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Rooftop Rainwater Harvesting for Recharging Shallow Groundwater

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Abstract

Water management is very critical for the growth and development of any economy, more so in a developing countries like India. However, resource is now under stress, because of excessive groundwater abstraction in the course of socioeconomic development and meeting increasing needs of growing population. Therefore, we need to conserve this precious resource while benefiting from it. The prime objective of the study is to identify the potentiality of rainwater for recharging shallow Groundwater in the Jawaharlal Nehru Technological University Hyderabad, Kukatpally campus. Normal annual rainfall in the study area is 821mm with unutilized non-committed surplus monsoon runoff. Artificial recharge of ground water through rooftop rainwater harvesting was done by constructing three recharge structures each with a capacity of 1,00,000 litres at different places in the study area with two recharge shafts for injecting rainwater into unconfined and confined aquifer system. Three measuring bore wells (piezometers) with a diameter of 6" were dug upto a depth of 30 m near the recharge structures for impact assessment studies. Water levels measured in the three bore wells on daily basis during the monsoon period were found to be 86.3, 90.2, 38.3 ft on 15th June 2012 before rainwater recharge and the corresponding water levels have been improved to 50.7, 56.5, 10.3 ft respectively on 1st October 2012 due to recharge of rainwater. A corresponding rise of 35.6, 33.7, 28.0 ft in groundwater levels has been registered indicating significant improvement of groundwater levels. Rainfall received during the years 2012 and 2013 is 774 and 1104 mm respectively. Total amount of surplus rainwater received during 2012 is 7,11,174, 8,93,849 and 4,74,814 liters recharged near Near Library, Near Girls Hostel and Near New IST respectively. Total amount of surplus rainwater received during 2013 is 10,13,563, 12,73,911 and 6,76,703 liters recharged near Near Library, Near Girls Hostel and Near New IST respectively. A total rainfall of 774 and 1104 mm has been found to be recorded and a total quantity of 50,44,013 liters of groundwater has been found to be recharged during the years 2012 and 2013 years respectively.

Keywords: Rainwater; Recharge; Groundwater; Water-level; Fluctuation; Volume augmentation

Introduction

Groundwater has now become a major natural resource contributing the water supply system in Kathmandu Valley and people have been using groundwater since ages through dug wells and stone spouts. Usually groundwater gets recharged during rainfall period. Due to urbanization, surface infiltration has been vastly reduced while consumption of groundwater is ever rising. At present day context, this rate must have been exceeded at for more rates. Therefore, we need to consider how we can conserve this precious resource while taking full advantage of it for the development purposes. Groundwater is a reliable resource for drinking and production both in terms of quantity and quality. However, the resource is now under severe stress in most parts of the country, particularly in developing countries because of the excessive groundwater abstraction in the course of socioeconomic development. The consequences of these over exploitation of groundwater are either irreversible in nature or require extended periods to abate. Therefore, we need to consider how we can conserve this precious resource while taking full advantage of it for the development purposes. Today, only 2.5 per cent of the entire world's water is fresh, which is fit for human consumption, agriculture and industry. In several parts of the world, however, water is being used at a much faster rate than can be refilled by rainfall. In 2025, the per capita water availability in India will be reduced to 1500 cubic meters from 5000 in 1950. The United Nations warns that this shortage of freshwater could be the most serious obstacle to producing enough food for a growing world population, reducing poverty and protecting the environment. Hence the water scarcity is going to be a critical problem if it is not treated now in its peanut stage. The only one solution is rainwater harvesting in the urban as well in rural areas. Composed in a comprehensive system, the basic three components of rainwater harvesting; a collection surface, guttering and a water store, yields several benefits. According to Krishna [1], the most important benefit of rainwater harvesting is that the water is totally free, the only cost is for collection and use. Also the end use of harvested water is located close to the source, which eliminates the need for complex and costly distribution systems. When groundwater is unacceptable or unavailable, rain water provides a water source, or it can supplement limited groundwater supplies. A superior solution for landscape irrigation, rainwater harvesting reduces flow to storm water drains and also reduces non-point source pollution while reducing the consumers' utility bills. Having lower hardness than groundwater, rainwater helps prevent scale on appliances and extends their use [2].

Rain water harvesting (RWH) primarily consists of the collection, storage and sub sequent use of capture drain water as either the principal or as a supplementary source of water. Both potable and non-potable applications are possible [3]. Examples exist of systems that provide water for domestic, commercial, institutional and industrial purposes as well as agriculture, livestock, groundwater recharge, flood control process water and as an emergency supply for firefighting [4]. The concept of RWH is both simple and ancient and systems can vary from small and basic, such as the attachment of a water butt to rain water down spout to large and complex, such as those that collect water from many hectares and serve large numbers of people [5]. Before the latter half of the twentieth century, RWH systems were used predominantly

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in area slacking alternative forms of water supply, such as coral islands [1] and remote, a rid locations lacking suitable surface or ground water resources [6]. Gould et al [4] provide a detailed history of rainwater harvesting systems. The authors state that, while the exact origin of RWH has not been determined, the oldest known examples date back several thousand years and are associated with the early civilization so the Middle East and Asia.

In India, evidence has been found of simple stone-rubble structures for impounding water that date back to the third millennium BC [7]. During the twentieth century the use of rainwater harvesting techniques declined around the world, partly due to the provision of large, centralized water supply schemes such as dam building projects, ground water development and piped distribution systems. However, in the last few decades there has been an increasing interest in the use of harvested water [4] with an estimated 100,000,000 people worldwide currently utilizing a rainwater system of some description. Today due to rising population & economical growth rate, demands for the surface water is increasing exponentially. Rainwater harvesting is seems to be a perfect replacement for surface & ground water as later is concerned with the rising cost as well as ecological problems. Thus, rainwater harvesting is a cost effective and relatively lesser complex way of managing our limited resources ensuring sustained long-term supply of water to the community. In order to fight with the water scarcity, many

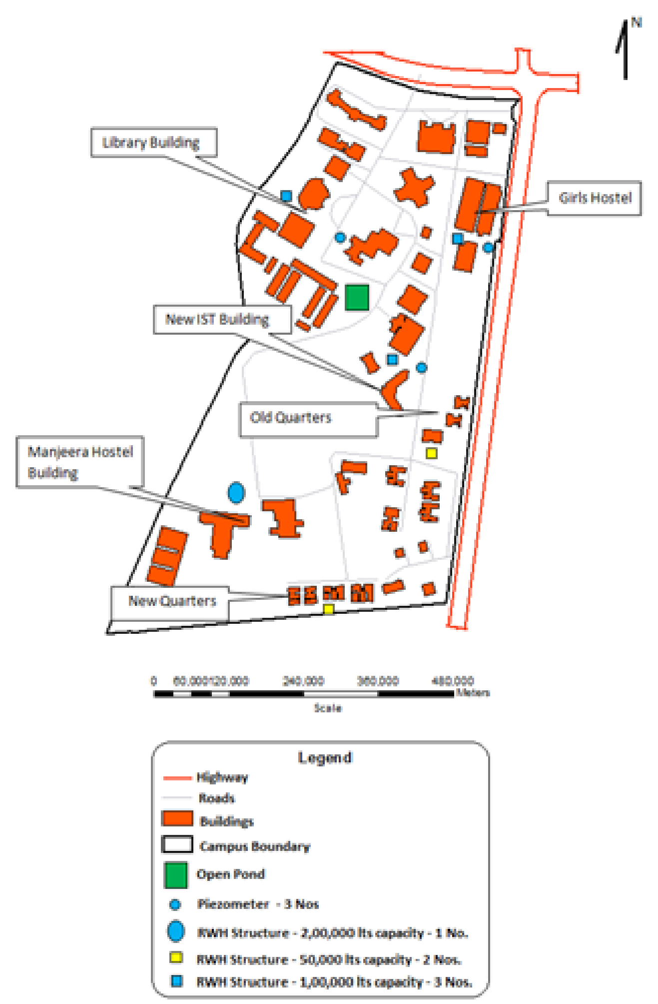

Figure 1: Location of Rainwater harvesting structures in the JNTUH campus.

countries started harvesting rain. Major players are Germany (Biggest harvesting system in Germany is at Frankfurt Airport, collecting water from roofs of the new terminal which has an large catchment area of 26,800 m^2), Singapore (as average annual rainfall of Singapore is 2400 mm, which is very high and best suited for rainwater harvesting application), Tokyo (as RWH system reserves water which can be utilized for emergency water demands for seismic disaster).

Reddy et al., [8] conducted study at Chevella watershed in Rangareddy district of Andhra Pradesh and Mittemari watershed in Kolar district of Karnataka, the income from all sources were higher by Rs. 463/household at Chevella and Rs.1046/household at Mittemari watershed area, compared to non watershed area. Singh et al. [9] examined the impact of watershed development programme on groundwater table in Bundelkhand region of Uttar Pradesh and revealed that the average annual increase in the water table was 3.7 meters, varying from 3 meters in rainy season to 6.5 meters in summer season. Singh et al. [9] assessed the impact of watershed programmed on rain fed agriculture in Jhansi district of Uttar Pradesh and indicated that the underground water table in the area showed a significant increase, the average annual increase in the water table being 3.7 meters. A shift in the area from pulses to cereals and from cereals to pulses was observed in Rabi and Kharif seasons, respectively. Bisrat [10] in his study on economic analysis of watershed treatment through groundwater recharge of Basavapura micro-watershed in Kolar district of Karnataka revealed that average yield of bore well increased from 1150 gallons per hour (GPH) to 1426 GPH that is by 24 per cent due to construction of water harvesting structures. Naidu (2001) in his study on Vanjuvankal watershed of Andhra Pradesh noticed that, because of water harvesting structures and percolation ponds the ground water level in watershed area showed a rise by 2 to 3 meters. Gitte et al., [11] conducted a study on the water conservation practices, water table fluctuations and ground water recharge in watershed areas. The study revealed that water conservation measures were found to be effective for rising of water table in observation wells, located in the middle and lower reach of the watershed. The prime objective of the study is to identify the potentiality of rainwater for recharging shallow Groundwater in the Jawaharlal Nehru Technological University Hyderabad, Kukatpally campus and to augment groundwater in the campus.

Study Area

Hyderabad city is situated in the Krishna basin and the river Musi, which is a tributary of river Krishna, passes through the city and bifurcates it into Northern and Southern Hyderabad. The Study region covers an area of 179 km^2 and is situated between 78°22’30” & 78°32’30” East Longitude & between 17°18’30” & 17°28’30” North latitude. The elevation is varying from 487 Meters to 610 meters above mean sea level. The region of interest for site selection includes all area, which falls within the buffer distance of 50km from the center of Hyderabad city. This area comprises of Hyderabad Urban Development Area, parts of Rangareddy, Nalgonda, Medak and Mahabubnagar districts of Andhra Pradesh. It is covered by toposheet No.56K on 1:2,50,000 scale. The study area stands on gray and pink granites as foundation materials, which is suitable for building construction. Meteorological data has been recording in the study area. The normal annual and seasonal rainfall recorded is 754mm. The southeast monsoon contributes 81% of the annual rainfall, while the north east monsoon contributes 81% of the annual rainfall. Variation in annual rainfall decreases in the trend for the study area. However, the pattern appears to be more inconsistent over the years. The minimum and maximum temperature recorded. December to January is the coldest period with

Sl. No	Title of the structure	Location	No. of Recharge shafts
1	Roof top rainwater harvesting structure with a capacity of 1,00,000 liters along with two bore well for recharge.	Behind EEE Department, College of Engineering, JNTUH	2
2	Roof top rainwater harvesting structure with a capacity of 1,00,000 liters along with two bore well for recharge.	Between Girls hostel compound wall and new incubator building	2
3	Roof top rainwater harvesting structure with a capacity of 1,00,000 liters along with two bore well for recharge.	Behind new JNTUHIST Building, JNTUH	2

Table 1: Details of structure, location and No .of Recharge shafts.

S.NO	LOCATION	NORTH	EAST.
1	Near Library	17°29'41.3"	78°23'29.9"
2	Near New IST	17°29'33.6"	78°23'32.3"
3	Near Girls Hostel	17°29'39.5"	78°23'37.1"

Table 2: Piezometers in JNTUH campus.

1	Capacity of Tank	1.00 lakh liters
2	Depth of Recharge well-I	30 mts
3	Depth of recharge well-II	60 mts
4	Rooftop area	681 sq.mts
5	Maximum rainwater can be harvested in a year	4.50 lakh liters
6	Size of the tank	5.0 x 6.0 x 3.3 m
7	PVC pipe line used	4" and 6" diameter

Table 3: Design specifications of the structure located near new IST building along with two recharge shafts.

1	Capacity of Tank	1.00 lakh liters
2	Depth of Recharge well-I	30 mts
3	Depth of recharge well-II	60 mts
4	Rooftop area	1282 sq.mts
5	Maximum rainwater can be harvested in a year	8.30 lakh liters
6	Size of the tank	11.0 x 5.0 x 2.0 m
7	PVC pipe line used	4" and 6" diameter

Table 4: Design specifications of the structure located between Girls hostel compound wall and new incubator building along with two recharge shafts.

mean daily maximum temperature of about 29°C and the mean daily minimum 17°C. There after the temperature rises rather rapidly in the initial period and steadily at later period till May, which is the hottest month with mean daily maximum temperature touches 39°C. However, temperature increases slightly in Sep and Oct after which both day and night temperatures begin to drop. The monthly mean maximum temperature is 32°C and minimum temperature is 21°C.

Structures Constructed

With the above objectives and based on the available roof top area the following rain water harvesting structures were constructed in JNTU campus. The location of building and location of the rainwater harvesting structures in the campus has shown is Figure 1. The description of the structure, locations and number of recharge shafts are listed in the following Table 1. The details about the piezometers installed in the study area were given in Table 2.

Recharge pit with a capacity 1,00,000 liters near new IST building along with two recharge shafts

Rooftop Collection from New IST Building and Computer Science Building with cumulative area of 681 m^2 is under consideration of the project. The rainwater falling on these buildings will be filtered near the entry then conveyed through PVC pipeline conveyance system from rooftop to sump located between new IST building and computer science building. Further, the collected water is filter again and has been recharged through recharge bore wells drilled up to 30mts and 60 mts to feed unconfined and confined aquifers. Initially rainwater mount is created in the piezometer then slowly mount disappears, the effect of injection has been measuring in the piezometer located 50 meters on downstream side. The design specification for the structure is listed in Table 3.

Recharge pit with a capacity 1,00,000 liters located between Girls hostel compound wall and new incubator building along with two recharge shafts

Rooftop Collection from New IST Building and Computer Science Building with cumulative area of 1282 m^2 is under consideration of the project. The rainwater falling on these buildings will be filtered near the entry then conveyed through PVC pipeline conveyance system from rooftop to sump located between Girls hostel building and New Incubator building. Further, the collected water is filter again and has been recharged through recharge bore wells drilled up to 30mts and 60 mts to feed unconfined and confined aquifers. Initially rainwater mount is created in the piezometer then slowly mount disappears, the effect of injection has been measuring in the piezometer located 50 meters on downstream side. The design specification for the structure is listed in Table 4.

Recharge pit with a capacity 1,00,000 liters located Behind EEE Department, College of Engineering, JNTUH along with two recharge shafts

Rooftop Collection from New IST Building and Computer Science Building with cumulative area of 1020 m^2 is under consideration of the project. The rainwater falling on these buildings will be filtered near the entry then conveyed through PVC pipeline conveyance system from rooftop to sump located between Civil Engineering building and

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1	Capacity of Tank	1.00 lakh liters
2	Depth of Recharge well-I	30 mts
3	Depth of recharge well-II	60 mts
4	Rooftop area	1020 sq.mts
5	Maximum rainwater can be harvested in a year	6.60 lakh liters
6	Size of the tank	5.0 x 6.0 x 3.3 m
7	PVC pipe line used	4'' and 6'' diameter

Table 5: Design specifications of the structure located between Girls hostel compound wall and new incubator building along with two recharge shafts.

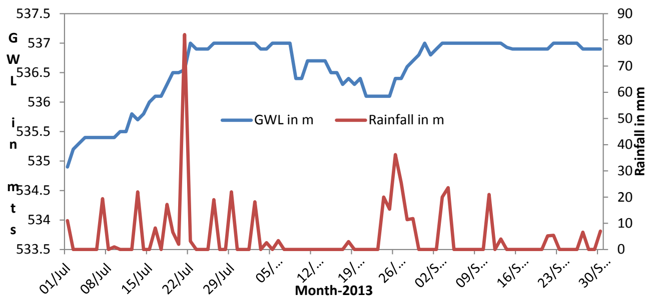

Figure 2: Variation of daily groundwater level and rainfall for the months of July to September 2012 for the piezometer located near Girls hostel in the campus.

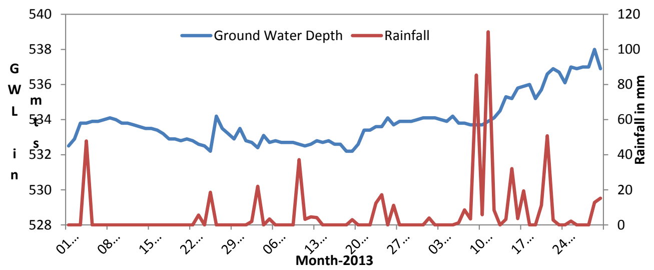

Figure 3: Variation of daily groundwater level and rainfall for the months of April to July 2013 for the piezometer located near Girls hostel in the campus.

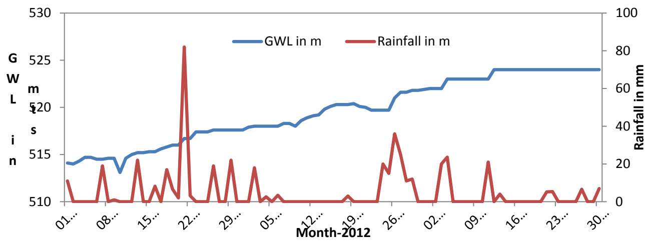

Figure 4: Variation of daily groundwater level and rainfall for the months of July to September 2012 for the piezometer located near new IST building in the campus.

Library building. Further, the collected water is filter again and has been recharged through recharge bore wells drilled up to 30mts and 60 mts to feed unconfined and confined aquifers. Initially rainwater mount is created in the piezometer then slowly mount disappears, the effect of injection has been measuring in the piezometer located 50 meters on downstream side. The design specification for the structure is listed in Table 5.

Results and Discussion

Entire campus was surveyed and three watershed boundaries were delineated using geomatic techniques for piezometer construction in each watershed using remote sensing, global positioning and GIS techniques. Influencing area under each piezometer was also established using geomatic techniques. Surface runoff is also estimated for further calculation of recharge. Every day water levels has been recording in all three piezometers.

Impact on groundwater levels due to recharge of rainwater

Three piezometers were drilled at 30 meters depth and well log also prepared. Daily groundwater levels with respect to mean seal level have been measuring using metal tape (manually). Daily ground water levels have been measuring since 01-07-2012. Measured ground water levels were plotted for each piezometer with respect to rainfall for the years 2012 and 2013 and the same has been depicted in the figures.

Piezometer located near Girls Hostel: Impact for the year 2012 is analyzed and variation of daily groundwater level and rainfall for the months of July to September 2012 for the piezometer located near Girls hostel in the campus is depicted in Figure 2.

- Lowest ground water level 537.0 msl observed on 22-07-2012
- Maximum ground water level 534.9 msl observed 01-07-2012
- Static water level rise is around 2.1 m due to recharge of rainwater in this watershed.

Piezometer located near Girls Hostel: Impact for the year 2013 is analyzed and variation of daily groundwater level and rainfall for the months of April to July 2013 for the piezometer located near Girls hostel in the campus is depicted in Figure 3.

- Lowest ground water level 538.0 msl observed on 26-07-2013
- Maximum ground water level 532.2 msl observed 25-04-2013
- Static water level rise is around 5.8 m due to recharge of rainwater in this watershed.

Piezometer located near IST admin building: Impact for the year 2012 is analyzed and variation of daily groundwater level and rainfall for the months of July to September 2012 for the piezometer located near new IST building in the campus is depicted in Figure 4.

- Lowest ground water level 524.0 msl observed on 09-12-2012
- Maximum ground water level 513.1 msl observed 07-10-2012
- Static water level rise is around 10.9 m due to recharge of rainwater in this watershed.

Piezometer located near IST admin building: Impact for the year 2013 is analyzed and variation of daily groundwater level and rainfall for the months of April to June 2013 for the piezometer located near new IST building in the campus is depicted in Figure 5.

- Lowest ground water level 516.1 msl observed on 29-06-2013
- Maximum ground water level 512.0 msl observed 25-04-2013

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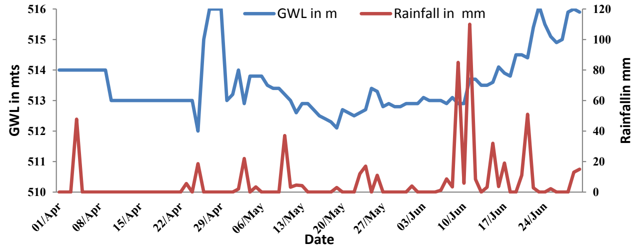

Figure 5: Variation of daily groundwater level and rainfall for the months of April to June 2013 for the piezometer located near new IST building in the campus.

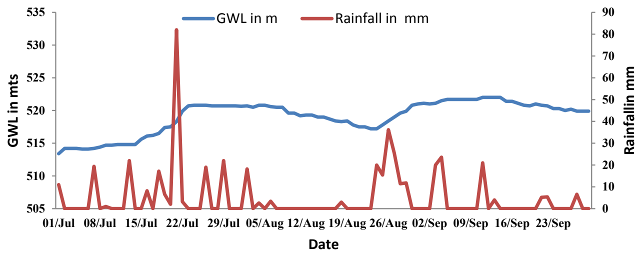

Figure 6: Variation of daily groundwater level and rainfall for the months of July to September 2012 for the piezometer located behind library building in the campus.

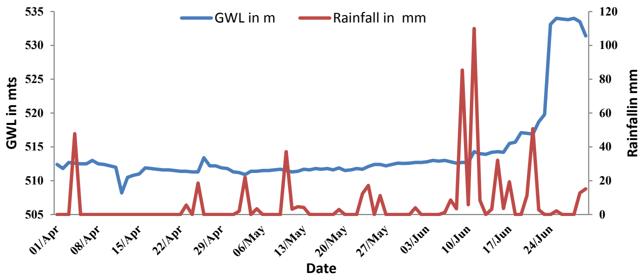

Figure 7: Variation of daily groundwater level and rainfall for the months of April to June 2013 for the piezometer located near behind library building in the campus.

- Static water level rise is around 4.1 m due to recharge of rainwater in this watershed.

Piezometer located behind library: Impact for the year 2012 is analyzed and variation of daily groundwater level and rainfall for the months of July to September 2012 for the piezometer located behind library building in the campus is depicted in Figure 6.

- Lowest ground water level 513.4 msl observed on 01-07-2012
- Maximum ground water level 522.0 msl observed 14-09-2012
- Static water level rise is around 8.6 m due to recharge of rainwater in this watershed.

Piezometer located behind library: Impact for the year 2013 is analyzed and variation of daily groundwater level and rainfall for the months of April to June 2013 for the piezometer located near behind library building in the campus is depicted in Figure 7.

- Lowest ground water level 508.2 msl observed on 12-04-2013
- Maximum ground water level 534.0 msl observed 22-07-2013 due to heavy rainfall
- Static water level rise is around 25.8 m due to recharge of rainwater in this watershed.

Amount of rainwater harvested and recharged

Three structures were constructed with a capacity of 1,00,000 liters at different locations for collection, filtration and injection of rainwater into unconfined and confined aquifers. The total water harvested injected is 20,79,837 and 29,64,177 liters in the year 2012 and 2013 respectively. Total rainwater harvested is 50,44,013 liters in the study area. The month wise rainwater amount harvested is given in the Table 6.

Conclusion

Demand on water resources has increase day by day due to the population growth and expansion in urbanization, industrialization and irrigated agricultural. Adopting the concept of sustainability and conservation of water resources can help to cope with the global water shortage. Rainwater harvesting system is one of the concepts that can be implemented to meet the water shortage problem. The quantity and quality of rainwater collected is different from place to place depending on the weather, geographic location, activity in the area and storage tank. Furthermore, rainwater has a lot of potential as an alternative water resource for the future because of its high quality. The delineated study area is taken from Google map. Remote sensing, watershed

Sl. N	Month	Rainfall (mm)		Rainwater recharged in liters					
				Near Library		Near Girls Hostel		Near New IST	
		2012	2013	2012	2013	2012	2013	2012	2013
1	Apr	0	72	0	66096	0	83073.6	0	44128.8
2	May	0	14	0	12852	0	16153.0	0	8580.6
3	Jun	200.	120.4	183691.8	110527.2	230875.4	138918	122641.3	73793.16
4	Jul	193.2	380.1	177357.6	348931.8	222914.2	438559	118412.3	232963.3
5	Aug	170	160.6	156060	147430.8	196146	185300	104193	98431.74
6	Sep	94.8	170.2	87026.4	156243.6	109380.2	196377	58102.92	104315.6
7	Oct	61.6	168.8	56548.8	154958.4	71074.08	194761	37754.64	103457.5
8	Nov	55	18	50490	16524	63459	20768.	33709.5	11032.2
9	Dec	0	0	0	0	0		0	0
Total in liters		774.	1104	711174	1013563.	893848.9	1273911	474813.6	676702.9
Total in cu. mts		0.77	1.10	711.174	1013.56	893.848	1273.9	474.816	676.709

Table 6: Month wise rainfall, rainwater harvested in liters near library, near girls hostel and near new IST building.

modeling and GIS techniques are modern research tools that proved to be effective in mapping, investigation and modeling. These tools were used to determine the potential sites or areas for Rain Water Harvesting (RWH) in JNTUH Hyderabad. Water levels measured in the three bore wells on daily basis during the monsoon period were found to be 22.6, 23.6, 10.1 m on 15th June 2012, and the corresponding water levels have been improved to 14.63, 16.46, 3.35 m respectively on 1st October 2012. A corresponding rise of 7.97, 7.14, 6.75 m in groundwater levels has been registered indicating significant improvement of groundwater levels.

- Suitable ten Rain water harvesting structures constructed in the campus to take care of rooftop rainwater.
- Total 12,000m^2 roof top area covered under this project. Ten building roof tops were covered under this project.
- Total 11 bore wells / recharge shafts were drilled in the campus.
- Total 50,44,013 liters of rain water was harvested during the years 2012 and 2013.
- Ten meter groundwater depth (static) increased due to artificial recharge of rainwater.
- Further, groundwater quality also improved.

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