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Water Resource Management by Minimizing Urban Wastewater and Adopting Sustainable Techniques

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Abstract: The available surface water resources are inadequate to meet all the water requirements for all purpose ultimately groundwater is intensively used for irrigation and industrial purposes, a variety of land and water based human activities are responsible for polluting this precious resource. Frequent changes in land use pattern bring more area under urbanization and changes have resulted in the expansion of the watershed total impervious area which reduces the infiltration and surface storage of precipitation, thus increasing the surface water runoff. Water shortage, quality degradation and increased storm-water drainage are the major problems being faced by urbanized cities like Chandigarh. Water resource management technique through rain water harvesting and artificially recharging to sub-surface scheme is adopted which deals with all aspects of water and wastewater management in the form of storm-water drainage and run-off from both paved and unpaved area with the objective of maximizing utilization of the limited resources. Around 54 structures are constructed in the study area so as to recharge the runoff generated from various catchment areas with recharging capacity of approx. 5400 cum of runoff generated in the study area. The attempt of this paper is a positive first step towards understanding the design versus operational evaluation of large water management systems to have proper understanding of technique adopted.
Keywords: runoff; recharge; sustainability; urbanization; water resource management.

I. INTRODUCTION

Water has been one of the most important natural resource for the substance of life on the earth. The available surface water resources are inadequate to meet all the water requirements for all purpose, so the demand of groundwater has increased over year. In countries like India, groundwater is intensively used for irrigation and industrial purposes, a variety of land and water based human activities are responsible for polluting this precious resource [1]. The assessment of quality and quantity of groundwater is essential for the optional utilization. Urbanization changes drastically the hydrologic cycle of natural areas; buildings, roads, sidewalks, and parking lots make the land surface impermeable to the infiltration of precipitation, thereby diminishing the natural recharge to the aquifers. In the present scenario, the population boom with enhanced pace of urbanization followed by industrialization has ensured that the groundwater abstraction has swayed the peak and the usage of surface water resources alone may not be enough to tide over this growing demand. In the last 10 years, much more attention has been paid to urban land use/land cover change because ecosystems in urban areas are strongly affected by human activities and have close relations with the life of almost half of the world's population [2]. The number of groundwater wells has increased from less than 1 lakh in 1960 to nearly 12 lakhs in 2002 [3].Scientists have already predicted that by 2025, nearly two billion people will be forced to live in areas with absolute water scarcity [4].

Chandigarh is famously known as first planned city of urban and independent India. Union Territory (U.T.) located at the foothills of the Siwaliks about 250 kms north of New Delhi. The city also has the distinction of being the joint capital of Punjab and Haryana states even though it does not form part of any of the two States. It lies between north latitudes 30^o 40' and 30^o 46' and east longitudes 76^o 42' and 76^o 51' and falls in Survey of India toposheet no. 53B/14. Punjab state borders the UT in the south and southwestern sides and Haryana state on eastern side. UT of Chandigarh has an area of 114 sq.km, out of which 36 sq.kmis rural and remaining 78 sq.km is urban.

Frequent changes in land use pattern bring more area under urbanization, developmental activities in peripheral zone and deforestation are leading to land degradation and deteriorating environmental quality in the Union Territory of Chandigarh. The hydrochemical analysis indicated groundwater quality variation with respect to aquifer dispositioning in urbanized watershed of Chandigarh where the shallow aquifers exhibited a strong degree of contamination through leaching and was more prone to pollution and the water was being tapped from deeper aquifer across the city and this resulted in decrease or fall in the piezometric head of the deeper aquifer [5].Urbanization is based on the economic change mainly and in particular the growth of secondary and tertiary occupation in urban areas [6]. With the high pace of social and economic development in world, the constant growth of population with increasing urbanization are leading to immense environmental degradation along with shortage of productive green lands and uncontaminated water. Urban pressure in watersheds involve denudation by removal of vegetation, alterations in land use due to construction of buildings, streets, re-routing of surface runoff by storm sewers and detention/retention basins. Such changes have resulted in the expansion of the watershed total impervious area which reduces the infiltration and surface storage of precipitation, thus increasing the surface water runoff [7].Movement of water i.e. runoff and wastewaters in urban environment which are reason of flooding in different systems and ultimately discharged treated partially in water body is shown below in fig.1 [8].

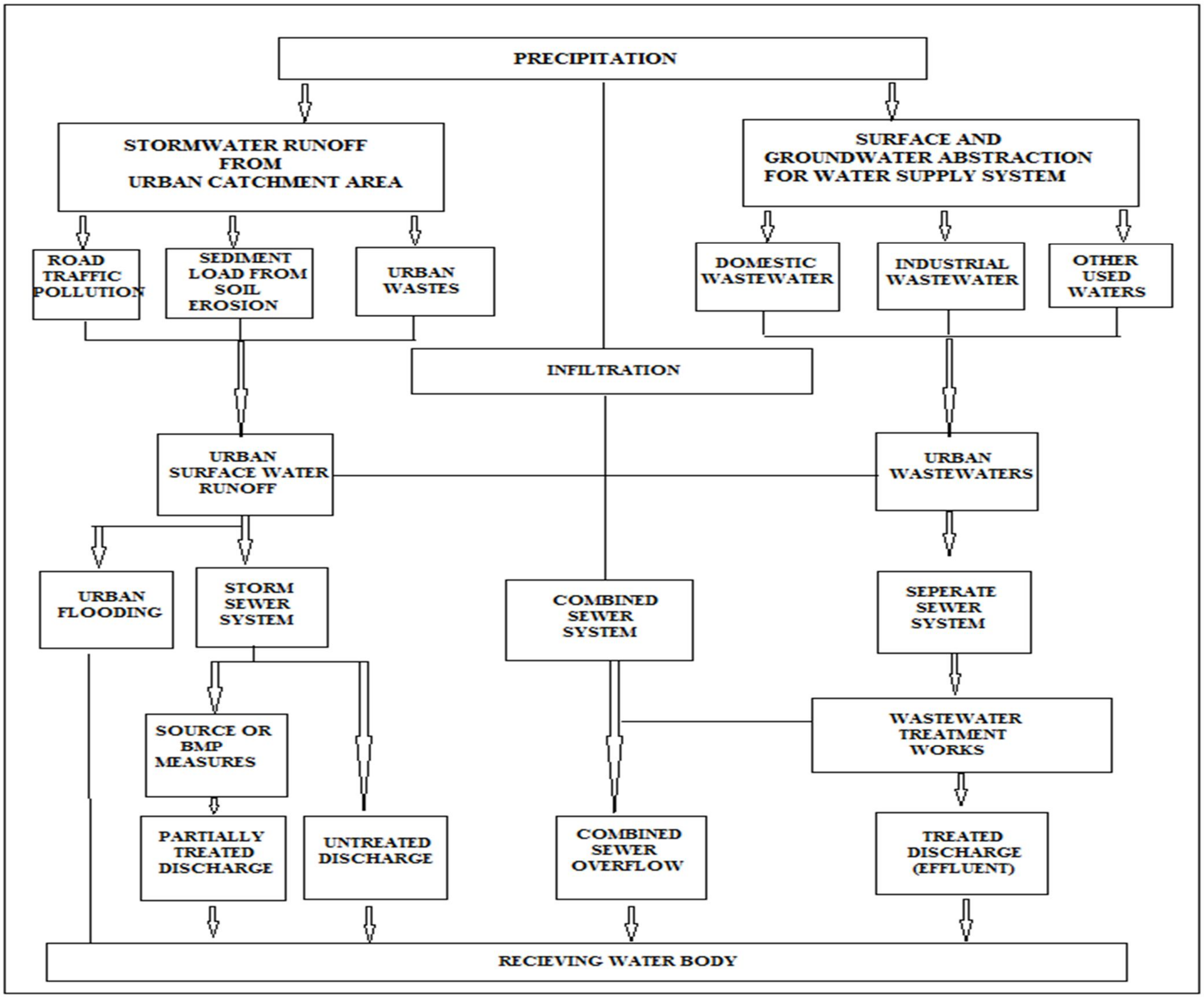

Fig.1 Movement of water in urban environment in different systems

Urban population growth, new urban consumption patterns, pollution of water bodies and inappropriate management of local resources are responsible for current water shortages along with the increasing dearth in rainfall [9].The major driving force affecting land in Union Territory is population. Demographic data indicates that between 1961 and 1971, the population increased by 144.59 %. According to 1981 census, it grew by another 75.55 %, followed by 42.16 % in 1991, 40.33 % in 2001 and 17.10 % in 2011(with the total population of 10,54,686 as against 5 lacs).This is followed by unplanned expansion of villages, growth of slums and unplanned development around peripheral zone. These have resulted in change in the land use pattern and degradation of surface and subsurface water regimes.

There are no large natural surface water bodies in Chandigarh though small ponds do exist in the rural areas. The water requirement of the city for drinking and domestic purposes is 493 MLD (Million liters per day) water, whereas available supply is only 363 MLD. Thus there is a shortage of about 130 MLD. A major part of water requirement of the city is met by canal water. In Chandigarh, use of private tube wells has been banned and tube wells tapping shallow aquifers are facing contamination problem. Water shortage is likely to get worsen in the coming years as the population is already more than double the planned capacity for the city. The demand of water for the other purposes such as industrial and commercial will also increase concurrently with the demand for domestic water demand. In the rapidly urbanizing world, issues relating to the availability, accessibility, and security of drinking water have emerged as major obstacle for sustainable development globally [10;11].

This paper outlines the measures taken to:

Sustain the depleting groundwater resource.

Augment the water supply by artificial recharge.

Protect the aquifer against pollution.

Nullify the effect of water logging in the research area.

Balance the problem of shallow and deeper aquifer facing problem of water level rise and lowering of piezometric head in the later.

Cut down the extraction charges of water from deeper aquifers due to installation of big pumping machines and usage of electricity to run them.

A. The Water Resource Management Scheme

For proper water resource management a demonstrative scheme on ‘Rain water harvesting and artificial recharge to groundwater covering the entire Campus of Punjab University, Sector- 14, Chandigarh’ was funded by the Ministry of Water Resources, Government of India through Central Ground Water Board. This demonstrative project aims to utilize the available run-off in the University Campus, which otherwise, goes to drains and squatters on the roads to augment the ground water resources for beneficial use. It would help in arresting the ground water levels and saving of energy for lifting of water from the aquifer lying deep beneath the surface. It will also help the sustainability to the existing tube well/ groundwater extraction structures. The scheme deals with all aspects of water and wastewater management in the form of storm-water drainage and run-off from both paved and unpaved area with the objective of maximizing utilization of the limited resources in an essentially closed system. Rainwater harvesting systems are becoming an integral part of the sustainable storm-water management ‘toolkit’[12].

B. Features of the Punjab University Water Resource Management Scheme are:

1) Carefully designed rainwater harvesting and artificial recharge structures where rainwater is abstracted economically from the surrounding area. An exploitation strategy has been developed to ensure sustainability of the resource by placing limits on abstraction areas and pumping rates.
2) A zone of transfer with very fine and asymmetric lithological features which ensure the transfer of natural and clean form of water to the aquifers from the surface to sub-surface.
3) Separate collection and channelization of rain water and surface runoff for recharge in different portions of aquifer. This allows the most beneficial use of storm-water which otherwise goes waste in drains.
4) Artificial recharge facilities which augment the natural recharge ensuring suitability of the groundwater supply. The higher quality storm water flows are diverted to recharge the aquifers which are close to depletion of groundwater.
5) Surface infiltration basin for the safe recharge of filtered storm-water drainage and water from roof tops. The recharge produces a subsurface hydraulic movement which ultimately increases the exploitable groundwater level up-gradient.

C. Management Strategy For Sustainable Resource Utiliation

Water conservation structures of Wagarwadi watershed are responsible for groundwater recharge, as rise of 0.5 to 2.5 m of the water table at different locations has been estimated [13] and conservation of local rainfall has reduced the dependence on imported water supplies in Bangalore City by storing in underground cisterns [14]. The strategy behind the Panjab University water resource Management Scheme at Chandigarh takes into consideration of both the water quantity which can be abstracted and the maintainance of groundwater quality particularly with regard to carbonate and bicarbonate ions and heavy metals, which is limiting factor in groundwater exploitation. The essence of the management strategy is:

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1) Separation of storm-water drainage and wastewater into components of different quality.
2) high quality peak storm flow is diverted from the lower quality base flow through filters.
3) domestic and wastewater from different departments are collected and treated separately from source.
4) Artificial recharge at strategic locations for
5) augmentation of fresh water supplies at different abstraction zones.
6) countering soil and another dust particle encroachments into recharge structures.
7) Aquifer protection involving
a) a comprehensive monitoring programme for the collection of water quality data.
b) regular evaluation and investigation of the threat posed by anthropogenic activities to recharge structures.
c) an environmental impact assesment for recharge well structures and the design of an environmental management system for the recharge zone and catchment areas.

The main recharge and abstraction areas form part of a specially secured and managed areas. An integrated conservation management plan incorporating eradication of alien vegetation and protection of less water accumulating plants which provides for beneficial utiliation of the area and aquifer protection. A public information and involvement programme is also under way to ensure full cooperation for maximum source protection.

II. RESULTS

In recharge well water from the surface is admitted to fresh water aquifers. The flow in the recharge well is the reverse of a pumping well, but its construction may or may not be the same (figure.2). The recharge head coupled with gravel strata within this region creates ideal conditions for recharge to groundwater. The normal annual rainfall of the area is 1074 mm and average rainfall is 866 mm. 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. For the present study runoff coefficient for roof top, paved area and green area has been considered 80%, 50% and 20% respectively.

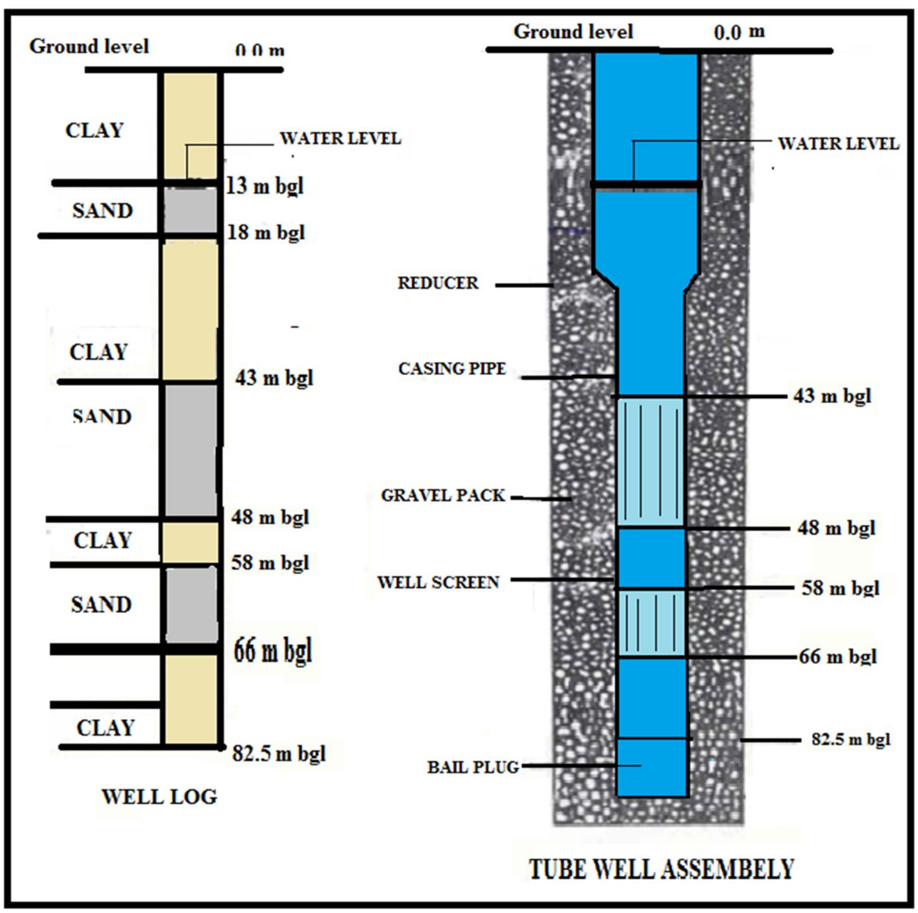

Fig. 2 Structure of Recharge wells Constructed in Punjab University Campus

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A. Evaluation Of Implemented Recharge Structures

The investigation of Recharge system is very much important if the Artificial Recharge structures are constructed as per the prevailing environmental conditions. This plays a vital role in assessing the possible recharge that would take place in the study area. In connection with that, the implemented system must be checked in following three different criteria. They are,

Interconnection of Recharge structures with the Aquifer Adequacy of Recharge system Recharging capacity of Recharge system adopted The information of the implemented artificial recharge system requires roof area/paved area/green area available, type of structure adopted with its size, soil type, rainfall intensity and aquifer parameters. Out of three criteria, firstly, the inter connection of recharge structure with the aquifer was assessed. The data needed for this is depth of recharge structure which was obtained from the on-site field visits while the construction of these structures. The interconnection of RWH is checked by comparing the depth of these structures and depth to aquifer. Data on depth to aquifer was also obtained in form of litho logs, in addition to electrical resistivity survey conducted in the study area. If depth of these recharge wells is greater than depth to aquifer then it is termed as "penetrated". If it is equal, then it is termed as "partially penetrated" and lesser case will be termed as "Not penetrated".

Adopting a scientifically based artificial recharge programme has ensured that the minimum volume of useable water is lost from the system only, and also the natural quality of the groundwater has been maintained .

Intensity of Rainfall	30 mm / hour
Rainfall Runoff generated from the roof top	3344 cum
Rainfall Runoff generated from the road/paved area	1196 cum
Rainfall Runoff generated from the grounds/lawn area	927 cum
Total run off generated	5400 cum

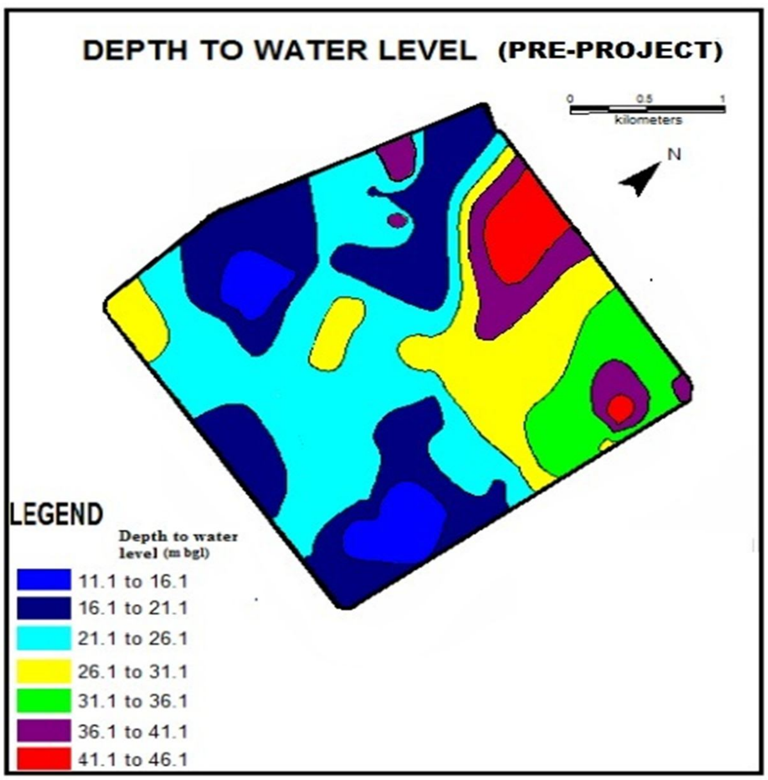

Fig. 3 Depth to Groundwater Level (Pre- Project)

Water levels showed varied response in the study area as shown in figure 3,where northern part of the study area is showing deeper water levels whereas shallow water levels were observed in southern parts. As per the study conducted, there is constant decline in water levels and to a certain extent, recharging of aquifers can compensate for the overdraft.

Around 54 structures are constructed in the study area so as to recharge the runoff generated from various catchment areas. Each recharge structure is supposed to store 101 cum of water approimately. Recharging capacity of Recharge system estimated is approx. 5400 cum of run-off generated in the study area.

III. CONCLUSION

Artificial recharge to groundwater by consuming rain water is a basic concept for the sustainable management of dynamic freshwater resources. A comprehensive study of its impact will throw more light on Artificial Recharge scenario and its future implication. Further research is required to fill this knowledge gap and future studies of RWH systems should aim to address these issues. Consequently, this paper aimed to discuss the methodology adopted to assess the impact of RWH and AR technique for an urban aquifer system and can help decision-makers to adopt for vast urbanized area like Chandigarh City. To ensure long-term sustainability of water resources in any area rainwater harvesting along with direct recharge to groundwater can be a simple and effective solution. This project aims to utilize the available run-off in the University Campus, which otherwise, goes to drains and squatters on the roads to augment the ground water resources for beneficial use. It will also help the sustainability to the existing tube well/ groundwater extraction structures. It is necessary to mention that success of such big budgeted projects and their real performance rely mainly on their maintenance which is must for proper functioning of recharge system.

IV. ACKNOWLEDGEMENT

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