Using monsoonal river flows to recharge groundwater: An experiment in India

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Summary

In 1987, the government of Uttar Pradesh constructed the Madhya Ganga Canal to divert surplus monsoonal river flows for development of kharif (wet season) irrigation in dry pockets of the Ghaziabad, Bulandshahr and Aligarh districts, and to intensify paddy cultivation in the existing command of the Upper Ganga Canal.

Seepage losses from the 115-kilometer unlined canal, the newly developed system it supplies (the Lakhaoti Branch system), and from paddy fields were expected to recharge the rapidly declining aquifers in the area. This stored water could then be used to irrigate a second crop during the dry season (rabi).

An IWMI study evaluated the success of the project in 2000. The main conclusion of this research is that for the climatic and hydrogeologic conditions of the Indo-Gangetic Plain, an unlined kharif irrigation system such as the Lakhaoti Branch appears to be an effective way to recharge groundwater over a large area.

In 1989, IWMI undertook a two-year study in collaboration with Roorkee University, the Water and Land Management Institute of Uttar Pradesh and the State's Irrigation Department to model groundwater system behavior in the areas affected by the new canal. The purpose was to develop a sustainable management regime for conjunctive use of groundwater and surface water.

In 2000, an IWMI research team returned to the Madhya Ganga Canal Project (MGCP) to document how diversion of surplus Ganga water during kharif season has affected the groundwater level, land use, cropping pattern, and the costs and benefits of agricultural operations. The larger objective of this study was to determine if diverting monsoonal flows for paddy cultivation is a viable option for artificially recharging groundwater in similar geohydrologic settings. For the present analysis, only the newly developed area, the Lakhaoti Branch system, is considered.

Background

The western part of the Indo-Gangetic Plain (IGP) receives rainfall ranging between 650 and 1,000 mm, most of which is received in the three months of the monsoon period. Out of this amount, only around 200 mm percolate through the soil layer to recharge groundwater aquifers.

Before the construction of the Madhya Ganga Canal and the Lakhaoti Branch System, the source of irrigation in the study area was primarily groundwater. Groundwater was pumped through State tube wells, private tube wells, Persian wheels and dug wells. Total withdrawal of groundwater in the area was exceeding recharge and, therefore, the water table was progressively declining. There was only enough water for one cropping season, during kharif; during the rabi season there was not always sufficient water.

A surface storage dam was not a good solution in view of the high cost of construction, the nonavailability of suitable places for constructing such a dam in this flat alluvial terrain and stringent environmental requirements. Instead, the Government of Uttar Pradesh chose to utilize existing subsurface storage (aquifers) to capture monsoonal flows. Monsoonal flood water is diverted to grow paddy and other crops during the kharif season. Seepage from unlined channels and irrigated fields increase recharge to the groundwater reservoir, making additional groundwater available for irrigating crops during the rabi season.

Overview of the Project

The Madhya Ganga Canal Project (MGCP) involved the construction of a barrage across river Ganga at Raolighat, which diverts 234 m^3/sec of water into the Madhya Ganga Canal. This canal feeds the existing Upper Ganga Canal system and the newly constructed Lakhaoti Branch Canal.

The Lakhaoti Branch Canal commands an area of 193,000 ha; the proposed area under paddy cultivation is 49,500 ha. Head discharge of the branch canal is 64 m^3/sec. The length of the branch canal taking off from the MGC is 72 km. The length of the distribution channels of various capacities is 1,030 km. In the head reach, the Lakhaoti Branch has a bed width of 35 m, water depth of 2.25 m, and a bed slope of 15 cm/km. At the tail reach, discharge is 20 m^3/sec, bed width reduces to 14 m and water depth to 1.56 m. Canal water input into the area has varied between 27,202 m in 1988 and 64,301 m in 1996. All main canals and distribution systems are unlined earthen canals.

The canal water use balance indicates that in the initial years, canal water was not used very efficiently, but did serve to recharge the groundwater. Conveyance losses were estimated to be about 98 percent of canal water input in 1988; these had dropped to 48 percent by 1998. There is scope for further reducing the conveyance losses, while still recharging groundwater. Field water application losses have ranged between 1 and 19 percent of canal water input.

Impact of the project on groundwater levels

Groundwater data collected from 102 observation wells for the years 1984 to 1988 (84 maintained by the State Groundwater Department and 18 by the Central Groundwater Board) were used for this study. In order to study the behavior of the water table in space and time, water table depth below ground level, water table elevations, and the rise of the water table during the monsoon and fall of the water table during the

Figure 1. Water table elevation contours (meters above sea level) Post Monsoon 1984.

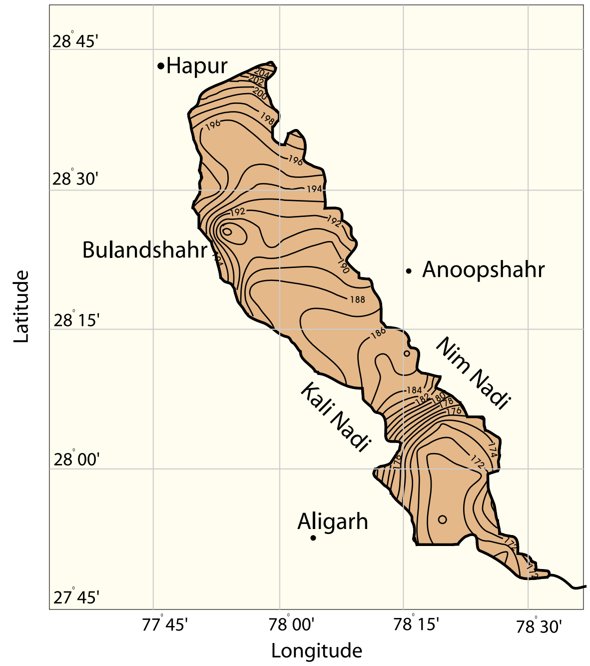
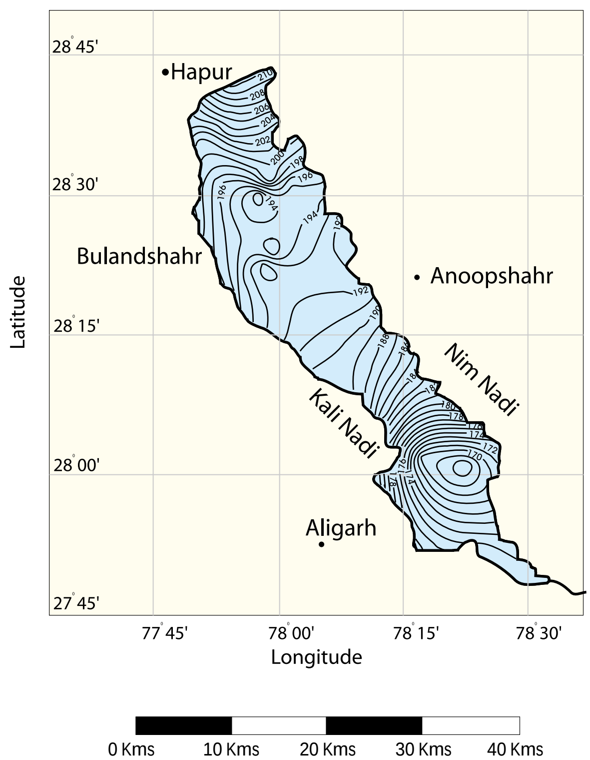


Figure 2. Water table elevation contours (meters above sea level) Post Monsoon 1998.



non-monsoon season were computed. Using the Krizig method of interpolation, water table elevation contours have been prepared for the pre- and post- monsoon seasons for all years of study. Typical post-monsoon contour plots for 1984 (pre-project) and 1998 (post-project) are shown in Figures 1 and 2.

In general, the water table shows a downward trend up until 1988 after which it starts rising due to canal water input. The water table in general had been going down progressively up to 1987-88, falling from 10 m below groundwater in 1984 to 12 m by 1988. After the commissioning of the Lakhaoti Branch in 1987-88, the water table started rising and in general continued rising steadily up until 1994. Between 1995 and 1996 the water table fell in some locations. This may be due to less rainfall in 1994 and 1995. The water table has again shown an upward trend during 1997, 1998 and 1999 due to better rainfall during 1996 and 1997 and larger canal water input.

On average, the water table rose to about 11 m below ground level in 1989 and continued to rise to 9.5 m in 1997. From 1997, it began rising rapidly and reached 6.5 m below ground level in 1999. Due to canal water input the downward trend was checked, and the water table has actually risen from 12 m to 6.5 m below ground level.

Benefits of the project on farm budgets

Before the construction of the Lakhaoti Branch Canal, the farmers in the Lakhaoti Command were dependent entirely on groundwater. The Lakhaoti Branch, supplies irrigation water in the monsoon season to irrigate the proposed area of 49,500 ha under rice cultivation. Seepage from the Lakhaoti Branch unlined system also refills the aquifers, enabling farmers to use recharged groundwater to irrigate a second crop during rabi.

Farm budget, with and without canal

			Without canal				With canal			
Crops	Yield Quintal/ ha 10 Quintals=1 Ton	Gross receipts	Cost of cultivation	Net benefits	Weightage	Weighted average	Cost of cultivation	Net benefits	Weightage	Weighted average
		18000								
Rice	22/35	21,000*	15,400	2,600	0.02	50	13,200	7,800	0.15	1,170
Maize	20	9,000	7,100	1,900	0.35	660	6,600	2,400	0.20	480
Bajra	20	8,000	7,050	950	0.10	100	6,150	1,850	0.10	185
Sugarcane	600	43,000	23,400	9,600	0.13	2,550	21,100	21,900	0.15	3,285
Fodder (K)				1,500	0.20	300		1,500	0.20	300
Total kharif					0.80	3,660			0.80	5,420
Wheat	35	17,000	11,000	6,000	0.60	3,600	10,200	6,800	0.60	4,080
Barley	35	17,000	10,700	6,300	0.10	630	9,800	7,200	0.10	720
Potato	200	50,000	18,000	32,000	0.03	960	17,300	32,700	0.03	980
Peas/Chana	20	15,500	10,000	5,500	0.07	390	9,250	6,250	0.07	440
Total rabi					0.80	5,580			0.80	6,220
Total annual					1.60	9,240			1.60	11,640

* Gross receipts for rice without canal = Rs. 18,000/hectare.
Gross receipts for rice with canal = Rs. 21,000/hectare.

Before the project, the cost of pumped groundwater had been increasing steadily due to the progressive lowering of the water table. After the introduction of the Lakhaoti Branch Canal, the cost of pumping has gone down as the water table has risen. Farmers have been able to raise the position of their pumps due to the rise in the water table.

According to simulation modeling, without canal water input the water table would have dropped to an average depth of about 18.4 m by 1999. This would have not only increased the cost of pumping, but also made it necessary for farmers to deepen their wells and lower their pump sets.

From resource 'development' to 'management': the paradigm shift we need to save groundwater

Groundwater offers us precious opportunities for alleviating the misery of the poor. But tapping this resource in a responsible way poses many complex and daunting challenges.

Around the world, the number of locations that have a sustainable groundwater balance is shrinking by the day. The many consequences of groundwater overdevelopment are becoming increasingly evident.

The problems and opportunities surrounding groundwater in Pakistan are a good illustration of the work to be done. Along with India, this country is one of the world's biggest users of groundwater, mostly for irrigation and also for domestic and industrial requirements. The massive development of groundwater from the Indus Basin aquifer started about 30 years ago. Today, groundwater provides the country with some 60 billion m^3–some 40% of the total irrigation water available. This source is tapped by 20,000 public and about 550,000 private tube wells. Some 70% of the tube wells are located in canal command areas, while the rest provides irrigation based on groundwater alone.

The tapping of useable groundwater gives farmers the supplemental irrigation they need to cope with the vagaries of the surface water supplies. But the uncontrolled and unregulated use of groundwater in this way has serious consequences. The lowering of groundwater tables, due to unsustainable use, increases the pumping cost–which often places the resource out of reach for the poorest members of society. Saline intrusion into fresh groundwater aquifers kills farming areas. Many planners and policy makers speak of *developing* water resources to serve the needs of more people. But what is needed is management– *sustainable management*.

If a business-as-usual approach is taken to groundwater use, these problems will only become more acute, widespread and visible. The frontline challenge is to put into operation a range of corrective mechanisms *before* the problem becomes insolvable. The foundation to these measures must be an attitudinal change, where people's thinking is changed from 'developing' the resource to 'managing' it.

But this paradigm shift cannot take place without a foundation of credible and accessible information that conclusively proves the need for management. Today, resource planning is severely hampered by limited and incomplete information on groundwater availability, quality, withdrawal and other variables. This is how research can help.

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The cost of pumping at a water table depth of 18.4 m would have been approximately Rs. 4,650/ha.m. The cost of pumping groundwater at the actual 1999 water table depth, 6.5m, is Rs. 2,650 per ha.m—a savings of Rs. 2,000/ha.m for farmers. Considering that close to 90,000 ha.m are pumped annually, the amount saved in pumping costs comes to Rs. 180 million per year.

Weighted average net income per hectare for kharif and rabi seasons without the canal works out to about Rs. 3,600 and Rs. 5,580, respectively, for an annual income per hectare of Rs. 9,240. With the introduction of canal water, average net income has gone up to 11,640 per hectare—an increase of 26 percent.

The benefits of the project to individual farmers, in addition to a reduction in the cost of pumping include increased production, a better cropping pattern and better operational conditions. Paddy area has increased from 2 to 15 percent in the area and sugarcane from 13 to 15 percent.

Conjunctive use of groundwater and surface water

The kharif channel enables conjunctive use of surface water and groundwater. The farmers can pump groundwater for irrigation during the rabi crop season and also to supplement canal water, if necessary, during the kharif season.

Because the canal operates in the kharif season only, the farmers are forced to use groundwater for their second crop in the rabi season. This regime of sustainable conjunctive use of groundwater and surface water ensures that the water table is maintained at a reasonable depth and waterlogging conditions do not develop.

Water demand for domestic use (2,397 ha.m in 1997-98) and industrial uses (1,797 ha.m in 1997-98) are also met from recharged groundwater.

Project recommendations

There is considerable scope for improving management of the system to achieve the planned irrigated area under paddy and to ensure that water is distributed to the entire command. Construction of minors and provision of outlets has to be completed.

An aerial view of water distribution indicates that more water is being supplied to the head reaches. Here the water table has risen steadily due to seepage losses. In the lower reaches, the water table continued to go down after the project was implemented; it only began to rise after 1994. The water table has still fallen below its 1984 level in some areas in the lower reaches.

Concluding Remarks

Several methods of artificial recharge of groundwater are being tested and implemented in India. But, for the climatic and hydrogeologic conditions of Indo-Gangetic Plain, an unlined kharif irrigation system such as the Lakhaoti Branch appears to be the best arrangement for recharging the subsurface reservoir. The Lakhaoti Branch system demonstrates how monsoonal flows can be captured for use during the dry season, using subsurface reservoirs for storage, without the construction of a dam.

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The work presented here is based on a forthcoming paper.