallow aquifer with excellent groundwater yield. Natural levee is a bund along river bank formed with fluvial sediments brought by river. It extends like narrow strip from north to south along Ganga river and a small strip along Ramganga river. Natural levee comprises characteristics of low runoff, high infiltration and moderate depth to water level and good prospects of ground water. Back swamp is low-lying swampy/marshy area adjoining natural levee. It has good prospect of groundwater. It extends from north to south along natural levee formed by the Ganga river. Channel scares are found in lower part of back swamp.

Water Table Decline

The contour maps showing rise and fall of water table during pre-monsoon and post-monsoon conditions for 20 years' period (1983-2002) were prepared for the study area. These figures showed that water declined by about 2 to 9 m in Haldaur, Nahtaur, Dhampur, Kotwali, Jaleelpur and Noorpur blocks of Bijnor district. In some parts of Nazibabad, Seohara and Noorpur blocks water table declined below 1 m. Post-monsoon water table depth variation during above mentioned 20 years' period was found to vary in the range of 2 to 4 m in Noorpur, Kotwali, Haldaur, Jaleelpur and Kiratpur blocks. All identified landforms under the study area were correlated with situation of rise and fall of water table within 20 years' period (1983–2002). The area of block lying under a particular landform, along with the decline of water table, is given in Table 2. The area lying under OFP-1 was having a water table decline range of 0-2 m and this landform comprises high percentage of sand content. The maximum decline of water table, observed to be about 9 m, was in OFP-2 and OFP-3 landform. Hence these areas need immediate recharge plan. Although some parts of the study area are experiencing no decline of water table, almost all blocks of the study area are facing the danger of groundwater mining or blocks would come under the groundwater mining situation if the present agricultural practices prevail and no steps are taken for groundwater recharge.

Feasible Recharge Measures

The effective methods of the recharging underground reservoirs are construction of recharge structures, reducing pressure on groundwater draft and increasing surface water sources up to some extent. On the basis of the foregoing discussion and guidelines, the following measures may be adopted for recharging the groundwater aquifer in Bijnor district.

Table 2. Water table decline under different landforms in Bijnor district in pre-monsoon and post-monsoon season during 20 years' period (1983–2002)

Landforms	*Blocks*	*Water table decline, m*	
		Pre-monsoon	*Post-monsoon*
P1	Northern part of Nazibabad, Afzalgarh, Kotwali	0-2	0-1
P2	Central part of Nazibabad, Kotwali	0-3	0-2
P3	Nazibabad. Kotwali, Dhampur, Afzalgarh	0-1	0-1
YFP	Nazibabad,Mohd.pur Deomol, Kotwali, Jaleelpur, Afzalgarh	0-3	0-1
OFP-1	Mohd.pur Deomol, Afzalgarh	0-2	0-1
OFP-2	Nazibabad, Mohd.pur Deomol, Kotwali, Kiratpur, Nahataur, Haldaur, Dhampur, Jaleelpur, Seohara	0-6	0-4
OFP-3	Mohd.pur Deomol, Haldaur, Jaleelpur, Noorpur, Seohara	0-9	0-6

Series of Check Dams on Natural Streams

In this system the artificial recharge is made to restrict the surface runoff through streams and by making additional water available for percolation. The surface water impounded during monsoon, behind the structure, spreads over the entire stream bed thereby increasing the wetted area. The impounded water helps in replenishment of ground water. A series of check dams can be constructed on a stream to recharge the depleted groundwater aquifers in the Najibabad, Kotwali and Dhampur blocks of Bijnor district where a number of 1st and 2nd order steams flow under piedmont landforms.

Percolation Tanks

Percolation tanks are generally constructed on the small streams or rivulets of the 2nd and 3rd order with adequate catchment for impounding surface runoff. These tanks are used entirely for recharging the aquifer through percolation. Construction of percolation tanks take into account the catchment area, likely runoff, designed storage as well as the area to be benefitted due to the structure. The basic requirement for percolation tank site is a permeable stratum to facilitate easy infiltration and percolation.

In the present study, the landforms Young Flood Plain-2 (YFP-2) and Old Flood Plain-1 (OFP-1) are highly suitable sites for percolation tanks because these landforms contain high percentage of sand contents and favourable stream orders. The Young Flood Plain-2 is highly suitable for the construction of trenches across the slope because in this landform areas shallow permeable strata are available. In the YFP-1 and OFP-3, the silt content retards the infiltration rate; therefore, these areas should have the percolation tanks having more width and less depth.

Bunds, Trenches and Stream Modification

Bunds may also be constructed in farmers' fields. These serve dual purpose of rain fed farming and water harvesting during the scarcity period and recharging of the groundwater aquifer. As the soils are almost sandy in the problematic areas, the presence of bunds near cropped area would not create the waterlogged conditions. The percolation ponds may serve as a safety measure for absorbing the flood and mitigating its havoc, and as a venue for fish culture. The land with the construction of a percolation tank gets its value enhanced 2 to 6 times as compared to its initial value. Construction of a large number of smaller percolation tanks at different places in the problematic area would be more

useful and need satisfying than a single tank at a selective place. Since the percolation tank is useful for a large number of farmers living wide over, the construction of such tanks is socially tenable and grammatically beneficial besides their economic feasibility. The construction of trenches in upper piedmont zone and in the riverside area of YFP-2 across the slope would enhance the recharge of the area.

Dug well recharge method can be powerful tool for the landform OFP-3 where the silt content in the upper surface is high. Under subsurface practice, the existing dug wells may be utilized as recharge structures when filter materials or pebbles would properly back fill these wells. Most of the water of monsoon seasonal runoff flows wasteful since there is no recharge plan at either side of the channels. The recharge capability of the riparian area can be increased by modification of these channels like putting permanent low check dams or constructing ditches/furrows across slope.

CONCLUSIONS

In most of the blocks of Bijnor district the groundwater table has declined in the range of 2 to 9 m in pre-monsoon season and 2 to 4 m in post-monsoon seasons during the period of 20 years (1983–2002), which indicated that over-exploitation of ground water was taking place in major parts of the district. On the basis of Remote Sensing data, the district was classified into four major geo-morphological units—Piedmont zones (Upper Piedmont P1, Lower Piedmont P2, Piedmont Flood Plain P3), Young Flood Plain (YFP-1 and YFP-2), and Old Flood Plain (OFP-1, OFP-2 and OFP-3) and Fluvial Landforms. OFP-1 landform is highly suitable site for percolation tanks because this landform is composed of high percentage of sand content and has favourable stream orders.

Canal network of the area should be extended to the problematic areas so that it can serve as potential source of groundwater recharge or can reduce the groundwater draft. Conjunctive use of canal water and ground water will help in controlling the declining water table. Recharge capacity can be increased in riparian area by modifying the flowing channels like putting permanent low check dams or constructing ditches/furrows across the slope.

REFERENCES

Raju, Janardhan, N., Reddy, T.V.K., Kotaiah, B. and Nayudu1, P.T. (1995). Hydrogeomorphology of the Upper Gunjanaeru river basin, Cuddapah district, Andhra Pradesh, using remote sensing techniques. *J. of Applied Hydrology*. **VIII (1–4):** 99-104.

Rao, Babu, P., Sreenivas Prasad and Iftekhar S. Ahmed (1998). Watershed management and consequential conservation/augmentation to groundwater resources. International Conference Watershed Management and Conservation, pp. 259-268.

Sankar, K. (2001). Remote sensing study of groundwater occurrence in Kanyakumari District, Tamil Nadu, India. *Journal of Applied Hydrology*. **XIV (4):** 16-26.

Tejwani, K.G. and Dhruva Narayan (1961). Soil conservation survey and land use capability planning in the ravine lands of Gujarat. *Jl. Indian Soc. Soil Sci.* **9 (4):** 233-244.