Groundwater Management Options—A Case Study of Western Yamuna Canal Command, Haryana

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Abstract: Western Yamuna Canal (WJC) Command covers part of the Upper Yamuna Basin and inland alluvial basin in the State of Haryana. The WJC Command of an area about 13,543 sq. km, covers eastern, central and southern parts of the State of Haryana. The available water supply from WJC was not able to fully meet the water demand in the area. This has resulted in initiation of development of groundwater in many a ways. An augmentation canal with taking off from WJC at Yamuna Nagar and joining it back after a length of 72 km at Munak was constructed in 1972. One hundred sixty tube wells, which tap from the phreatic aquifer, were constructed along this canal. This development of groundwater was meant to augment water supply and to lower the groundwater level in the water logged areas lying between the WJC and the river Yamuna. Since year 2002, all these augmentation tube wells have been dried up due to failure and non-maintenance. This project has solved the problem of water logging in the area, but the stoppage of pumping of augmentation wells, has reduced the water supply in the canal.

This paper discusses about the performance of the augmentation canal project in terms of its impact on groundwater level and financial viability. The study has shown that it is a sustainable project. The possibility of revival of such projects in the emerging scenario of increasing water demand and constant water supply has been explored. It was observed that it may not be viable to use the already over developed phreatic aquifer because of possibility of existence of prolific semi confined aquifer below the phreatic aquifer.

THE STUDY AREA

The Western Yamuna Canal (WJC) Command covers an area of 13,543 sq. km in eastern, central and southern parts of the State of Haryana. The Canal takes off from the river Yamuna at Hathnikund Barrage (3 km upstream of Tajewala, the old barrage). At Hathnikund the water from Yamuna is diverted into two canal systems namely Eastern Yamuna Canal, serving the parts of U.P and WJC serving Haryana. The WJC is in existence since 1355 A.D and is in use in modern time since 1821. The water from WJC is also diverted to NCT Delhi for water supply. The WJC Command area is part of the well-known Indo-Gangetic alluvial area and is rich in groundwater potential. This area has witnessed phenomenal increase in the development of groundwater in the years by private and State Government agencies. To augment deficient surface water availability for ever increasing water needs, schemes of large-scale development of groundwater have been planned and executed.

A large number of augmentation wells were constructed along WJC in order to augment canal supplies and prevent water logging in adjacent tract. Further in order to prevent seepage losses along WJC and to augment its supply, a 72 km long lined augmentation canal was constructed between late sixties and early seventies (started functioning from 31st December, 1972). This augmentation canal takes off from WJC at Yamuna Nagar and outfalling again in WJC at Munak. Heavy duty wells constructed along this canal use to direct about 14-15 cumecs of groundwater to surface water canal system. In addition, there were similar augmentation wells constructed along Delhi parallel Branch and the Narwana Branch Karnal link.

To study this kind of development of groundwater, Central Ground Water Board carried out "Groundwater Studies in Upper Yamuna Basin" as a project from 1973 to 1977 (Anonymous, 1984, 2000). This study covered whole of Upper Yamuna Basin falling in the states of Himachal Pradesh, Haryana, U.P (including Uttaranchal) and NCT Delhi.

The present study area falls in the northern part of the WJC command between the north latitudes 29°30′ and 30°15′ and east longitudes 76°30′ and 77°30′ (Fig. 1). Figure 1 shows the alignment of

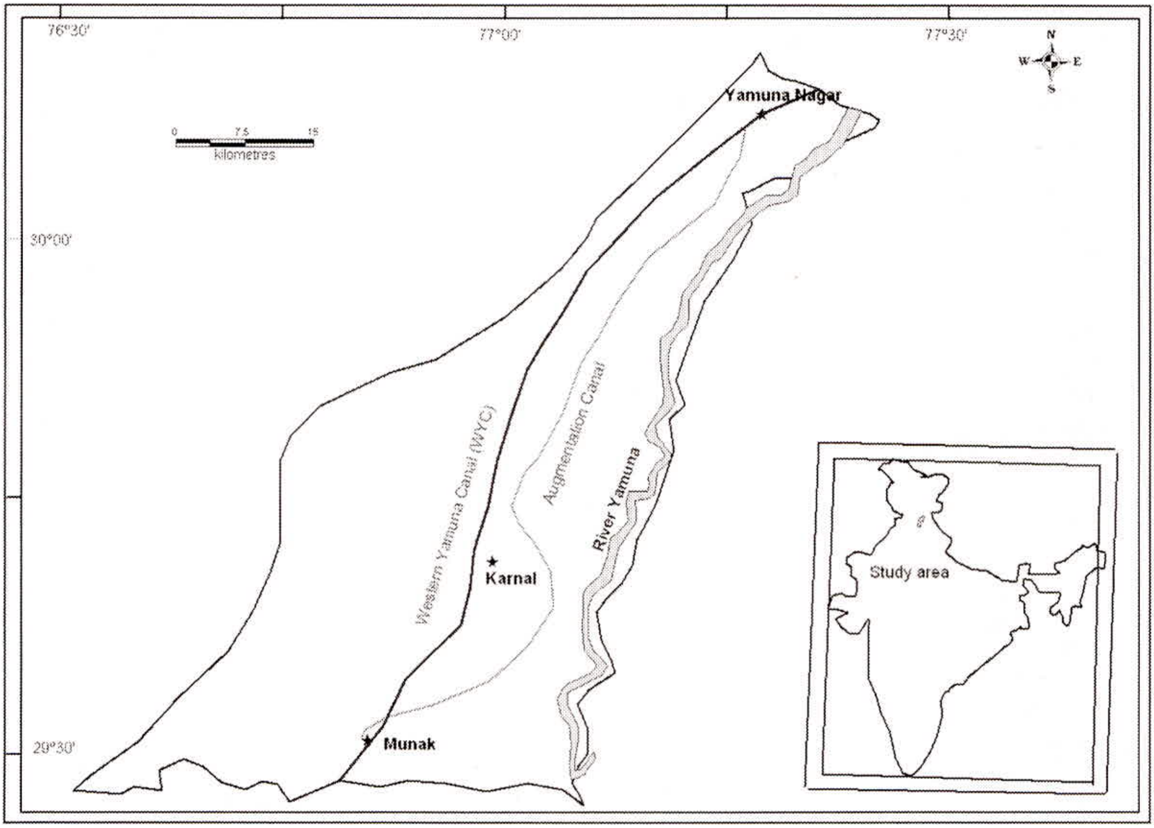

Fig. 1. Location of augmentation canal in the study area.

augmentation canal through the supposedly water logged area between the WJC and the river Yamuna around the famous city of Karnal.

CLIMATE, PHYSIOGRAPHY, SOIL AND LAND USE

The average annual rainfall of the WJC Command is 608 mm. The south-west monsoon rainfall sets in last week of June and withdraws in the end of September and contributes 82% of the average annual rainfall. July and August are the wettest months. The WJC Command area has a flat and monotonous topography with a regional slope from north-east to south-west direction. The surface elevation varies from 210 to 310 m amsl. The river Yamuna is the natural drainage in the command and is a perennial river. It takes a course of around 223 km from Hathni Kund barrage to the border of Delhi. Along its course it behaves as an influent at places (mostly in the northern part of the command area) and effluent at other places (mainly in southern part). The flood plains are highly potential for groundwater development, as they are underlain by thick aquifers which are hydraulically connected to the river Yamuna.

The soils in sub-montaneous region are classified as reddish soils. South of this zone, roughly up to Panipat, the soils are classified as 'Tropical Arid Brown'. In area south of Panipat the soils are arid brown soils. The soils in the basin, west of Yamuna river are mostly sandy loam to loam with medium permeability. The area is predominantly an agricultural tract, with more than 70% area under cultivation. The major crops grown in the area are wheat, paddy, gram, pulses, oil seeds, bajra and sugar cane.

HYDROGEOLOGY

The WJC Command plain tract lying south of the Siwalik zone forms a part of Indo-Gangetic alluvial plains of recent origin. The thickness of the alluvial deposit is small along the fringe of peninsular mass but progressively increases towards northwards and is maximum in the foredeep area lying immediately south of the Himalayan zone. The alluvial plains are underlain by loose unconsolidated river-borne sediments and form very good repository of ground water. The aquifer system lying closest to the land surface holds water in unconfined condition. At deeper levels, particularly below regionally or sub-regionally extensive poorly permeable layers, the ground water occurs in semi-confined to confined conditions. It is expected that with increasing depth, the alluvium could get more and more consolidated because of the increasing overburden and hence have reduced porosity and permeability. The unconfined aquifer, which is quite potential, has been exhaustively used since irrigation started in this area. The groundwater levels in the phreatic aquifer show a general declining trend when analysed for the last 20 years, in most of the area.

Sub-surface Geology and Hydrogeological Units

Exploratory drilling and bore hole logging in the upper Yamuna basin has revealed existence of four aquifer systems down to 450 m depth. Except in areas close to Delhi where the bed rock occurs at a shallow depth, at most of the sites four distinct groups of permeable horizons were identified as under, especially in the area around augmentation canal (Fig. 2):

I. *Aquifer Group I*: This extends from the ground surface downwards to different depths to a maximum of 167 m below ground level (m.b.g.l). This is composed of relatively coarser sediments and at places is subdivided into two subgroups by occurrence of a sub-regional clay. It is

Fig 2. Fence diagram showing aquifer group in the study area (After C.G.W.B – Upper Yamuna Basin – Project findings and recommendations - 1984)

underlain by a clayey horizon, 10 to 15 m thick, which appears to be more to less regionally extensive except in the foothill region. The group is unconfined and semi-confined. The transmissivity varies from 800-5210 m^2/day, lateral hydraulic conductivity (K) from 8.75 to 47.1 m/day and specific yield from 2.1 to 24%.

II. ***Aquifer Group II***: This group consists of numerous sand and clay lenses occurring at variable depth ranging from 65 m to 283 m.b.g.l. The sediments of this group are less coarser and are occasionally mixed with kankar. The ground water occurs under confined to semi-confined conditions. This aquifer is underlain by another clayey horizon which is considerably thick at places and appears to be regionally extensive. The transmissivity varies from 350 to 1050 m^2/day, lateral hydraulic conductivity (K) from 3.95 to 10.70 m/day, Storativity from 5.6×10^{-4} to 1.7×10^{-3} and vertical conductivity of the upper confining clay layer (K) from 5.35×10^{-4} to 2.7×10^{-3} m/day.

III. ***Aquifer Group III***: This group comprises thin sand layers alternating with thicker clay layers occurring at variable depths ranging from 197 to 346 m.b.g.l. The granular material of this group is generally finer in texture. Kankar occurs in the southern parts of the area. In this aquifer group, the ground water normally occurs under confined condition. The transmissivity varies from 345-830 m^2/day, lateral hydraulic conductivity (K) from 3.50 to 10.70 m/day, storativity from 6.6×10^{-4} to 2.4×10^{-4}.

IV. ***Aquifer Group IV***: The aquifer group III is underlain, in turn, by a thick clayey horizon which in turn is underlain by another permeable granular horizon. This aquifer group IV was not fully penetrated and not studied in detail so far.

AUGMENTATION CANAL

With the twin objectives of augmenting canal water supply and prevention of water logging, a large number of augmentation wells were constructed along the WJC. Further, a lined canal, known as augmentation canal of 72 km length was constructed in 1972. This canal takes off from WJC at Yamuna Nagar and outfalls back in the WJC at Munak. One hundred sixty tube wells were constructed on both the sides all along the augmentation canal. All these tube wells were in the depth range of 100-150 m in general with some as deep as 200 m. The area selected for the alignment of the canal was a water logged area. These were, as already mentioned, constructed with the dual purpose of lowering the water level and to augment the canal water supply. These 160 tube wells all together use to direct about 14-15 cumecs of ground water to surface canal systems. The augmentation wells have become defunct since 2002 due to mechanical problems/non-maintenance of these tube wells (Fig. 3). The CGWB assumed the life of a tube well as 25 years during the project study (1974-77) and hence these tube wells have been utilized to the expectation. After the year 2002, the augmentation canal is being used as conduit to supply canal water as seepage loss will be less in the lined canal as compared to unlined one (Fig. 4).

Fig. 3. Abandoned augmentation tubewell (by the side of augmentation canal) which was pumping water into the augmentation canal.

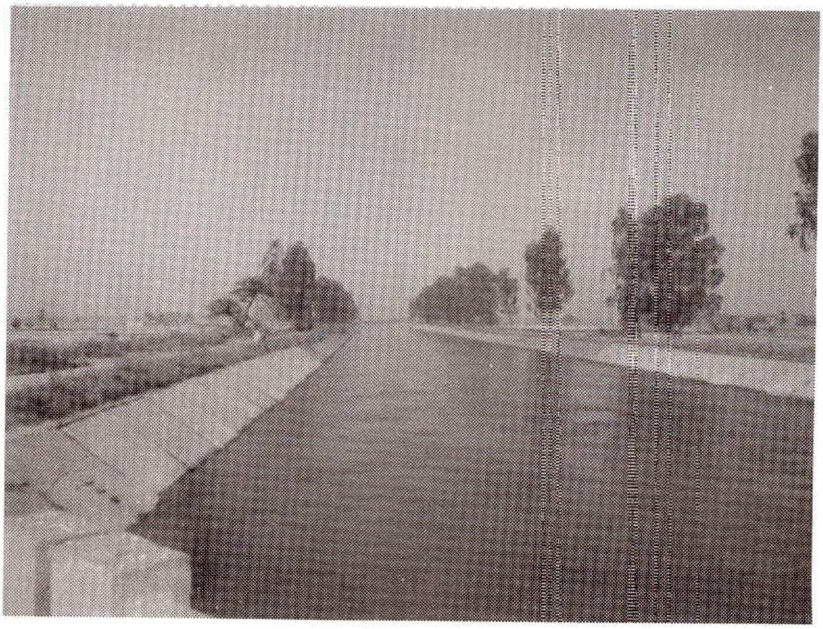

Fig. 4. Augmentation canal in the month of January, 2005 (being used as conduit of surface water).

PERFORMANCE OF AUGMENTATION WELLS

Impact on Groundwater Regime

During the seventies, the depth to water level in the area around augmentation canal varied between 2 and 7 m.b.g.l, with master slope from north to south. In the area around the augmentation canal, the aquifer I had a potential head of 0.4 m above the aquifer II. A comparison of the water level from 1963-64 (Geological Survey of India) and 1974 (after commissioning of augmentation canal) indicated a decline of 0.35 to 3.39 m. More than 2 m decline was recorded in the areas close to augmentation canal and 1 m decline close to WJC and the river Yamuna. Similarly, the water level showed an average decline of 0.886 m between 1972 and 1974 with a maximum decline of 1.89 m. The records of water level of 1974 and 1975 also showed a further decline of 1 m along the augmentation canal with a weighted average decline of 0.692 m. Similar decline was also observed between 1976 and 1977. However, the year 1975 to 1976 recorded a rising trend which may be due to the reduction in pumpage of ground water in 1975-76 in comparison to 1974-75. Also in year 1975, the area received higher rainfall as compared to less than normal rainfall received in 1973 and 1974. The study carried out by the CGWB concluded that there was a net decline of the order of 1.499 m in water levels in the vicinity of augmentation canal between 1972 and 1977. The study also concluded that the rate of pumpage from the augmentation wells and rainfall together are the significant factors affecting the water level fluctuation. The correlation between water level fluctuation on the one hand and pumpage and rainfall together on the other hand, showed a significant correlation (0.65) with a coefficient of determination of 0.43. This shows that 43% of the variation in the water level fluctuation is explained by the pumpage and rainfall. However, the significant finding of the CGWB study was that although both rainfall and pumpage had affected the water levels in the areas close to augmentation canal but the effect of pumpage was not as strong as rainfall. This clearly brings out that rainfall plays a significant role when water from the phreatic aquifer is being pumped than the pumpage itself. Marginal fall in water level was also observed during the follow up study (Saleem Romani et al., 1979) taken up by CGWB. The fall recorded was 0 to 1 m in 1976-77 and 0 to 0.5 m in 1977-78 with patches of rise in water level. Detailed study carried out adjacent to augmentation canal during the follow up study showed a fall of only 0 to 0.5 m in the southern part with a rise in water level from 0.5 to 1 m in the northern part along the augmentation canal between March 1977 and March 1978. The rise in water level was observed (generally 0.5 to 1 m) all along the augmentation canal between March 1978 and March 1979 with patches showing rise even more than 1 m going up to as high as 1.935 m.

The examination of the map of long term trend of the pre-monsoon water level from 1985 to 2004 shows a fall in water level ranging 0-5 m in the area around the augmentation canal. Hydrograph of an observation well at Gangatheri, District Karnal just bordering the sourthern portion of the present study area showed declining water level at a rate of 0.17 m/year during post-monsoon and at a rate of 0.19 m/year during pre-monsoon for last 20 years. The depth to water level around augmentation canal in 2003 varied between 5-15 m.b.g.l. (generally between 5-10 m) as compared to the water level of 2-7 m.b.g.l recorded in seventies. However a fall in water level in the range of 10-16 m is observed in general in the whole of WJC Command and even up to 16 m is also observed near the river Yamuna south of Samalkha very much away from the augmentation canal.

The above discussion of analysis of groundwater levels in the past 30 years of the running of the augmentation wells, clearly shows that the groundwater levels have declined to some extent, though the reason may not be only due to augmentation wells as otherwise also there was a declining trend all over the WJC area due over development of ground water. Moreover, a decline of around 3 m in 30 years when compared to water level of seventies, does not indicate any alarming situation considering the benefit reaped through this augmentation canal.

Financial Viability

During the CGWB's Upper Yamuna Basin Project Study, the data from the State Agencies was collected to assess the economics of the tube well irrigation. The details collected included completion, operation, maintenance cost of tubewells, distribution systems, land, pump efficiency, maintenance of motors, periodic development of civil works, cost of electricity, meter rent etc. The life of tubewell was considered as 25 years. The capital cost invested for construction of tubewells was treated as loan from commercial bank. The type of crops grown, their yields prior to and after irrigation and the prices of the produce were also utilized to know the benefit of tubewell irrigation.

The benefit of irrigation application was worked out to be Rs. 1500 per hectare per annum during 1974-77, considerably a reasonable benefit then. It was also observed that because of reduced production (yield potential) of tubewells in Aquifers II and III, the benefit derived sharply reduces with depth of aquifer. The benefit also directly increases with the level of utilization and operation of the tubewells. The table given below (After Anonymous, 1984) shows that for tubewells in Aquifer I, benefit cost ratio is uniformly of high order and this gets reducing for tubewells in Aquifers II and III.

Table 1. Benefit cost ratio of tubewells during 1974-1977 (After CGWB, 1984)

Tubewell in aquifer group	*Utilisation level*					
	2000 hrs/annum		*3000 hrs/annum*		*4000 hrs/annum*	
	*6 m**	*10 m**	*6 m**	*10 m**	*6 m**	*10 m**
I	4.17	4.54	5.62	5.91	6.53	6.95
II	2.20	2.75	3.08	3.71	3.66	4.50
III	1.11	1.64	1.61	2.30	1.97	2.89

*DD = Drawdown

Overall Performance

From the point of view of impact on ground water and financial aspect, the performance of the augmentation canal has been found to be a viable one. The canal on one hand recovered the area under water logging and also benefited other areas, where there was need of water for irrigation. Further the lined canal is even today in use as a conduit of surface water, the investment being utilized in justified way.

REVIVAL OF AUGMENTATION WELLS SCHEMES

Revival of such schemes in future in phreatic aquifer may not be feasible as it may have serious impact on the already over developed groundwater resources of the area. Secondly, all the water logged areas are prone to salinity and so the quality of pumped water may not be suitable and may not be sustainable for long term projects of this nature. Even as per recommendations of the Upper Yamuna Project Study (1974 -77), the surplus water balance of phreatic aquifer (Aquifer I) is marginal and any large scale groundwater withdrawals from this area was not recommended. It was further suggested that any planning of such schemes will have to take an integrated view of the system and work out all the implications in detail during the planning stage itself. The study has also recommended that the tubewells in Aquifer II can be profitable only at 4000 hrs/annum utilization level when operated at 10 m drawdown and the tubewell in Aquifer III may not be profitable even at 4000 hrs /annum level. It was further recommended that the Aquifers II and III are nearly virgin, which was supported by higher mineralisation. It was suggested to tap deeper aquifers in areas south of the present augmentation canal project. Taking this as a background, the revival of such schemes in pheratic aquifer is an impossible option and tapping of the Aquifer II (semi-confined to confined) just below the phreatic aquifer may be a suitable proposition. For this, detailed study can be taken up in the area and areas suitable may be demarcated and the proposals may be prepared by the State agencies and the financial support from the international agencies can be sought. In the era of liberalization such schemes with public partnership may prove to be successful in the prosperous state like Haryana.

CONCLUSION

The augmentation canal project commissioned in 1972 and running up to 2002, was found to be a viable management option in the study area to recover the water logged area and for augmentation of surface water sources. With the ever increasing water demand to meet the agriculture and industrial sector in the progressive area of Haryana, there may be a need in future to plan projects like the augmentation canal project. For making such a project viable proposition, the semi-confined to confined aquifer (Aquifer II), just below the phreatic aquifer may be utilized for augmenting the surface water supply. But this requires detailed study of the ground water to know the long term impact. As the cost of pumping (both drilling and operation) for Aquifer II is high, the Government-Public–Private partnership is necessary for such development of ground water.

ACKNOWLEDGEMENTS

The authors are grateful to the Chairman, Central Ground Water Board and Director, National Institute of Hydrology for kind permission to publish this paper. The authors are grateful to the help, assistance, cooperation and suggestion of various officers of CGWB, Chandigarh associated with this study and the retired officers who have worked in Upper Yamuna Project. Lastly the paper is based on data drawn from various sources including CGWB and State Ground Water Organization, which are duly acknowledged.

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