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CONJUNCTIVE USE OF SURFACE AND GROUNDWATER IN CHAMBAL COMMAND, M.P.

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ABSTRACT

It is found that due to the advent of high yielding varieties of crops, vagaries of monsoon and other inter-state problems, the tail reaches of canals of the lower Chambal Command are unable to meet the irrigation requirements of the crops even during winter months. So far, out of 2.21 lakh hectares, 1.89 lakh hectares area has been irrigated during the years 1977-80 but due to shortage of water in the Gandhi Sagar dam, the actual irrigated area in years 1982-85 has come down to 1.25 lakh hectares due to low rainfall in the catchment area of Gandhi Sagar dam. The average quantity of surface water used for the last three years is 0.121 million hectare metres. The total 0.188 million hectare metres water is required to irrigate 2.21 lakh hectares area. Out of this, 1/3 requirement is proposed to be met out of groundwater resources. At present only 0.40 lakh hectares area is irrigated by the groundwater resources in the Chambal Command. In this paper an attempt has been made to utilise the surface water with available groundwater in the Chambal Command area to increase the intensity of irrigation in the Chambal Command, M.P.

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1.1 Introduction

Conjunctive use implies co-ordinated and harmonious development of surface and groundwater for meeting the water requirements by optimally utilizing the total available water resources. Availability of insufficient water in tail reaches of surface canals and inadequate water supply during lean period of river flows call for conjunctive use of surface and groundwater supplies to ensure timely irrigation of crops through out the year at all the points along the canal. The integrated use of surface and groundwater may be made in four manners such as (i) by utilizing the full surface water supplemented by groundwater, (ii) direct use of groundwater during paucity of surface water (iii) supplying tube well water to increase the canal water supply in tail reaches of canals and (iv) mixing saline water with good water.

The Chambal Command area in Madhya Pradesh lies between N. latitudes, $25^{o}0'$ to $26^{o}45'$ and E. longitudes $75^{o}30'$ to $79^{o}5'$ and located in Morena and Bhind districts. The total Command area in Madhya Pradesh is 3.20 lakh hectares out of which only 2.21 lakh hectare is irrigable farmland. It fall under the drainage basins of Chambal and Sind rivers. The lower reaches of the Chambal area is facing water scarcity problem particularly for irrigation. Therefore, it is selected for such study to solve the water requirement for irrigation. It lies in between $26^{\circ}10'$ - $26^{\circ}55'$ N. latitudes and $77^{\circ}45'$ to $79^{\circ}5'$ E. longitude. This area is divided in to two parts namely Chambal-Kunwari doab and Kunwari-Sind doab. The area irrigated by Ambah Branch canal comes under Chambal-Kunwari doab whereas the area irrigated by Bhind Main canal comes under Kunwari-Sind doab. It is highly eroded along Chambal and Sind rivers forming deep gullies and ravines adjacent to both banks of the rivers. The terrain is generally flat and slightly rolling. It is sloping towards N.E. The average annual rainfall is about 800 millimetres and the climate of the area is warm semi arid type.

1.2 Hydrogeology of the area

The study area is mostly composed of alluvial formations with a few isolated out crops of Vindhyan sandstones, limestones and shales. Alluvial formation consists of sands, silts, clays, lenses of gravels and pebbles, etc. It underlies the Vindhyan sandstone and limestone. Generally, the unconsolidated material is very important to store and transmit the groundwater. In the study area, in these formations, groundwater occurs in granular zones consisting of fine to coarse-grained sands, gravels, pebbles and boulders, which are often intercalated with varying thicknesses of clay beds. As a consequence, the study of subsurface geology becomes very important from the availability point of view of the groundwaters of the area under investigation.

There are a large number of bore holes drilled throughout the Chambal Command area. These are drilled by the Directorate of Tube Wells (DTW), Government of Madhya Pradesh. Further, the Madhya Pradesh Lift Irrigation Corporation (MPLIC) has drilled a few deepest exploratory bore holes in the year 1980-81. These wells have penetrated the entire thickness of the Chambal alluvium, whereas the wells drilled by DTW are mostly production tube wells. The bore holes have not drilled on a planned basis. They are neither evenly distributed nor are they aligned in certain specific traverse or longitudinal directions. The deepest bore holes have considered as representative bore holes in the study area and considered for the correlation study of the litho units present in the alluvial formation for their vertical and lateral extents.

The lithologic sections have been drawn by using the bore hole log data along the lines in East-West and North-South to get a picture of the subsurface geology of the alluvial formations. These data were collected from the office of the Superintending Engineer, Tube Well Construction Division, Gwalior and also from the office of the Branch

Manager, Madhya Pradesh Lift Irrigation Corporation, Morena. These sections show that the bed rock surface slopes towards the Yamuna river (east). It means that the thickness of alluvium increases from west towards east. Therefore, there is possibility of the presence of more granular beds in the eastern part than what it is in the western part. It also indicates that the availability of groundwater is more in the eastern part than the western part of the study area. The granular beds become thick and thin at places with small lenses of clay in between. But at places, the lenses of clay also occur in sandy beds. These are common features of the alluvial deposits. There is lateral as well as vertical variations in the nature of the litho units of the alluvium of the study area. There are four granular zones (aquifer) present in the study area up to the basement rock. The upper surface of the first granular zone lies at an approximate depth of 20 metres and present throughout the area whereas the upper surface of the second granular bed occurs at depth ranges of 77 to 105.18 metres below the ground surface. The depth of the xx upper surface of the third granular bed is approximately 106 metres below ground surface whereas the upper surface of the fourth granular bed lies at a depth of 128 metres below the ground surface. The second, third and fourth granular bed generally occurs in extreme eastern part of the study area.

1.3 Occurrence of Groundwater

The groundwaters of the alluvium of the study area are found in clay-kankary beds, sands, lenses of gravels and pebbles. The groundwater probably occurs in clay-kankary beds under perched water table conditions. In the sandy, gravelly and pebbly beds, the groundwater occurs under semi-confined to confined conditions.

The groundwaters present in the dugwells may or may not be occurring under water table conditions. Probably the dugwells receive water from the underlying semi-confined (first) aquifer. It is one of the reasons why the dugwells are often converted into dug-cum-bore wells to get more water, by piercing through the clay bed, which separates the first aquifer with that of clay-kankary bed. Therefore, one may assume that the groundwater in the kankary clay horizon is on account of leakages and seepages of the confined water of the underlying sand bed due to uplift pressure. If this is so, the groundwaters of the dugwells may not truly represent water table conditions.

Wherever the sandy, pebbly and gravelly beds are underlain and overlain by the clay beds, groundwater occurs under semi-confined to confined conditions. If topography favours, flowing wells also occur. They are found in the villages, Bagchini, Gospur, Mrigpura, Dimni, Mahua, Dandoli, Raduapura, Kuthiyana, etc. The pressure-surface conditions of the area under investigation come under moderate to high initial pressure head type. (Tolman, 1937). During the field investigation, it has been measured that the pressure head of the flowing wells near the villages Dandoli, Raduapura and Kuthiyana, etc., was 7 metres above the ground surface. It is interesting to note that some of the dugwells which are found in the vicinity of the villages, Gospur, Mrigpura, Kuthiyana, Dandoli Raduapura, Mahua and Khurd, etc., which are situated on the right bank of the Chambal river derive their water directly from the underlying confined aquifer, though their bottoms do not touch the aquifer. Wherever, the farmer reports to auger boring below the bottom face to short depths, the water comes under very high pressure, so that the dugwells over flow. Similar conditions are also noticed in the dugwells of the villages, which are situated on the banks of the Kunwari river. A typical example is the dugwell situated on the left bank of the Kunwari river near the village Para. It is also noticed, that whenever the Chambal and Kunwari rivers are in floods, the pressure heads of the flowing wells increase. This indicates that the loading of the clay bed above the first confined aquifer results in the increase of pressures due to compression of the aquifer, specially near the recharging grounds.

5.4 Annual Groundwater Increment

From what is to stated above, it is obvious that to calculate the annual groundwater increment in the alluvium of the Chambal Command, The fluctuation method for both the doabs has to be utilised by taking the dugwell inventory data into consideration. Further, it has to be noted that the annual groundwater increment is not only due to the rainfall but also application on account of surface waters for irrigation. To use the fluctuation method, the area in between two contours (at one meter interval), has been determined by the graphical method. Then the area obtained is multiplied by the average thickness of the fluctuation in the groundwater levels, between the two contours. This gives the volume of the saturated alluvial material occurring in between the contours. Thus the saturated volumes of the aquifer materials lying in between two contours have been found out and added to get the total saturated volume of the aquifer materials. According to A.R.D.C. (1979), twelve percent average specific yield value has been used for upper water bearing beds within the alluvium to calculate the annual groundwater increment. Then, the total volume of the saturated material (within the pre and post-monsoon fluctuation zone), is multiplied by the specific yield to calculate the annual groundwater increment. It means that the equation used in the calculation is as follows:

Annual Groundwater Increment = Volume of saturated material. x Specific yield.

The data are given in the table No.1.

<u>Table No.1</u>

Annual Groundwater Increment of the lower reaches of the Chambal Command, (M.P.)

S.No.	Name of doab	Average fluctuation (in m.)	Area of fluctuation (in Hect.)	Volume of rock material in which fluctuation take place (in Hect. M.)	Annual groundwater increment (in Hect. mts.)
1.	Chambal-	0.50	9,996.80	4,998.40	
	Kunwari	1.00	140,768.24	1,40,768.24	
	Doab	1.50	34,611.32	51,916.98	26,350.33
		2.00	1,568.96	3,137.92	
		2.50	6,261.87	15,654.67	
		3.00	1,035.97	3,107.91	
	Total		1,94,243.16	2,19,586.12	
2.	Kunwari-Sind	0.50	12,379.75	6,189.87	
	Doab	1.00	45,106.11	45,106.11	
		1.50	1,44,187.18	2,16,280.77	
		2.00	18,263.64	36,527.28	
		2.50	32,653.36	81,633.40	57,258.18
		3.00	3,386.93	10,160.79	
		3.50	14,316.71	50,108.48	
		4.00	4,951.90	19,807.60	
		4.50	2,174.95	9,787.27	
		5.00	309.99	1,549.95	
	Total		2,77,730.52	4,77,151.52	

A glance at the table No.1 brings out that the total annual groundwater increment for both the doabs works out to be 83,608.51 Hect. Mts. or 0.083 Million Hectaremetres.

1.5 Annual Groundwater Draft

It has to be noted at the outset that for want of even approximate data on (a) evaporational and evapotranspirational losses, (b) groundwater losses (out flows) due to effluent flows into streams and rivers and also, (c) inflows into the aquifers have not been taken into account, while determining the annual groundwater draft on the groundwater bodies. Therefore, to determine an approximate annual groundwater draft in the study area, the number of different types of existing wells have been recorded Doabwise, though most of the wells are not in use due to the advent of surface water irrigation. The number of existing wells have been given in the table No.2.

Table No.2

Number of existing wells in the lower reaches of the Chambal Command, M.P.

S.No.	Type of wells	No. of wells in Chambal-Kunwar Doab.	No. of wells in Kunwari-Sind Doab	Total number of wells
1	2	3	4	5
1.	Dugwells			
	(a) Domestic	7,000	8,387	15,387
	(b) Irrigation (fitted with Rehats and Motes)	1,550	1,975	3,525

Table No.2 Contd.

	(c) Irrigation (fitted with diesel and/or electric pumps)	225	227	452
2.	Dug-cum-bore-wells or shallow tube wells fitted with electric pumps.	1,500	631	2,131
3.	Deep tube wells (fitted with submersible pumps)	110	230	340
4.	Flowing wells	75	25	100
	Total	10,460	11,475	21,935

To calculate the annual groundwater draft by the different types of wells, the number of pumping hours have been recorded by consulting the users and the average rates of discharges have been measured for different wells. In the case of the dugwells used for domestic purposes, the villagers have been consulted. The average rates of discharges of irrigation dugwells with rehats and motes has been measured by the V-notch method, whereas for irrigation dugwells, dug-cum-bore wells or shallow tube wells and deep tube wells fitted with diesel or electric pumps, the rates of discharges have been measured by the horizontal jet line method or L - scale method (Gokhale and Rao, 1981). The average rate of discharge of flowing wells has been determined by using the standard flow rate data from vertical pipe given by Lawrence and Braunworth (1906).

With the help of above mentioned methods, the average rates of discharges for different types of wells have been determined. The number of pumping hours for different types of wells in a year have been recorded by consulting the users. Particularly most of the flowing wells are discharging groundwater continuously throughout the year though the irrigation by these wells is done only in the rabi season. Rarely, the flowing wells are capped after the irrigation season to prevent damages to the flowing wells by putting stones into the wells by people. Therefore, approximately hours of discharge in a year has been considered for calculating the annual groundwater draft for a flow well. The number of pumping hours and average rates of discharge for different wells have been given in the table No.3.

Table No.3

Average rates of discharges for the different types of wells in the lower reaches of the Chambal Command, M.P.

S.No.	Types of wells	Mode of lift	Average rate of discharge from ground-water bodies in KLPH	Number of pumping hours in a year
1	2	3	4	5
1.	DUG WELLS			
	(a) Demestic	Bucket	1/2	1,000
	(b) Irrigation	Rehat & Mote	4	1,000
	(c) Irrigation	Diesel/electric pump (10 HP)	47	1,500
2.	Dug-cum-bore wells			
	Shallow tube wells	Electric pump (10 HP)	47	1,500
3.	Deep tube wells	Submersible pump (10 HP)	47	2,000
4.	Flowing wells	-	10	8,000

By using the above data, the annual groundwater draft has been calculated for each doab with the help of the following formula.

$$\text{Annual Draft} = \text{Number of wells} \times \text{Average rate of discharge in KLPH} \times \text{Number of pumping hours in a year.}$$

The results obtained have been given in the table No.4.

Table No.4

Annual groundwater draft of the lower reaches of the Chambal Command, M.P.

S.No.	Types of wells	Mode of lift	Annual groundwater draft in Chambal-Kunwari Doab (in Hect.mts.)	Annual groundwater draft in Kunwari-Sind Doab (in Hect. mts.)	Total annual groundwater draft (in Hect. mts.)
1.	Dug Wells				
	(a) Domestic	Bucket	350.00	419.35	769.35
	(b) Irrigation	Rehat and Mote	620.00	790.00	1,410.00
	(c) Irrigation	Diesel/ electric pump (10 HP)	1,586.25	1,600.35	3,186.60
2.	Dug-cum-bore wells				
	Shallow tube wells	Electric pump (10 HP)	10,575.00	4,448.55	15,023.55
3.	Deep tube wells	Submersible pump (10 HP)	1,034.00	2,162.00	3,196.00
4.	Flowing wells	-	600.00	200.00	800.00
	Total		14,765.25	9,620.25	24,385.50

The above table shows that the annual groundwater utilization approximates to be 0.024 million hectare metres. The annual groundwater recharge approximately determined amounts to be 0.083 million hectare metres. Therefore, the balance of groundwater available for future development in a year works out to be 0.059 million hectare metres. But after the advent of the Chambal Complex, the irrigation is mostly done by using the surface water of the Chambal canal system. A number of irrigation wells have become idle for most of the time at present. Therefore, the annual groundwater draft calculated has to be much less than 0.024 million hectare metres. It means that more groundwater is available for pumping in the study area.

1.6 An assessment of the availability of groundwater in the first aquifer (Semi-confined to confined)

In the study area, the bore hole log data indicate that at places as many as four semi-confined to confined aquifers are present in the alluvium. Out of these, the first aquifer is mostly present throughout the area, for which reliable lithological log data are available to permit and to calculate the water-holding and yielding capacities of this aquifer approximately, as if the water is occurring under the water table conditions. Therefore, to assess the quantity of groundwater available in the first aquifer, an approximate isopach map has been prepared by using the lithological log data of the bore holes made available by the Directorate of Tubewells, the Groundwater Surveys and, the Madhya Pradesh Lift Irrigation Corporation Limited (MPLIC), Government of Madhya Pradesh.

The tube wells drilled in the study area are widely distributed, covering the entire area under investigation. Therefore, the data obtained from the map represent approximate thicknesses of the aquifer. This map has been prepared on a scale of 1 cm. = 1.25 kilometres at 10 metre contour intervals.

The thicknesses of the first aquifer vary from 6.08 to 107.61 metres. It is elliptical in shape. It looks like a mound near the Ambah and Kheri-Ratanpur villages. The areas covered by the widely spaced isopach contours show uniformity in the thicknesses of the first aquifer, which consist of a mixture of fine to coarse-grained sands with a very little fine gravel and silt.

By using the isopach map, the volume of the first aquifer, which is under semi-confined to confined conditions, has been calculated. A porosity value of 36% and a specific yield value of 25% have been used. By using these values, water holding and water yielding capacity of this aquifer have been calculated. The results are given in the table No.5

Table No.5

Groundwater availability of Semi-confined to confined (First) Aquifer, Lower reaches of the Chambal Command, M.P.

S.No.	Average thickness of aquifer (in m.)	Area in Hectares	Volume of aquifer in million Hectare metres (mhm)	Water-holding capacity in (mhm)	Water-yielding capacity in (mhm)
1.	5	9,934.80	0.049	0.017	0.012
2.	15	93,807.16	1.407	0.506	0.351
3.	25	73,616.56	1.840	0.662	0.460
4.	35	55,434.91	1.939	0.698	0.484
5.	45	39,367.22	1.771	0.637	0.442
6.	55	29,576.42	1.626	0.585	0.406
7.	65	21,786.57	1.416	0.509	0.354
8.	75	11,395.77	0.085	0.030	0.021
9.	85	4,018.91	0.341	0.112	0.085
10.	95	1,967.95	0.186	0.066	0.046
11.	105	475.98	0.049	0.017	0.012
	Total	3,41,382.25	10.709	3.839	2.673

The Table No.5 brings out that the water-holding capacity of the first aquifer (due to porosity), in the study area works out to be approximately 3.839 million hect. mts. Its water-yielding capacity (assuming as if the groundwater occurs under the water table conditions) is about 2.673 million hect. mts, though the groundwater occurs under semi-confined to confined conditions.

The utilization of the groundwater from the first aquifer by the tube wells, the dug-cum-bore wells and the flowing wells amounts to be 0.019 million hect. metres. Therefore, the available groundwater for exploitation in the study area is much more than 2.654 million hect. mts. It has to be mentioned that most of the irrigation wells are kept idle, since the coming in of the surface water irrigation.

1.7 Quality of Water

In recent years it has been recognized that the quality xxxxxx of water is of nearly equal importance to quantity (Todd, 1959; p. 177). To assess the quality of water, 31 water samples were collected from the surface water sources such as rivers and canals whereas 103 water samples were collected from dugwell, dug-cum-bore wells, flowing wells and tube wells from the study area. The major cations and anions have been determined for all the samples. It is found that the quality of surface water as well as groundwater in general is suitable for irrigation but in a few localities, the groundwater is unsuitable for irrigation. In such areas, it is suggested that the groundwater should be mixed with the surface water to improve the quality for irrigation.

1.8 The Necessity of Exploitation of Groundwaters

As earlier mentioned that in the Chambal Ayacut Development - Phase II Works (1986-87), out of 2.21 lakh hectares irrigable area, 1/3 area is proposed to be irrigated by the groundwater resource due to shortage of surface water in the Gandhi Sagar dam (MPLIC, 1981). At present 0.4 lakh hectares area of the Chambal Command is irrigated by the groundwater resource only. It is also mentioned that a balance of 0.059 million hectare metres of groundwater is available every year, if the groundwater is exploited as it was done in the past, prior to the advent of irrigation. As the groundwater resources are more or less kept idle, the groundwater levels are rising slowly year after year in the Command area. Therefore, in parts of the ayacut area, water logging conditions have come into existence. There is a paucity of water for irrigating the farmlands in the tail reaches of the lower Chambal Command due to inadequacy of surface water. The rainfall as a source of irrigation is effective for about 65 days in a year. Therefore, the only way to get over these problems is to exploit groundwater on a planned basis in the Chambal ayacut area.

To solve the above problems and also to make use of of existing canal systems for delivery of water to the farmlands, 630 medium to high production tube wells for construction along the main canals and its laterals have been proposed with a safe spacing distance of 1200 metres between two adjacent tube wells. A high production tube well can be pumped at an average rate of about 200 m^3/h safely, for the Phupkalan tube well in the study area is already being pumped at this rate for a drawdown of about 3 metres. Similarly a medium production tube well can be pumped at an average rate of about 100 m^3/h for a drawdown of about 5 metres. Numerous tube wells of this type already exist in the study area. No emphasis has been laid on dug-cum-bore wells, for in their place, shallow tube wells come in. The number of proposed tube wells for construction have been given in table No.6. From this table, it is clear that 280 tube wells may be drilled along the Ambah Branch canal system while 100 tube wells can be constructed safely along the Morena Branch Canal System. Further 250 tube wells have been proposed along the Bhind Main Canal System.

Table No.6

No. of proposed tube wells to be constructed along the Chambal Canal System, lower reaches of the Chambal Command, M.P.

S.No.	Name of canal/distributory	No. of proposed tube wells
1	2	3
I - The Ambah Branch Canal System		
1.	Ambah Main Canal	59
2.	22 L distributory	18
3.	24 L "	03
4.	27 L "	04
5.	30 L "	12
6.	31 L "	05
7.	39 L "	02
8.	43 L "	01
9.	45 L "	06
10.	26 R "	03
11.	28 R "	03
12.	29 R "	01
13.	32 R "	11
14.	33 R "	58
15.	37 R "	01
16.	40 R "	01

..Contd.

1	2	3
17.	41 R distributory	03
18.	44 R "	01
19.	46 R "	01
20.	48 R "	10
21.	49 R "	02
22.	51 R "	02
23.	52 R "	01
24.	53 R "	01
25.	54 R "	03
26.	60 R "	04
27.	61 R "	08
28.	62 R "	01
29.	63 R "	01
30.	64 R "	18
31.	65 tail distributory	36.
	Total	100

..Contd.

1	2	3
II.	The Morena Branch Canal System	
32.	Morena Main canal	10
33.	4 L Distributory	05
34.	10 L "	03
35.	12 L "	03
36.	14 L "	07
37.	15 L "	01
38.	18 L "	02
39.	17 R "	03
40.	20 R "	01
41.	22 TR "	13
42.	21 L Tail lift distributory	52
	Total	100
III.	The Bhind Main Canal System	
43.	Bhind Main Canal	33
44.	2 L Distributory	48
45.	3 L "	47
46.	4 L "	15
47.	4 R "	44
48.	5 R "	15
49.	6 RA "	01
50.	6 RB "	04
51.	6 RC "	04
52.	6 R "	08
53.	7 R "	31
	Total	250
	Grand total	630

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References

A.R.D.C. (1979) : Report of the Groundwater over exploitation committee, Chapter IV.

Gokhale, K.V.G.K. and Rao, D.M. (1981) : Experiments in Engineering Geology : 1st Ed. Tata Mc Graw Hill Publishing Co. Ltd., New Delhi, p. 122.

M.P.L.I.C. (1981) : Chambal Command Area Modernization Project (Phase II Proposal) Report : Madhya Pradesh Lift Irrigation Corporation Ltd., p. 8 (Unpublished).

Lawrence, F.E. and Braunworth, P.L. (1906) : Fountain flow of water in vertical pipe : Transactions. Amer. Soc. of Civil Engs., New York, Vol. 57, p. 264.

Todd, D.K. (1959) : Groundwater Hydrology : John Willey and Sons, Inc., New York, p. 177.

Tolman, C.F. (1937) : Groundwater : Mc Graw-Hill Book Co., New York, p. 359.