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Shallow water regime in the Chambal command area, western India: environmental implications of modification in surface drainage

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ABSTRACT

Introduction of canal irrigation in the Kota region (western India) has significantly modified the groundwater regime of the region and has resulted in water logging and soil salinisation. Present paper focuses on diagnosis and correlation of such problems with surface irrigation in the Left Main Canal region of the Chambal command area. The results of the studies carried out for a two year period (1994-1996) have been discussed.

The area of present investigation is predominantly alluvial covered with limestone-sandstone ridges, belonging to the Vindhyan Supergroup (late Proterozoic), exposed along the western and southwestern fringe. The water table is controlled by the topography and both the pre- and post-monsoon water table profiles are quite similar. The seasonal water table fluctuation varies from 1.62 to 8.82 m. Major part of the area of study having water level depth < 6 m falls under the category of shallow water table zone. The region with < 4 m depth, the 'critically water logged' region needs special attention. The insufficient circulation of water, resulting in water stagnation at shallow depths has attributed to soil salinisation. The mitigation methods suggested in the study include judicious use of water, alternate cropping pattern, conjunctive surface and groundwater irrigation and application of subsurface drains.

INTRODUCTION

The hydrologic regime in any area is predominantly controlled and influenced by the prevailing drainage network. Any interference with the natural drainage system would, hence, affect and irreversibly modify the drainage system. The post-independence era in India (after 1947) has witnessed ambitious irrigation projects to increase the agricultural output. The canal alignment and command areas are usually decided on the concept of gravity flow and vital geologic cum morpho-tectonic considerations are apparently overlooked. Compounded by unfavorable hydrogeologic conditions, introduction of any surface irrigation project would result in hydrologic imbalance, ultimately leading to water logging, salinity-alkalinity problems. The effect is usually visible only after elapse of sufficient time when it is too late to reverse the process. Increased irrigation also leads to higher consumption of chemical fertilizers, where unabsorbed chemical constituents pollute the groundwater. As each area has its own specific morpho-tectonic setting, generalisations could be problematic and simple solutions are impossible. It becomes imperative to review the existing projects on individual basis and avoid the shortcomings while planning and implementing the new ones.

The present paper embodies the observations and findings on the effect of introduction of canal network in the Chambal command area, western India where shallow groundwater regime and an increase in soil salinity have been reported to be a major problem. The quantitative assessment of the problem is based upon long term variation in the hydrologic characters and its possible bearing on the

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increased soil salinity. The area of present investigation, forming a part of the Left Main Canal of Chambal Command Area in Kota-Bundi tract in Rajasthan (western India) extends between latitudes 25°11'N and 25°41'N, and longitudes 75°37'E and 76°19'E (Fig. 1).

GEOMORPHOLOGY AND GEOLOGICAL SETTING

The investigated area is bound on east and northeast by the Chambal River and on west and southwest by Bundi and Mukandwara hill ranges, respectively. Rapid erosion of the soil has led to development of gullies. Development and growth of ravine land is one of the major problems of the region. The general slope of the ground is northeastward, however, along the rivers it converges towards the rivers. Small rivers like Mej, Kural, Talera, Ghorapachar and Mangli have intercepted the area. The latter three join Kural and Mej rivers and ultimately to the river Chambal in the northeast direction, which has been identified as the fifth order stream (Strahler, 1957). The drainage density ranges from very coarse to coarse drainage category (Smith, 1950). The drainage pattern is dendritic or trellis, corresponding to the prevalent geological setting. The southeastern tributaries of river Chambal, flowing over horizontally disposed sandstone have given rise to Pinnate dendritic pattern whereas the northwestern tributaries, flowing over contrasting lithologies have resulted in development of trellis pattern. The natural drainage has further been modified by main canals and smaller channels (usually unlined) (Fig. 2).

Geologically, the area forms the western margin of the Vindhyan Supergroup (late Proterozoic to early Palaeozoic) of central India. Although the area

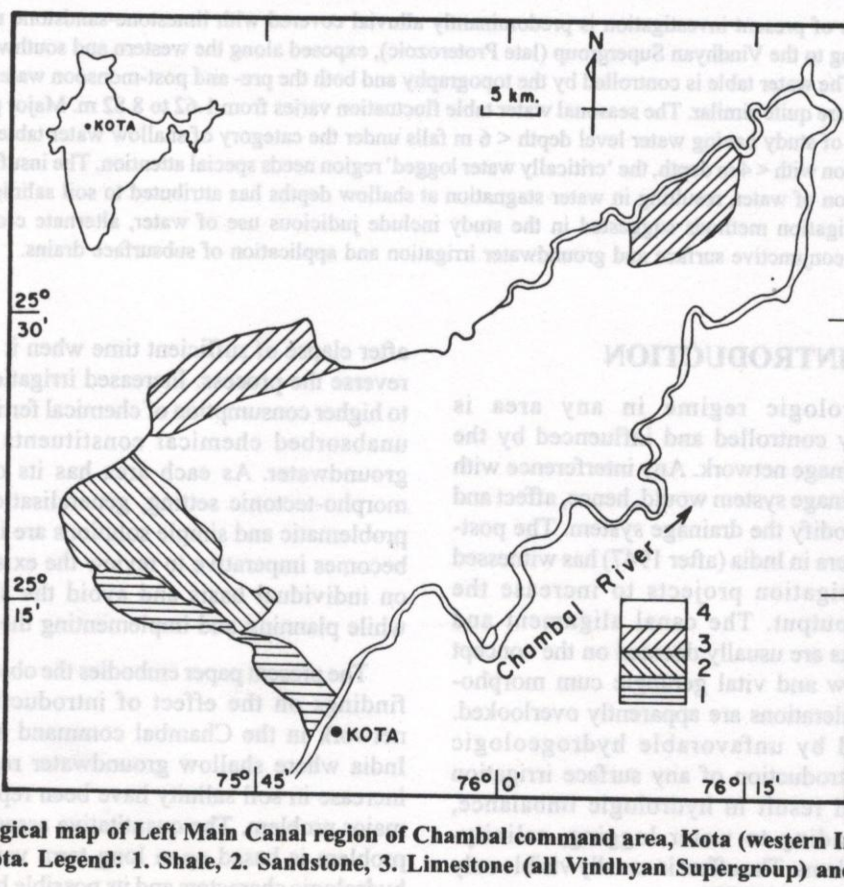

Fig. 1: Lithological map of Left Main Canal region of Chambal command area, Kota (western India) with the location of Kota. Legend: 1. Shale, 2. Sandstone, 3. Limestone (all Vindhyan Supergroup) and 4. Alluvium (Quaternary).

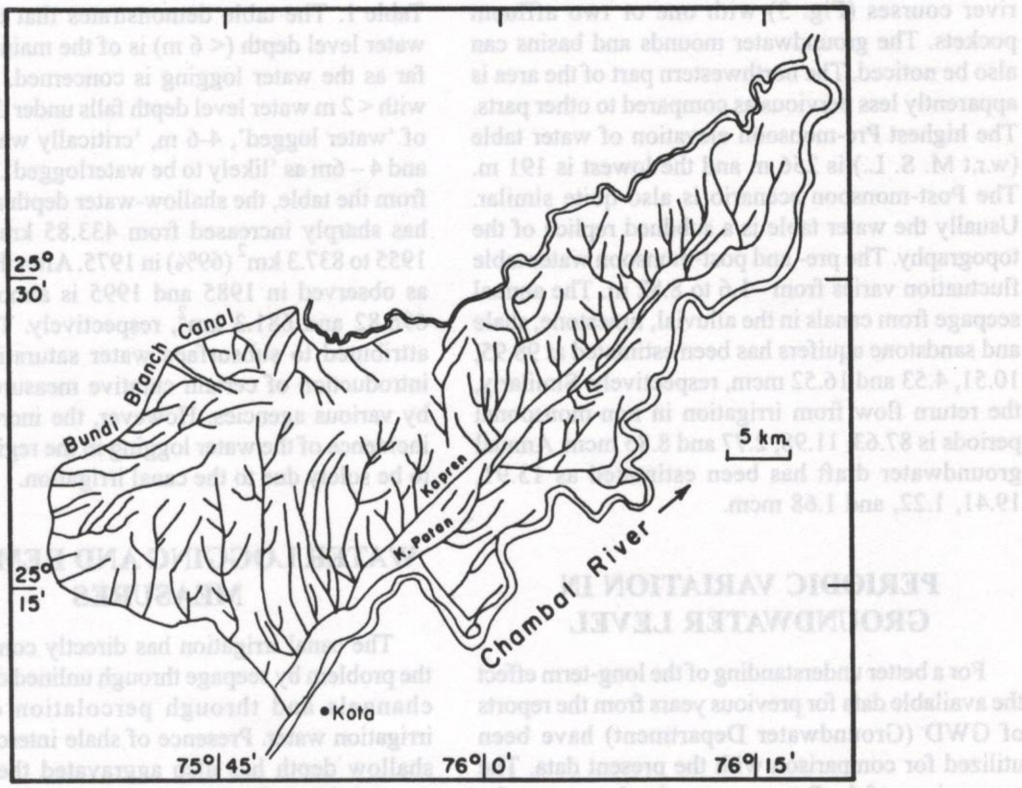

Fig. 2: Canal network map of Left Main Canal area.

is predominantly covered by alluvium, minor outcrops of shale, limestone and shale belonging to the Bhander Group are exposed along the western margin of the area. The beds are horizontally disposed. Regional folding has resulted in open fold patterns with moderate plunge. The western margin of the Vindhyan basin is controlled by a NNE-SSW trending fault, the Great Boundary Fault, which has juxtaposed the older Precambrian rocks with the Vindhyan sedimentary. Prasad (1975) and Ramasamy (1995) have described detailed geological setting. Subsurface geology, worked out on the basis of Vertical Electrical Soundings reveals semiconsolidated to partially weathered lithologies at shallow levels, showing an increase in the degree of compactness with depth. The estimated thickness of alluvial cover ranges from 2 to 40 m (maximum along the river courses), usually followed by limestone (with shale intercalation) of variable thickness. The inferences have also been corroborated by observations on open dug wells.

HYDROLOGICAL CHARACTERISTICS

Topographic features, physical characteristics and regional structure control the occurrence and movement of groundwater. In the hard rocks the groundwater occurs in weathered zone at shallow depth and in fractured zone at relatively deeper horizons. Joints, extending into deeper levels act as conduits for groundwater movement and accumulation at depth. In the present area the groundwater occurs under water table conditions in alluvium, sandstone, limestone and shale, although their water bearing capacities are extremely variable. Alluvial formations are the major aquifers in the area amounting to a total of 71 dug well selected for present study. Shale amounts to 16 dug wells and limestone and sandstone aquifers are represented by 13 and 6 dug wells, respectively.

The Pre-monsoon water table map shows that the movement of groundwater is towards the main river courses (Fig. 3) with one or two affluent pockets. The groundwater mounds and basins can also be noticed. The northwestern part of the area is apparently less pervious as compared to other parts. The highest Pre-monsoon elevation of water table (w.r.t M. S. L.) is 256 m and the lowest is 191 m. The Post-monsoon scenario is also quite similar. Usually the water table is a subdued replica of the topography. The pre- and post-monsoon water table fluctuation varies from –1.6 to 8.82 m. The annual seepage from canals in the alluvial, limestone, shale and sandstone aquifers has been estimated at 98.95, 10.51, 4.53 and 16.52 mcm, respectively. Similarly, the return flow from irrigation in non-monsoonal periods is 87.63, 11.98, 2.77 and 8.85 mcm. Annual groundwater draft has been estimated as 13.91, 19.41, 1.22, and 1.68 mcm.

PERIODIC VARIATION IN GROUNDWATER LEVEL

For a better understanding of the long-term effect the available data for previous years from the reports of GWD (Groundwater Department) have been utilized for comparison with the present data. The comparison of the Pre-monsoon depth to water for the years 1955, 1975 and 1985 (GWD Reports) with that of 1995 has been used in the present study. The 1955 data represents the prevalent hydrologic regime, prior to the introduction of canal network, the 1975 and 1985 data is for the periods when canal irrigation was in use and 1995 data shows the effect of conjunctive use of canal and groundwater irrigation. The periodic variation in groundwater level and other relevant data is summarised in Table 1. The table demonstrates that the shallow water level depth (< 6 m) is of the main concern as far as the water logging is concerned. The region with < 2 m water level depth falls under the category of 'water logged', 4-6 m, 'critically water logged' and 4 – 6m as 'likely to be waterlogged'. As evident from the table, the shallow-water depth area (< 6m) has sharply increased from 433.85 km^2 (36%) in 1955 to 837.3 km^2 (69%) in 1975. After that the level as observed in 1985 and 1995 is almost static at 696.82 and 681.3 km^2, respectively. This can be attributed to subsurface water saturation and by introduction of certain curative measures initiated by various agencies. However, the increase in the incidence of the water logging in the region appears to be solely due to the canal irrigation.

WATER LOGGING AND REMEDIAL MEASURES

The canal irrigation has directly contributed to the problem by seepage through unlined distribution channels and through percolation of excess irrigation water. Presence of shale intercalations at shallow depth has also aggravated the problem. Availability of the water has also developed a tendency among the farmers to use more water for better crop yield. The ignorance of the soil chemistry has led to use of excessive nitrate fertilizers. The unabsorbed nitrate has percolated into the groundwater, resulting in high nitrate levels (Singhal, 1996). The potential water logging hazard map of the region shows that the southeastern stretch of the area is 'critically waterlogged' to 'potentially waterlogged' (Fig. 4).

Table 1. Periodic variation in groundwater levels and area covered.

S. N.	Depth to water level (m b.g.l.)	1955		1975		1985		1995	
		No. of samples	Area km^2	No. of samples	Area km^2	No. of samples	Area km^2	No. of samples	Area km^2
1	0 - 2	0	0.00	5	87.21	2	31.67	1	11.35
2	2 - 4	3	85.97	24	418.60	19	300.90	33	374.70
3	4 - 6	12	343.88	19	331.43	23	364.25	26	295.22
4	6 - 8	5	143.22	4	66.77	13	205.88	19	215.74
5	8 - 10	9	257.19	4	63.77	9	142.53	12	136.26
6	10 - 12	4	114.63	7	122.10	2	31.67	4.	45.42
7	> 12	9	257.90	6	104.66	8	126.69	11	124.90
	Total	42	1203.6	69	1203.6	76	1203.6	106	1203.6

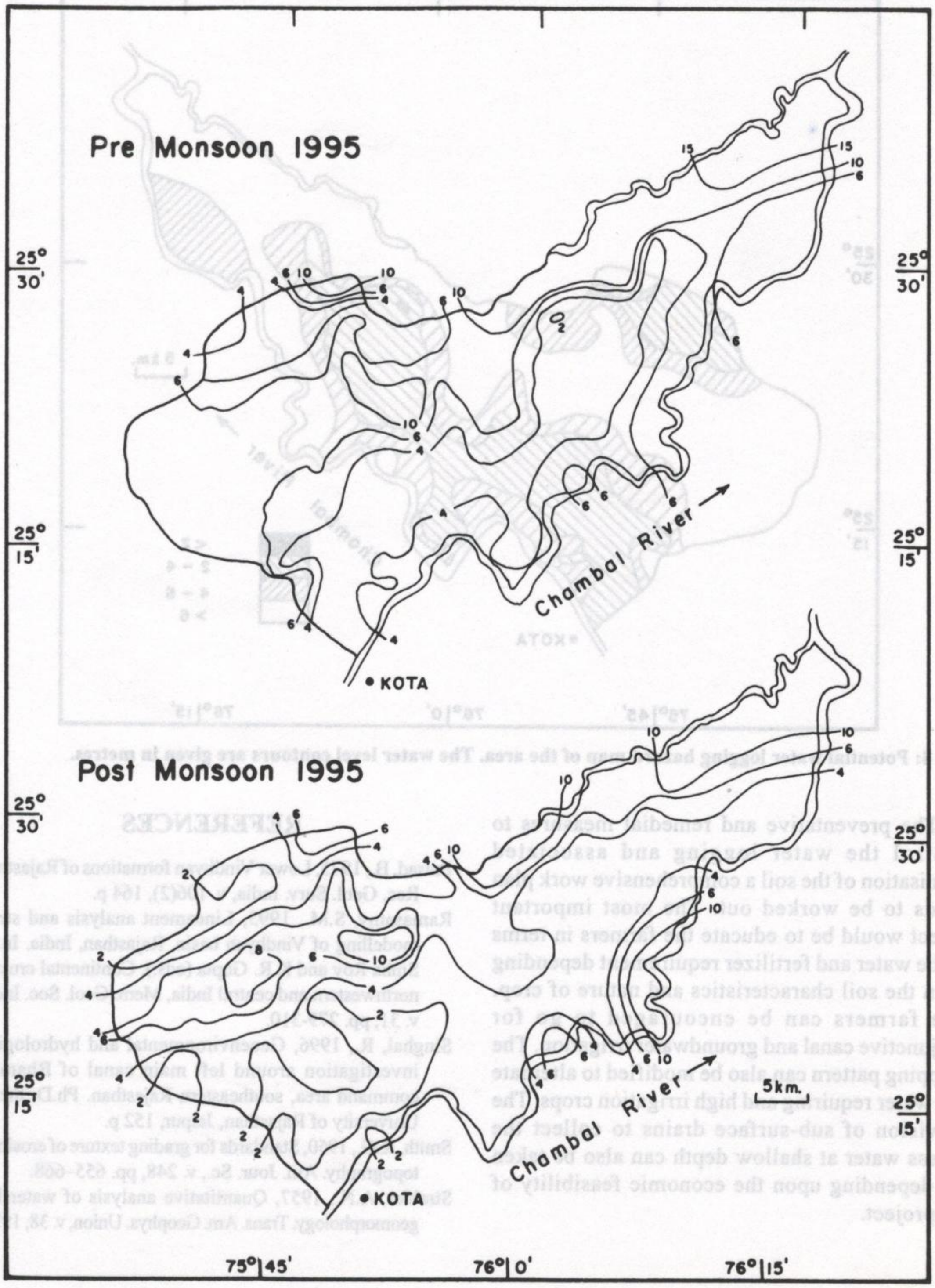

Fig. 3: Pre- and post-monsoon water table maps for the year 1995, of the Left main Canal area.

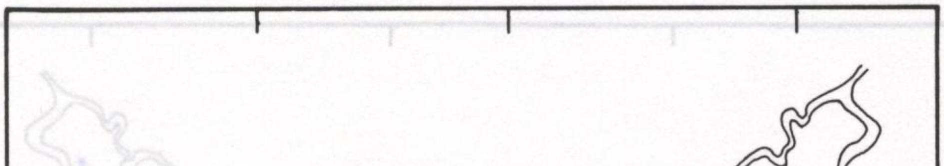

Fig. 4: Potential water logging hazard map of the area. The water level contours are given in metres.

The preventative and remedial measures to control the water logging and associated salinisation of the soil a comprehensive work plan needs to be worked out. The most important aspect would be to educate the farmers in terms of the water and fertilizer requirement depending upon the soil characteristics and nature of crop. The farmers can be encouraged to go for conjunctive canal and groundwater irrigation. The cropping pattern can also be modified to alternate low water requiring and high irrigation crops. The provision of sub-surface drains to collect the excess water at shallow depth can also be taken up, depending upon the economic feasibility of the project.

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