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Resource Development and Management of Groundwater Focusing Sustainability Issues in Urban City

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Abstract

In a developing country like India, we do not have enough resources to fulfill basic requirements of drinking water. Groundwater is the major source of drinking in both urban and rural areas. The groundwater potential with respect to its quantity and quality in major cities and urban centers is getting deteriorated due to the population explosion, fast urbanization, rapid industrialization and also the fluctuating pattern of monsoon and improper management of rainwater. Groundwater is especially exploited as an alternative resource to provide water distribution in areas where the surface water is either contaminated or is not available. To endure the increasing pressure of water demand in various developing and developed sectors, it is imperative not only to develop new water resources, but also to conserve, recycle and reuse the water wherever possible. The recharge structures established in the Panjab University Campus Chandigarh have been a step forward in effectively recharging the roof top water harvested and stored in the recharge wells established on the campus. These structures have resolved the twin problems of the declining water table and water logging to a large extent in the area under investigation. The measures adopted by the government will be more fruitful by creating awareness among the masses about the long term effects of rising water level and water depletion problems. By educating masses about various conservation strategies and benefits of conjunctive use of surface and groundwater can impede situation of water crisis. This study brings to light the importance of sustainable micro level management of water resources in a highly urbanized watershed of city beautiful Chandigarh.

Keywords: Groundwater, recharge structures, water-logging, conjunctive use, sustainable management.

1. INTRODUCTION

The groundwater resources throughout the country have been depleting fast due to continue pumping and being used indiscriminately. To endure the increasing pressure of water demand in various developing and developed sectors, it is imperative not only to develop new water resources, but also to conserve, recycle and reuse the water wherever possible. Groundwater is particularly important as it accounts for about 88% safe drinking water in rural areas, where the population is widely dispersed and the infrastructure needed for treatment and transportation of surface water does not exist (Kumar, 2004). In a developing country like India, we do not have enough resources to fulfill basic requirements of drinking water. In India, where groundwater is used intensively for irrigation and industrial purposes, a variety of land and water based human activities are causing pollution of this precious resource (De, 2002). Groundwater is the major source of drinking in both urban and rural areas. Although groundwater comprises the greatest proportion of globally available fresh water, our ecological knowledge of these ecosystems lags far behind that of lakes and rivers (Boulton et al., 2003). Meanwhile, demand for groundwater intensifies, and over two billion people now depend on this resource for their daily supply (Kemper, 2004). The groundwater potential with respect to its quantity and quality in major cities and urban centers is getting deteriorated due to the population explosion, fast urbanization, rapid industrialization and also the fluctuating pattern of monsoon and improper management of rainwater. Increased concerns about declining groundwater quality and recharge rates (Alley et al., 1999) have prompted urgent calls for greater understanding of how groundwater ecosystems are affected by human activities and potential remediation strategies (Kemper, 2004). The composition of surface and groundwater is dependent on natural factors (geological, topographical, meteorological, hydrological and biological) in the drainage basin and varies with seasonal differences in runoff volumes, weather conditions and water levels (Trivedy, 1990).

Rain water is a major source of fresh water and the activity of collecting rainwater directly for beneficial use or recharging it into the ground improves the groundwater storage in the aquifer. Groundwater quality in the wells has shown improvement after implementing the artificial recharge when compared with the wells in which rainwater harvesting was not implemented in Rajasthan in India (Stiefel et al., 2009). Based on the available data and the knowledge about the local hydrogeology, we can choose the most suitable recharge method and estimate the natural groundwater recharge (Amitha Kommadath, 2000). The impact of the artificial recharge would depend upon four factors like the slope of the area, surface infiltration, thickness of the aquifer and the quality of water (Saravi et al., 2006). The rate of the aquifer recharge is also one of the most difficult factors in the evaluation of the rainwater harvesting of groundwater resources (Kumar & Seethapathi, 2002).

2. STUDY AREA AND SITE DESCRIPTION

Chandigarh is a Union Territory (U.T.) located at the foothills of the Siwalik range of the Himalayas in North-West parts of India. The exact cartographic co-ordinates of city are 30°46'N 76.79°E and it has an average elevation of 321m (1053ft). Chandigarh has an area of 114 Km^2 out of which 34.66 Km^2 is rural and remaining 79.34 Km^2 is urban. Many new residential and commercial areas have been developed at the expense of removing agricultural or natural area. The city is divided into 56 dwelling sectors and among these sectors, our site of the research Panjab University is situated in the northwestern part of the city and covers entire sector-14 and part of sector-25. Total land area of Sector- 14 is 15, 60,840 sq.m. Out of which undeveloped area is 38,000 sq.m., while road and footpath cover an area of 1,40,000 sq.m. Open space and lawn area is 10,49,840sq. m, whereas, the area covered by the buildings is 3,33,000 sq.m.

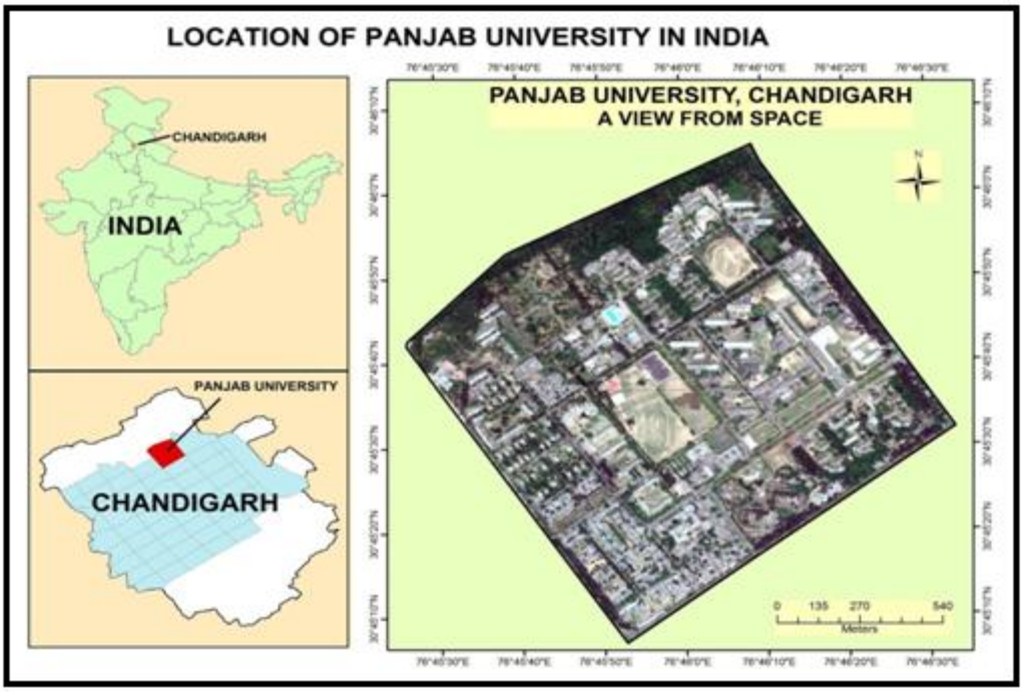

Figure 1: Map Showing Location Of Sector-14, Panjab University, Chandigarh.

Chandigarh stands second next to Delhi in terms of population density, i.e. 9252 person per sq. kms. Chandigarh which was planned for the finite population of half a million has now grown beyond its planned capacity to the total population of 10, 55,450 as against 5 lacs. Demographic data indicate that between 1961 and 1971, the population increased by 144.59 %. According to the 1981 census, it grew by another 75.55 %, followed by 42.16 % in 1991, 40.33 % in 2001 and 17.10 % in 2011 (Census, 2011).

Average Annual Rainfall of Chandigarh is 1110.7 mm and as per Construction office, Panjab University, Chandigarh the normal annual rainfall of the area is 1074 mm and the average rainfall is 866 mm is recorded in the research area. There are 34 rainy days in a year and maximum rainfall (80% - 90%) occurs during the monsoon period. The analysis of rainfall frequency indicates that in maximum cases, per hour rainfall is around 30 mm.

2.1 Urbanization-Major factor Impacting Environment

Chandigarh stands second in India when calculations are made on the urbanized population, among the other cities,with 89.8% population living in urban area. Due to all the facilities available easily in the city beautiful,the population of the city is increasing and hence there is increased land use followed by increase in use of resources in addition to this for residing peripheral area in and around Chandigarh is turned into the urban area. Chandigarh was planned in phases, only 25 sectors were palnned in first phase which are now increased to 56 sectors. Due to such fast development and urbanization,agricultural area is decreasing simultaneously urban area/urban population and industrial area are increasing.

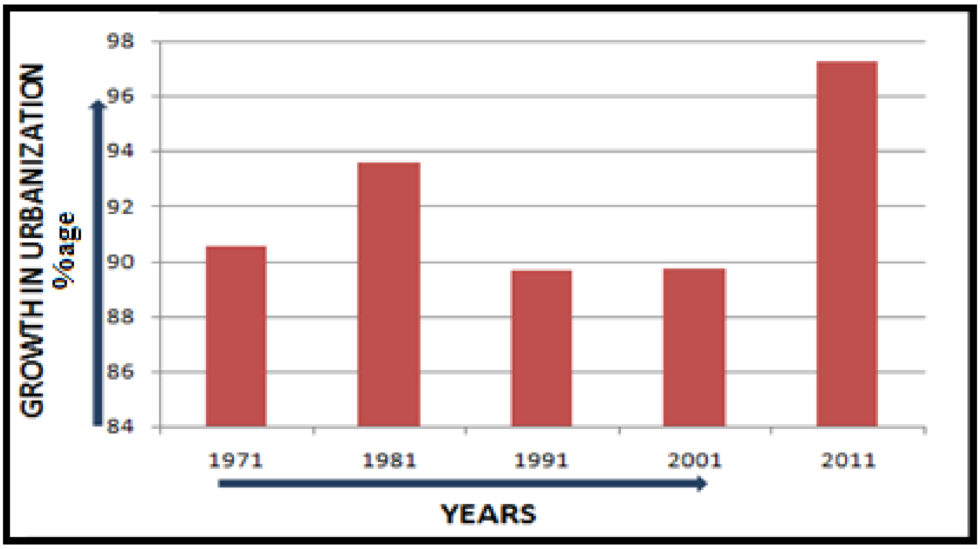

Figure 2: Graphical representation of Urbanization trend in Chandigarh (1971-2011)

This is followed by unplanned expansion of villages, the growth of slums and unplanned development around peripheral zone. The growing demand from India's towns and cities and by the industry has meant increased groundwater use not only from within urban agglomerations, but also the export of water from adjoining villages (Janakrajan, 2008). These resulted change in the land use pattern of the city, bringing more and more area under build-up land leading to the increase in the surface runoff and discharge of untreated wastewater from the residential and commercial areas of the city into the nearby drains, causing degradation of surface and subsurface water regimes. It is well known that no straightforward reasons can be advanced for the deterioration of water quality, as it is dependent on several water quality constituents (Jothivenkatachalam et al., 2010). Every year during the rainy season people mostly living in slums and southern areas suffer a lot because of the chocking of the drains. The flooding is not just confined to the low-lying areas like roundabouts, markets, etc. but has now entered the houses also. The drainage system was designed to handle 12.5 mm per hour of rain, but sometimes during the intensity of rainfall was between 40 mm and 60 mm per hour, as a result of which waterlogging took place in low-lying areas.

3. PROBLEM OF GROUNDWATER RESOURCE

The pressure of increased commercialization has driven change in land use pattern over a period of time in Chandigarh due to which city has been facing the twin problem of groundwater decline as well as rise. The study area is not having any option to source surface water, but aquifer system has the potential to store water itself. There are two distinct aquifer systems - shallow and deep. Shallow aquifer occurs under semi-confined conditions and exists down to 20 to 30 m bgl. Deep aquifers below 40 m are under confined conditions. The piezometric head of the deep aquifers stands much below the water table of shallow aquifers and thus it can receive water easily on being recharged artificially. The tubewells in Chandigarh are tapping only the deeper aquifer system which causes fall in piezometric head of deeper aquifer system; whereas water level in the shallower aquifer system is rising.

In report maintained by Centre for Science and Environment 2010 have already discussed about the declining trend of groundwater in Chandigarh, where the tubewells taping deeper aquifers falling in sectors 12 ,37, 39 and 10C have shown a sharper decline in water level in those areas.

To balance this problem, it is essential that pumping from the deeper aquifers should be reduced and that from the shallow aquifers be increased. Artificial recharge of the deeper aquifer should be taken up to arrest the decline in the piezometric head. Water from shallow aquifer is not allowed for drinking purposes to avoid risk of bacteriological contamination. The storm water drainage system has been designed keeping in view the slope of the city i.e. from northeast to southwest. It was initially designed for a rain intensity of half inch per hour. However, because of the increased green areas/ open spaces coming under construction, the runoff co-efficient has increased tremendously. This has resulted in the overloading of the storm water drainage system and hence the problem of flooding of low lying pockets in the city is observed and this precious natural rainwater is wasted at city beautiful in the form of run-off. The alluvial sand and gravel deposits typically function as high-yield aquifers therefore shallow aquifer system in Chandigarh typically exhibits a strong degree of contamination through leaching and is more prone to pollution. This water is being tapped from deeper aquifers across the city to avoid the risk of contamination and is causing a fall in the piezometric head of the deep aquifer (Sidhu et al., 2013).

4. AQUIFER GEOMETRY

In order to understand the regional sub surface disposition of aquifer system and group of sediments in the UT and also to study the continuation of the system in the adjacent district of Panchkula of Haryana and SAS Nagar in Punjab , a fence diagram showing aquifer geometry of Chandigarh and adjoining areas of Panchkula and SAS Nagar is given in Fig.3.

The perusal of Fig.3 indicates:

i) These are group of sediments enclosing the three aquifer system drilled to a depth of 465 m bgl.

ii) The 1^{st} groups of sediments occur between the depth range of 20 to 100 m bgl. In general the bottom of the aquifer extends to a maximum depth of 110 to 120 m bgl and the thickness ranging 10 to 20 m discernible and extends to large distance. They are regional in nature.

iii) The shallow aquifer is semi-confined and its thickness decreases towards north western and south western parts due to the intervening clay beds.

iv) The second groups of sediments occur between the depth range of 125 to 220 m bgl. The thickness ranges 10 to 35 m discernible and extend to large distance. It is confined in nature.

The third group of sediments occurs below 220m to 465m bgl which is also regional in nature and extended to large distance (CGWB, 2012).

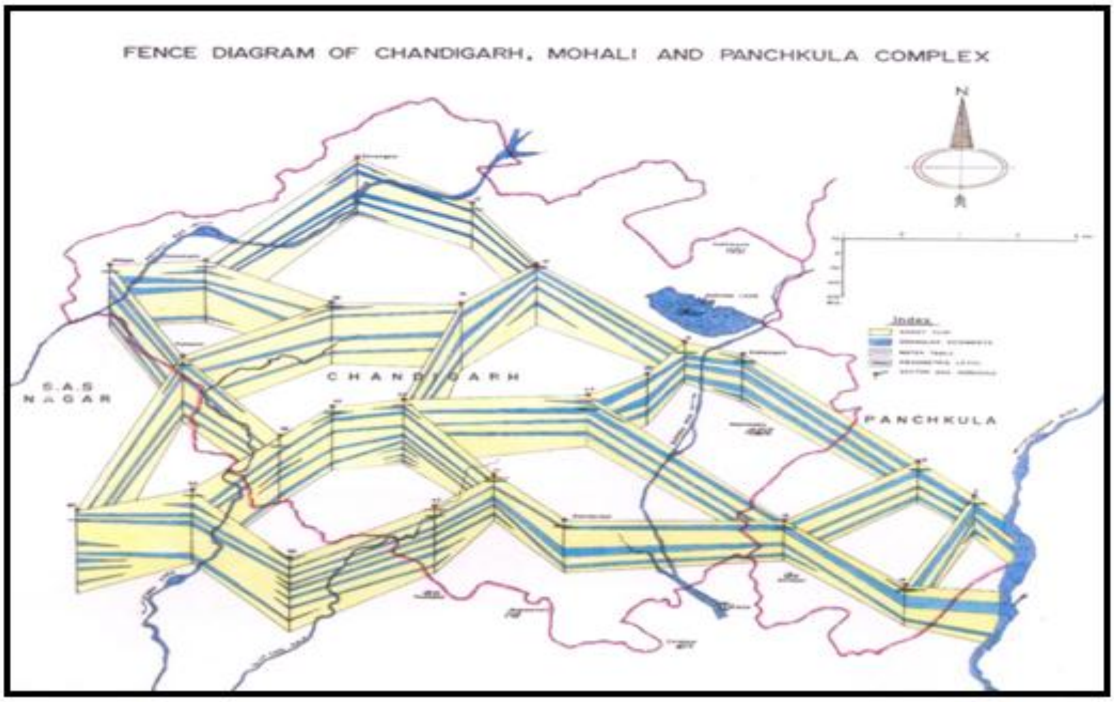

Figure 3: Fence diagram showing the aquifer geometry of Chandigarh and satellite areas of Panchkula and SAS Nagar

(Source: CGWB, 2012)

5. METHODOLOGY

To identify the soil profile, integration of thematic layers i.e land use, geomorphology, geology, hydrogeology, storm water and sewage network have been done. These layers are derived from conventional methods through geographic information system (GIS) application.

The work on mapping is divided into three parts:

- Collection of data related to land use, land cover, commercial areas , parks and important buildings, schools etc. is done through maps. Borehole logs have been collected to get an understanding of the soil profile below the surface.
- Geo referencing of all maps is done for the projection of geographical latitude and longitudes with Map Info 6.5.
- Digitization is the third step after the Geo-referencing of maps and transferred to illustrator for final map work in which different layers according to the preferences of visibility is marked.

After the preparation of the thematic layers decision about the solutions are taken to solve water crisis and the flooding problems according to the sites.

6. RESULTS AND DISCUSSION

Decline of water level, especially in summer season is a common problem not only being faced by Chandigarh and is prominent in other urbanized cities too. India is a groundwater-dependent nation. Even by conservative estimates, 85% of rural drinking water in India is derived from wells (The World Bank, 2010). In India even though an average rainfall is 1100 mm there is a scarcity of water that results in water crisis (Hajare et al., 2003). In Chandigarh, the area falling in the northern regions has remarkable low water levels and observe high fluctuations in relation to seasonal precipitation. Recharge to groundwater is affected by several factors and these factors also pose influence to the groundwater fluctuations. The fall and rise in groundwater level occur when the discharge exceeds or reduces over the recharge rate. Groundwater overexploitation may be defined as a situation in which, for some years, average abstraction rate from aquifers is greater than of closer to the average recharge rate (Custodio, 2002).

6.1 RESPONSE OF GROUNDWATER TO ARTIFICIAL RECHARGE

Analysis of water table fluctuations (WTF) is a useful tool for determining the magnitude of both short- and long-term changes in groundwater recharge and has been widely applied under varying climatic conditions (Gerhart, 1986; Hall and Risser, 1993; Healy and Cook, 2002).The re-emphasis of the shift in focus from a groundwater resource development agenda to a groundwater resource management programme is strengthened on how groundwater recharge and abstraction vary in proportion to each other as an aquifer depletes over a period of time (Comman,2005).

When water enters the saturated zone of the aquifer, the water table rises and recharge occurs; hence the amount of water table rise (WTR) in an aquifer was assumed to be proportionate to the amount of recharge the aquifer received. The monthly average water level fluctuation (pre monsoon) for 20 observation well sites were compared with the monthly average water level fluctuations (post monsoon) to determine whether a WTR occurred or not. All the values observed were then summed into the total annual WTR to evaluate seasonal and annual patterns of WTR (Table 1).

The water table measurements were then analyzed to evaluate how groundwater recharge varied along a topographic gradient. Results suggested that in Panjab University, a greater proportion of annual recharge has occurred at the sites falling in the southern region, followed by comparatively lesser recharge in slope areas. Whereas the sites falling in northern regions of the university campus showed lesser recharge, highlighting stabilization in Water Level (Site No. A9,A10,A11,A12) in Fig.5, Fig. 6 and Fig.7 where initially water table was at a very high depth >35 m bgl in the pre monsoon season.

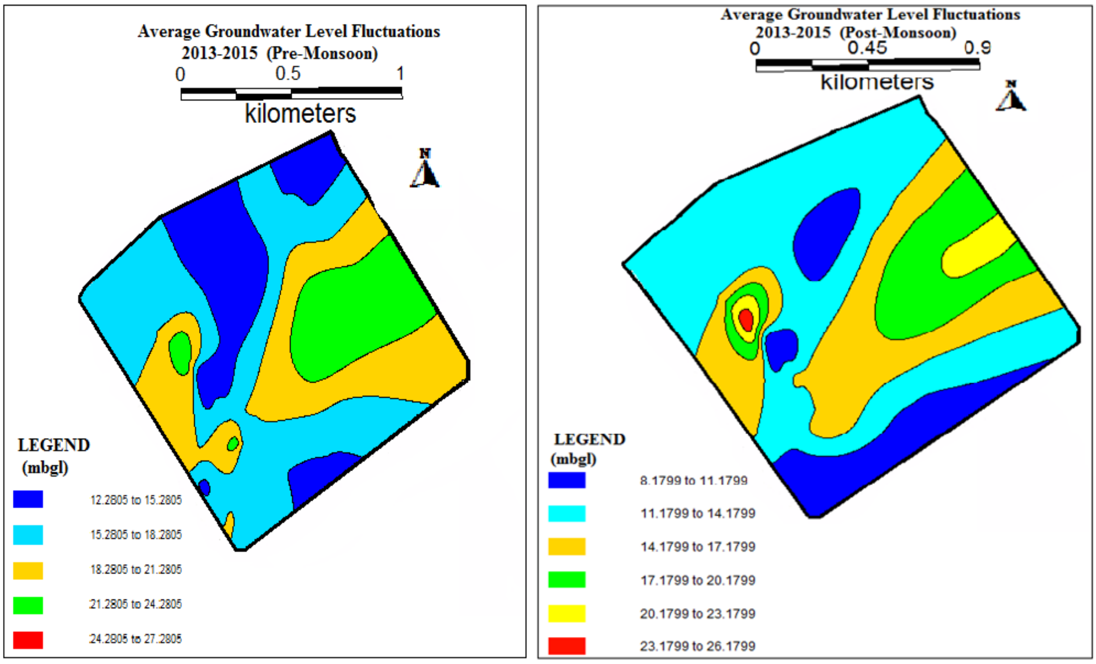

Figure 4: Showing Average Groundwater Fluctuations (2013-2015) a)Pre-Monsoon b)Post-Monsoon

Table 1: Showing Minimum and Maximum Values of Average Water Level Fluctuations For Pre-Monsoon and Post- Monsoon Periods From Year 2013-2015.

SITES	Year 2013				Year 2014				Year2015				AVERAGE (2013-2015)	
	Minimum		Maximum		Minimum		Maximum		Minimum		Maximum			
	PRE MONSOON	POST MONSOON	PRE MONSOON	POST MONSOON	PRE MONSOON	POST MONSOON	PRE MONSOON	POST MONSOON	PRE MONSOON	POST MONSOON	PRE MONSOON	POST MONSOON	PRE MONSOON	POST MONSOON
A1	17.0	20.0	25.0	21.0	10.0	10.8	15.5	15.8	12.0	14.0	16.0	18.3	15.92	16.65
A2	23.0	20.0	27.5	22.9	12.0	9.0	16.35	11.7	13.0	10.0	14.85	13.0	17.78	14.43
A3	22.0	7.3	26.3	17.0	4.7	4.5	9.0	10.1	5.9	6.3	6.7	6.5	12.43	8.62
A4	16.0	11.9	20.35	13.3	6.8	12.7	13.65	15.1	5.9	1.5	11.0	5.1	12.28	9.93
A5	28.3	7.9	27.0	8.8	10.0	12.3	11.3	13.8	12.0	11.0	13.6	12.7	17.03	11.08
A6	18.0	8.0	22.3	14.85	9.0	11.0	7.4	14.3	8.0	13.0	15.6	13.7	13.38	12.48
A7	21.0	14.0	24.3	14.8	10.5	12.5	11.0	14.0	12.0	11.5	17.0	14.0	15.97	13.47
A8	20.0	12.5	20.7	13.7	10.3	9.0	12.7	10.7	9.7	5.8	16.0	6.2	14.90	9.65
A9	30.5	17.1	34.0	17.7	17.0	17.0	19.0	20.0	17.3	20.0	21.3	23.4	23.18	19.20
A10	30.3	22.0	32.7	24.0	17.9	15.1	16.0	16.7	17.1	15.0	17.9	13.8	21.98	17.77
A11	28.0	23.3	29.2	26.0	19.2	18.3	19.4	18.9	19.0	18.3	19.9	18.7	22.45	20.58
A12	15.7	12.0	17.1	12.7	11.5	8.7	11.8	9.1	14.0	15.1	15.8	15.5	14.32	12.18
A13	21.7	22.0	26.0	24.7	17.7	12.2	18.35	12.65	14.1	13.3	14.7	14.2	18.76	16.51
A14	18.0	15.7	22.0	15.3	22.3	10.3	22.7	17.9	8.7	8.9	10.0	10.1	17.28	13.03

A15	23.35	13.7	26.0	14.95	13.7	11.0	14.8	12.2	11.5	11.4	14.6	12.1	17.33	12.56
A16	25.1	5.7	27.0	13.0	20.7	12.8	22.2	15.45	17.0	13.7	18.9	14.6	21.82	12.54
A17	21.0	25.4	28.4	26.8	22.3	25.7	24.9	26.6	23.0	20.3	21.0	22.44	23.43	24.54
A18	18.0	11.4	22.0	17.2	12.65	12.7	20.0	14.35	7.7	6.0	8.7	9.5	14.84	11.86
A19	22.0	8.5	20.5	9.3	8.1	7.25	9.7	8.75	22	24.6	28.35	26.8	18.44	14.20
A20	20.4	12.9	22.3	14.2	14.5	5.0	16.8	6.7	16.4	4.6	19.5	5.7	18.32	8.18

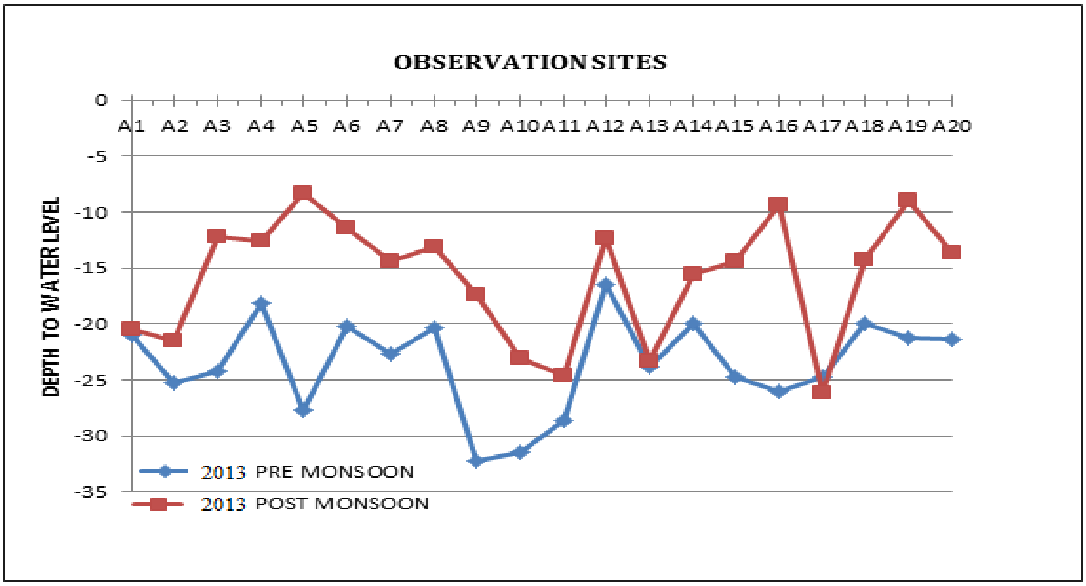

Figure 5: Hydrograph Showing Annual Water Level Fluctuations for Year 2013

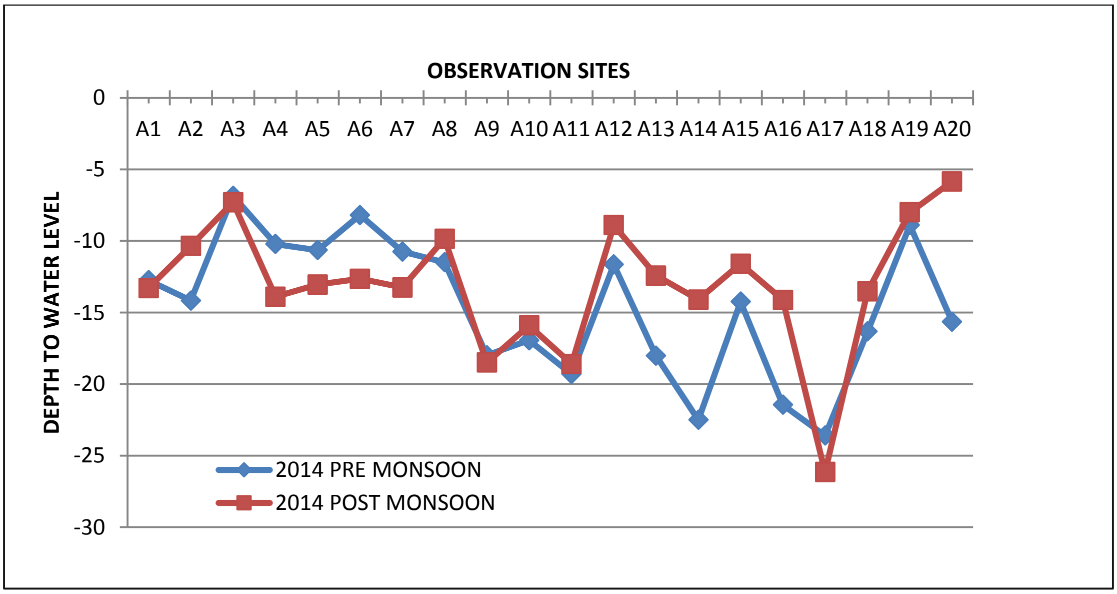

Figure 6: Hydrograph Showing Annual Water Level Fluctuations for Year 2014

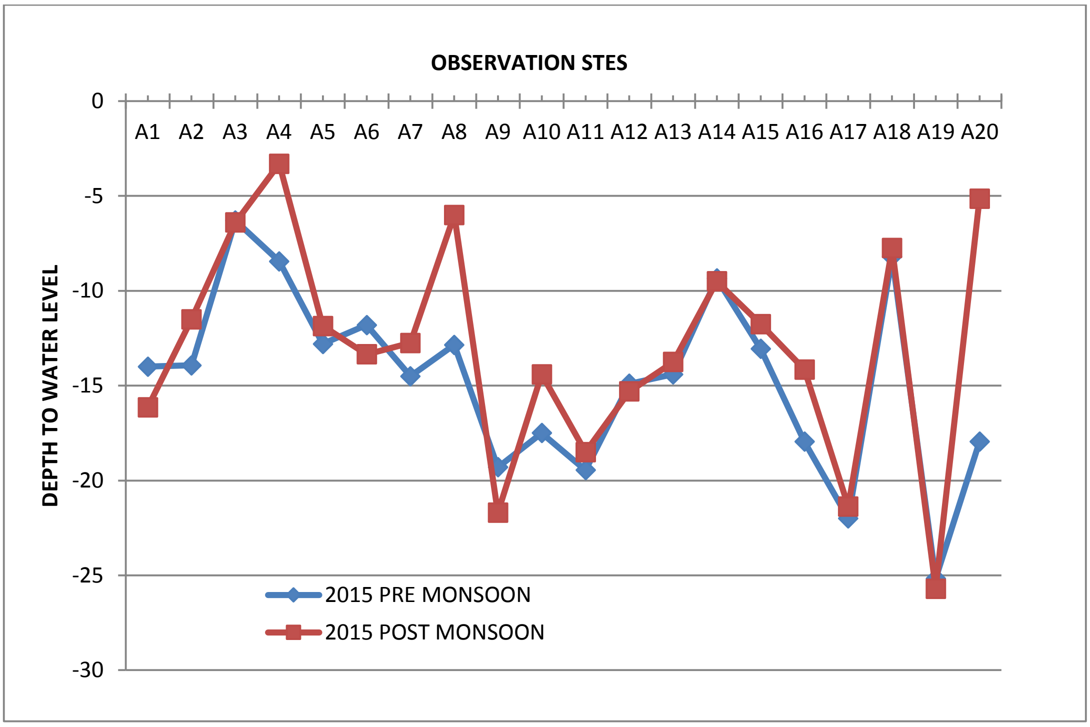

Figure 7: Hydrograph Showing Annual Water Level Fluctuations for Year 2015

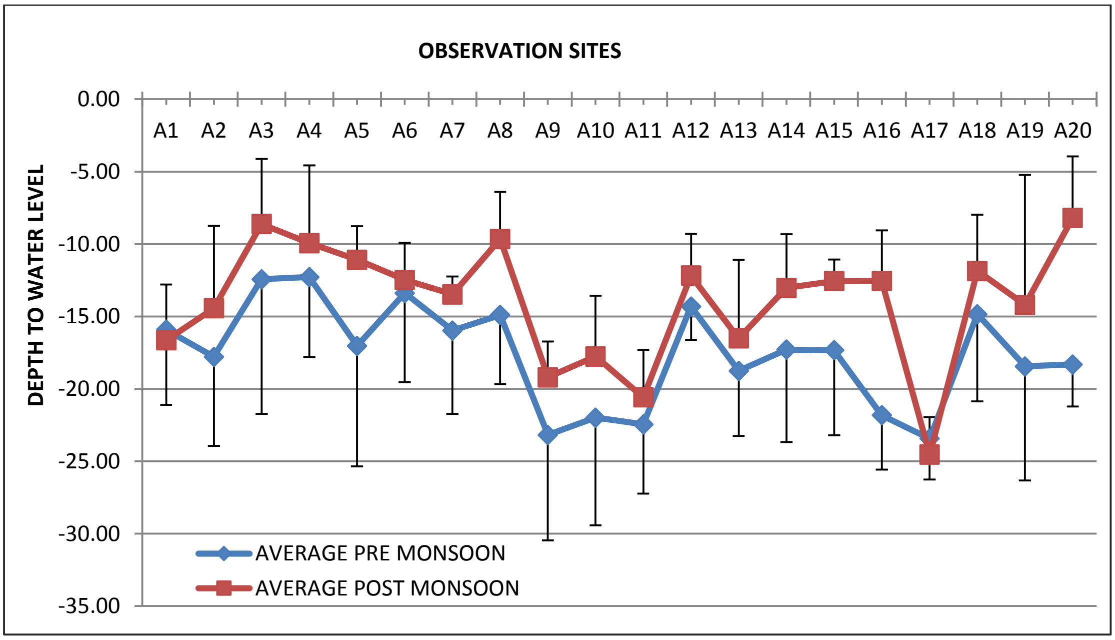

Figure 8: Hydrograph representing the Average Depth to Water Level Fluctuations From The Period Of 2013-2015. The values are expressed as mean ± Standard Deviation.

Through Fig.8, it can be inferred that Average Water Level Fluctuation for the period of 2013-2015 and the maximum and minimum deviation in the WTF corresponding to site A3 and A19 (post monsoon) and site A7 and A12 (pre monsoon),was ±9.28, ±8.96(post monsoon) and ±1.22 , ±2.29 (pre monsoon) respectively. It can be concluded from the above data that the changes in groundwater flow into or out of the study area, due to processes occurring in adjacent areas also generate water-level fluctuations.

7. LIMITATION

Overall, despite similar soil textures and land cover among the sites, it is difficult to estimate actual recharge occurring consistently across sites with variable water table depths encountered in the 20 toposequence. Further work is recommended to refine methods for estimating monthly and annual recharge using field monitoring data that would be applicable to all landscape positions. Implementing groundwater management and protection measures need quantitative appraisal of aquifer evolution and effects based on detailed multidisciplinary studies supported by reliable data (Custodio, 2002).

8. CONCLUSION

In Chandigarh, though the natural recharge of the aquifers is very less but water from the deeper aquifers is being pumped out. To ensure the long term sustainability of the water resources of the city, rain water harvesting system is recommended and care should be taken to avoid further contamination and degradation of the shallow aquifer system and overexploitation of groundwater from deeper aquifer.The population density of the city is rising and it is increasing pressure on water resources for its varied needs. Among the options, rain water harvesting (RWH) along with an artificial recharge stands out as the most workable solution. The harvested rainwater can be used by other people also since the aquifer is common to all. Thus we contribute to a social cause. A planned approach is hence needed in order to fully utilize the potential of rainwater to adequately meet our water requirements. Hence, an equal and positive thrust is needed in developing and encouraging both the types of water harvesting systems. The cost of implementation of these systems is undoubtedly very high and once it is implemented the benefits derived from it are lifelong. It can be concluded from the above findings that rainwater, if conserved and utilized using the rainwater harvesting technology, can be an effective tool of replenishing groundwater resources. An artificial recharge system should be made to recharge the water from the storm water drain, it will not only tackle the groundwater decline but also resolve the flooding problems in the field. This will really be beneficial if this is managed at a planetary level, so we will be in position to sustain well with the problem of water crisis.

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