Groundwater Fluctuation and Its Excessive Usage for Irrigation in the Command Area of Muhammad Khan Distributary

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***Abstract*: Since the surface water at the tail reach of Rohri canal is decreasing day by day, the formers have installed tubewells to irrigate their lands for food and fiber for survival. Due to the excess use of ground water the water level of the aquifer is disturbed .This research focuses on investigation of groundwater fluctuation in the command area of Muhammad Khan distributary on the tail reach of Rohri canal (RD 1038).This research was done under the umbrella of HEC funded project "Sustainable fresh management for irrigated Agriculture of Lower Indus Basin).The ground water fluctuation data was collected from installed piezometers and hand pumps at head, middle and tail reaches of the selected command area. The water level indicator was used to collect the water Table fluctuation data in Rabi and Kharif season (2018-2019). Total four readings were carried, at the start & end of Rabi as well as at the start & end of Kharif season. From the results it is shown that, the average water table depth throughout the research area in 01 September 2018, 20June 2019, 23 September 2019 and 25 November 2019 were assessed as 20.91, 21.05, 20.52 and 20.77ft. Further calculation revealed that from 01 September 2018 to 20June 2019, 23 WT is lowered 0.14 ft and from 20June 2019 to 23 September 2019 the WT is raised 0.53 and from 23 September 2019 to 25 November 2019again lowered 0.25ft. However annual (from Sep 2018 to Sep 2019) watertable raised 0.39 ft. Regarding water quality in terms of EC of collected water samples from piezometers and hand pumps varies from 544 to 1504 pp, which is ranging from fresh to marginal quality of water. It is further suggested that for the sustainability of groundwater in terms of WT and water quality the artificial recharge is essential, that can be done through open wells in depressed areas within research areas for rainwater harvesting to recharge the aquifer.**

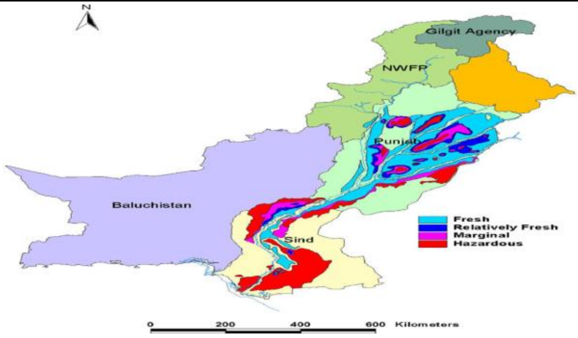
Key Words: **Groundwater fluctuation, groundwater quality, artificial recharge, Muhammad Khan distributary, Rohri canal.**

I. INTRODUCTION

Approximately 2.5% of the Earth's water resources is the fresh water; 30% of the fresh water is present as groundwater [1]. Unfortunately, this small quantity of fresh, earth's water resources especially groundwater, is threatened due to the rapid growth of population, increasing urbanization and unsustainable consumption of water in domestic, industrial, and agricultural sectors. The water related problems are further increased in developing countries due to the lack of resources, improper management of available resources and financial restrictions [2]. Groundwater is highly useful and often abundant resource; it is a significant part of the hydrologic cycle. Groundwater aquifers are recharged from surface waters e.g. precipitation, lake, reservoir, river, sea, etc. The largest user of the groundwater is agriculture sector to irrigate crops. Worldwide annual groundwater extraction was 982 km^3 in 2010 [3]. Over pumping of groundwater has led to water shortage and a smaller availability of drinking water. Pakistan is listed as one of the countries where renewable water resources are less than the calculated threshold of 1500 m^3 per capita by 2030. Hence, Pakistan is ranked among water scarce countries [4].

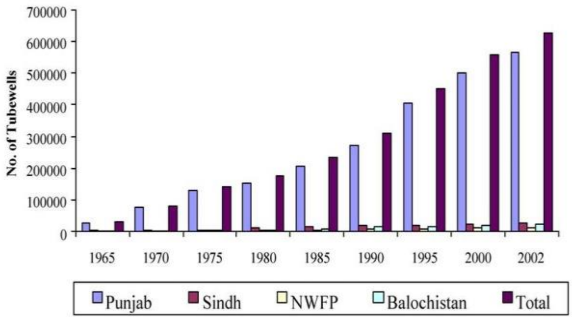
More than 50% of agricultural irrigation in the Punjab Province uses extracted groundwater [5]. Because of high extraction of groundwater, the water Table of Punjab Province of Pakistan has decreased from 20 to 40 feet bgl in the past 20 years [6]. Baluchistan is the most water-deficient province of the country, which has led to excessive depletion of the water level, e.g. in Quetta 95 feet depletion was observed during 2006–2013 (Umar et al., 2014) [2]. Groundwater reduction is mainly caused by sustained groundwater pumping. Adverse effects of groundwater depletion include falling groundwater level, rising groundwater cost, decreasing supply of surface water, ground subsidence, concern about water quality.

In Pakistan, groundwater is a significant freshwater resource; it is of considered importance due to its ever-growing demand in domestic, industrial and agriculture usages. Most area of Pakistan is located in the arid climate zone, where the average rainfall is below 200 mm per annum and the availability of groundwater is limited [7]-[8]. The major groundwater resources of Pakistan are in irrigated areas of the Indus Basin followed by areas outside the basin. In some drought-affected regions of Pakistan, people already do not have fresh drinking water and consume brackish water instead. Before the irrigation system was developed, the groundwater level of the Indus Plain was naturally 20 to 30 m below ground level (bgl). In Figure 1, it is clear that in the Indus basin command, the more area of Sindh province have hazardous groundwater as compared to Punjab.



Source: [9] Fig.1: Groundwater quality Status of Indus basin of Pakistan

Figure 2 shows the historical development of tubewells in all four provinces of Pakistan, it also shows that province of Punjab captured the greatest initiative in the expansion of private tube wells [11]-[12].



Source: [13] Fig.2: Tubewells' development in Pakistan (1965-2002).

The use of groundwater has increasing the cropping intensity from 63 % in1947 to 120 % in 2000 in Pakistan [14].
Surface water and ground water are mutually connected. If groundwater is used excessively, the supply of rivers, lakes and streams connected to the groundwater may decrease. Ground falling occurs when underground support is lost. Excessive pumping in areas with coastal zones and freshwater aquifers shallow and covering saltwater aquifers may move seawater inland and upward. It causes saline-water contamination of tap water. Overuse, over abstraction, or overdraft can be said to cause significant problems for human users and the environment. In some parts of the world, for example in California, Texas and India, excessive abstraction of groundwater dropped the groundwater surface several hundred feet bgl. Such as, in the Punjab India, the groundwater level has declined by 10 meters since 1979, and the depletion rate is accelerating. The rapid development of social economy, the involvement of groundwater is becoming more and more obvious and has produced a series of environmental negative effects [15]. In the past half century, easy access to pumping wells brought about a global "explosion" of groundwater development for agricultural, industrial and municipal supply. Groundwater intake of the whole world is 750–800 km^3/year [16].

Looking at the rapid increase in population and urbanization trends has put a serious impact on freshwater consumption. Therefore, the optimal development of water resources is eagerly desired. A good policy is to develop water resources with a plan based on shared use of surface and groundwater. The first task for this is to make a realistic assessment of surface water and groundwater resources and then to plan their use. It is necessary to maintain the groundwater reservoir in a dynamic equilibrium state over a period of time and the water level variation must be maintained during the monsoon and within a specific range shortly before the monsoon.

The groundwater storage in the aquifers depends on discharge from and recharge into the aquifer. During monsoon season recharge usually exceeds discharge and difference goes into storage, resulting in increase in the groundwater level. Whereas, in non-monsoon seasons (dry season) the discharge usually exceeds the recharge, resulting in increase in the groundwater level. In case of annual recharge equal to annual discharge the change in storage over the year will be negligible and water Table may not show any noTable change on an annual basis. This does not mean that the aquifer is continuously in equilibrium. It depends on the nature of the aquifer and the rainfall pattern for that year. Groundwater fluctuation research can help to develop strategies for rational management and efficient utilization of groundwater and also serves to provide scientific management for developing groundwater resources. Dynamic studies of groundwater also provide a scientific basis for rational development and utilization of groundwater resources effectively, which has important theoretical significance and practical value [17].

In Sindh province of Pakistan, farmers usually have skimming wells partially penetrating the relatively fresh groundwater aquifer. The fresh groundwater aquifer of the Sindh Province is shallower overlying a saline aquifer [18]. The well runoff rate exceeds the critical runoff speed, which disturbs the fresh-saline water interface (i.e. the equilibrium between freshwater and saltwater) and causes an increase salts in groundwater. Decrease in pumped water amount varies depending on not only discharge of well(s) but also pumping time, thickness of freshwater lens, and hydrological condition of the area.
The same is true for the tail reach of Rohri Main Canal, where the amount of water flowing through the canal is decreasing day-by-day. As a result, farmers set up many tube wells to irrigate the land to enhance food and fiber production for their survival. Growers of the study area are unaware from scientific knowledge for the sustainable groundwater management.
Hence, it is necessary to monitor water-Table fluctuation and make analysis of the collected data to develop strategy for sustainable and to provide research based information/recommendations to the concerned farmers. In this context, Muhammad Khan distributary command area of lower Indus basin (LIB), Sindh province of Pakistan was selected as study area. The data was assessed for two complete seasons; i.e. Rabi 2018-19 and Kharif, 2019.

II. MATERIALS & METHODS

A. Study Area

Muhammad Khan distributary command areas was selected as a study area. It is located in district Tando Muhammad Khan (Fig. 3). The GPS co-ordinates at head regulator of the distributary are 25.2606634 ºN and 68.5789813 ºE. The distributary branches from right side of main Rohri canal at Almani Cross-Regulator (RD 1038). The salient features of the selected distributary are given in Table 1.

Table 1: Salient Features of Muhammad Khan distributary

Description	Detail
Name of distributary	Muhammad Khan Distributary
R.D taking off from Rohri canal	1038
Design Discharge (cusec)	59
Length of distributary (R.D)	31
No. of watercourses	18
Gross Commanded Area (acres)	22,618
Cultural commanded Area (acres)	22,213

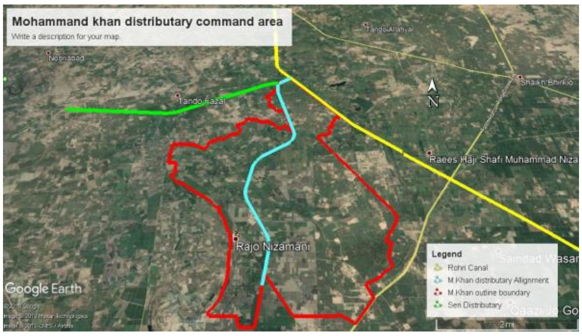


Fig.3: Map of the command area of Muhammad Khan distributary

B. Experimental Setup and Data Collection

Total three piezometers were installed, one at each; head, middle and tail reach, remaining six hand pumps (HPs) were chosen as water level observation sources and acquired at random points within the study area (Fig. 4). Three sets of water levels readings were observed, viz: 1. Pre-Rabi 2018-19, 2. Pot-Rabi 2018-19 or Pre-Kharif 2019 and 3. Post-Kharif 2019. Piezometer were composed of PVC pipes with a diameter of 1.5 inches inserted at depth of 80 feet bgl. Meanwhile, hand pumps were already installed by locals for drinking water extraction. The electrical conductivity (EC) was determined using imported EC-meter of HANNA Instruments. The water levels and EC values of the collected water samples are presented in Table 2 and Table 3 respectively.

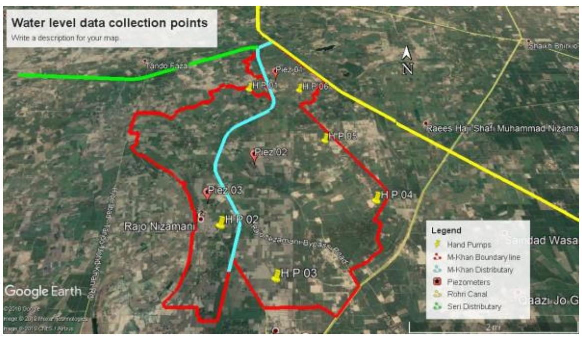


Fig.4: Map showing data collection points (Piezometers and Hand-pumps) for water levels

Fig.5: Water level readings collecting from Piezometer and hand-pump at command area of Muhammad Khan distributary

Table 2: Water level fluctuation during Kharif and Rabi Season (2018-2019)

Location Name		Co-ordinates		GS Elev. from MSL (ft)	Elev. from MSL (ft)	WTD from GS (ft)	Elev. from MSL (ft)	WTD from GS (ft)	Elev. from MSL (ft)	WTD from GS (ft)	Elev. from MSL (ft)	WTD from GS (ft)	Avg. Elev. From MSL (ft)	Avg. Elev. From WTD (ft)
		Latitude "N"	Longitude "E"		Sep 01, 2018		Jun 20, 2019		Sep 23, 2019		Nov 25, 2019			
Head	Piez 1	25.24226389	68.58043056	63	44.58	18.42	43.34	19.00	44.92	18.08	44.42	18.58	44.97	18.13
	H P 1	25.23616389	68.57255556	64	45.42	18.58	43.34	19.33	47.33	17.67	45.92	18.08		
	H P 6	25.23573056	68.58681389	63	45.92	17.08	43.35	17.83	45.58	17.42	45.50	17.50		
Mid	Piez 2	25.212972	68.5759139	59	32.33	26.67	43.39	26.63	32.83	26.17	32.33	26.66	40.63	26.03
	H P 4	25.19901389	68.60387222	69	40.33	28.67	43.40	28.96	40.58	28.42	40.33	28.66		
	H P 5	25.217125	68.59313889	69	46.58	22.42	43.38	23.25	46.17	22.83	45.92	23.08		
Tail	Piez 3	25.20015	68.56578611	61	40.25	20.75	43.37	20.67	40.00	21.00	40.33	20.66	41.86	18.27
	H P 2	25.19268056	68.56902222	56	42.50	13.50	43.36	12.08	44.67	11.33	44.25	11.75		
	H P 3	25.1809	68.58146389	62	39.92	22.08	43.40	21.67	40.25	21.75	40.00	22.00		

Table 3: Seasonal water quality of Mohammad Khan distributary command area

S No.	Location Name	Co-ordinates		EC (ppm)	
		Latitude "N"	Longitude "E"	Kharif Season	Rabi Season
1	Piez-1	25.24226389	68.58043056	839	807
2	HP-1	25.23616389	68.57255556	611	544
3	HP-2	25.19816111	68.56285000	1419	1373
4	HP-3	25.18090000	68.58146389	1680	1504
5	HP-4	25.19901389	68.60387222	878	810
6	HP-5	25.21712500	68.59313889	1439	1354
7	HP-6	25.23573056	68.58681389	730	671
8	Piez-2	25.19829722	68.58503333	1108	1059
9	Piez-3	25.20015000	68.56578611	1071	1101

III RESULTS

A. Seasonal watertable fluctuation:

Four water level readings have been assessed in Rabi-2018-19 and Kharif 2019. The data is recorded in Table 2 where the average water level elevation from mean seal level at head, middle and tail reaches is observed 44.97 ft, 40.63 ft and 41.86 ft respectively. Whereas, the average water Table depth at head, middle and tail reaches is 18.13 ft, 26.03 ft and 18.27 ft respectively. The results of these parameters are shown in Fig.6.

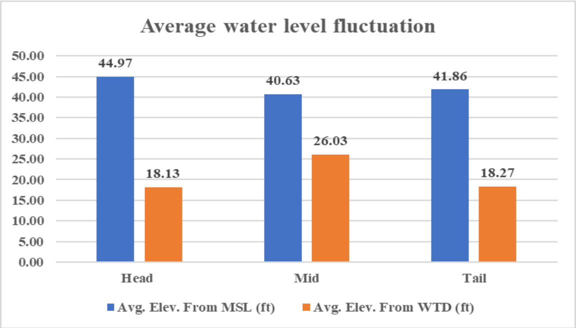


Fig. 6: Water level fluctuation during Kharif and Rabi Season (2018-2019)

B. Determination of electric conductivity of water samples.

The electrical conductivity (EC) in part per million (ppm) of the water samples were observed and are recorded from the nine location points during Rabi and Kharif season. The maximum and minimum EC were observed during Kharif season which is 1680ppm and 611ppm from HP-3 and HP-1 respectively, whereas, the maximum and minimum EC were observed during Rabi season were 1504ppm and 544ppm from the HP-3 and HP-1 respectively. The results of these piezometer are tabulated above in Table 3 and are shown in Fig.7

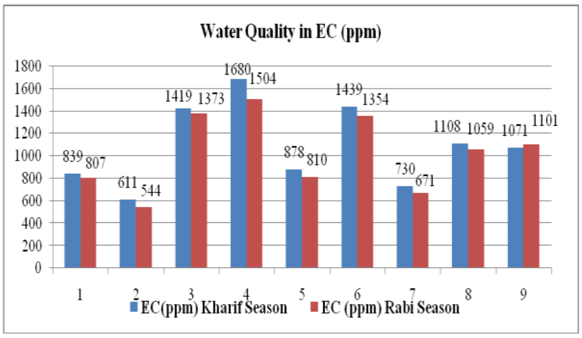


Fig.:7: Seasonal water quality of Mohammad Khan distributary command area

C. Monthly Rainfall Data for the Year 2019

The monthly rainfall data of 2019 of district Hyderabad presented in Fig. 8 shows that, the wettest month (with the highest rainfall) is August (60.8mm) and the driest month (with the lowest rainfall is January (1.2mm).

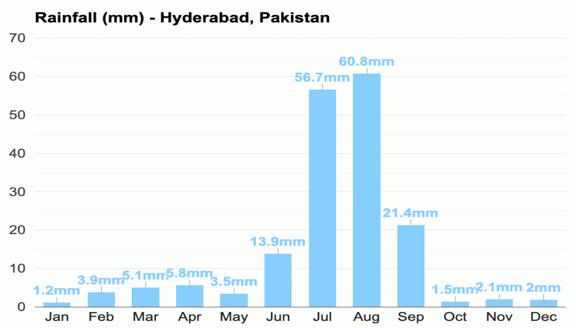


Fig.8: Rainfall data of District Hyderabad

IV CONCLUSIONS

From this research following conclusions are arrived:

From the results it is shown that, the average water table depth throughout the research area in 01 September 2018, 20June 2019, 23 September 2019 and 25 November 2019 were assessed as 20.91, 21.05, 20.52 and 20.77ft. Further calculation revealed that from 01 September 2018 to 20June 2019, 23 WT is lowered 0.14 ft and from 20June 2019 to 23 September 2019 the WT is raised 0.53 and from 23 September 2019 to 25 November 2019again lowered 0.25ft. However annual (from Sep 2018 to Sep 2019) watertable raised 0.39 ft. Regarding water quality in terms of EC of collected water samples from piezometers and hand pumps varies from 544 to 1504 pp, which is ranging from fresh to marginal quality of water.

V RECOMMENDATIONS

- As it was observed that at shallow depth groundwater quality of district Hyderabad found fresh, have recharge or seepage ponds area be identified to store fresh water for recharge the aquifer in rainy season.
- The groundwater monitoring be made regularly by the irrigation department and proper laws can be made and strictly implemented for extracting groundwater.

REFERENCES

[1] USGS. (2016). The world's water. U.S. department of the Interior. U.S. Geological survey. Retrieved from http://water.usgs.gov/edu/earthwherewater.html

[2] Umar, M., Waseem, A., Kassi, A. M., Farooq, M., Sabir, M. A., and Faridullah. (2014). Surface and subsurface water quality assessment in semi-arid region: A shah case study from Quetta and So range Intermontane Valleys, Pakistan. Global Nest Journal, 16, 938–995.

[3] Benejam, L., Angermeier, P. L., Munne, A., and Garcia Berthou, E. (2010). Assessing effects of water abstraction on fish assemblages in Mediterranean streams. Freshwater Biology, 55, 628–642.

[4] Ishaque, W., and Shaikh, S. (2017). Water and energy security for Pakistan a retrospective analysis. Grassroots, 51(1), 90–100.

[5 Bastiaanssen, W. G., & Feddes, R. A. (2005). A new technique to estimate net groundwater use across large irrigated areas by combining remote sensing and water balance approaches, Rechna Doab, Pakistan. Hydrogeology Journal, 13(5-6), 653-664.

[6[Kahlown, M. A., Raoof, A., Zubair, M., and Kemper, W. D. (2007). Water use efficiency and economic feasibility of growing rice and wheat with sprinkler irrigation in the Indus Basin of Pakistan. Agricultural Water Management, 87, 292–298.

[7] Salma, S., Rehman, S., and Shah, M. A. (2012). Rainfall trends in different climate zones of Pakistan. Pakistan Journal of Metreology, 9, 1–17.

[8] Alamgir, A., Khan, M. A., Schilling, J., Shaukat, S. S., and Shahab, S. (2016). Assessment of groundwater quality in the coastal area of Sindh province, Pakistan. Environmental Monitoring and Assessment, 188, 1–13

[9] Qureshi, A.S., Asghar, M.N., Ahmad, S., Masih, I., 2004. Sustaining crop production under saline groundwater conditions: a case study from Pakistan. Aust. J. Agric. Sci. 54, 421–431

[11] Pakistan Water Partnership (PWP). 2001. The Framework for Action for Achieving the Pakistan Water Vision 2025.WAPDA: Lahore, Pakistan.

[12] Government of Pakistan (GOP). 2000. Agricultural Statistics of Pakistan. Islamabad, Pakistan: Ministry of Food, Agriculture and Livestock, Economics Division, and Government of Pakistan, Islamabad, Pakistan.

[13] Qureshi AS, Mc Cornick PG, Sarwar A, Sharma BR. 2010. Challenges and prospects for sustainable groundwater management in the Indus Basin, Pakistan. Water Resources Management 24(8): 1551–1569.

[14] Alam, S. M. & Naqvi, M. H. 2003. Pakistan Agriculture-2003 "The gap between the supply and demand of agricultural products is widening day by day". May 19-25, 2003. Ali, I. 1993. Irrigation and Hydraulic Structures, Theory, Design and Practice. First edition.

[15] Jinzhu MA, LI Jijun and GAO Qianzhao. Groundwater evolution and its influence on eco-environment under climatic change and human activity in the south of Tarim Basin. Arid Land Geography, 2002, 25(1): 16-23. (in Chinese).

[16] Shah T, Molden D, Sakthivadivel R, Seckler D (2000) The global groundwater situation: overview of opportunities and challenges. International Water Management Institute.

[17] Xia, J., Ye, A. Z., Wang, L., et al. Water cycle mechanisms on the Loess Plateau, China: The Chabagou catchment case study. Methodology in Hydrology, 2007, 311: 10-17.

[18] Qureshi, A.L., Lashari, B.K. and Kori S.M., Lashari, G. A., Hydro-Salinity Behavior of Shallow Groundwater Aquifer Underlain by Salty Groundwater in Sindh Pakistan, Proceedings 15th International Water Technology Conference IWTC15, Alexandria, Egypt, May 28-30, 2011.