Design of Rainwater Harvesting System in FIT Campus

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Abstract—Water is the prime product of the forest and it is the basic human need which is felt more acutely in the drought condition being faced by the country. Even the basic need of two and half liters of water per day for drinking purpose ,has become difficult to meet .The other effect of drought is loss of agriculture, fodder, water for cattle and migration of people and cattle from the area in search of water. As we all know there is increasing trends towards construction of building for residential and non residential purpose in urban areas and making the open area paving of area or parking etc. This trend decreased drastically infiltration of rain water into the sub soil and recharging of ground water was diminished due to over development which has depleted the aquifer. Hence water conservation had become need of the time. Rain water harvesting is a way to capture the rainwater at the time of downpour, store that water above the ground or charge the underground water and use it later. As the ground water resources are depleting, the rain water harvesting is the only way to solve the water problem. Rainwater harvesting will not only be helpful to meet the demand of water supply but also be helpful to improve the quantity and quality of water.

Keywords—Rainwater,WaterQuality,Population, Runoff,Harvesting,Rooftop.

I. INTRODUCTION

In most urban areas, population is increasing rapidly and the issue of supplying adequate water to meet societal needs and to ensure equity in access to water is one of the most urgent and significant challenges faced by decision-makers. With respect to the physical alternatives to fulfill sustainable management of freshwater, there are two solutions finding alternate or additional water resources using conventional centralized approaches or better utilizing the limited amount of water resources available in a more efficient way. To date, much attention has been given to the first option and only limited attention has been given to optimizing water management systems. Among the various alternative technologies to augment freshwater resources, rainwater harvesting and utilization is a decentralized, environmentally sound solution, which can avoid many environmental problems often caused in conventional large-scale projects using centralized approaches. Rainwater harvesting is a process of direct collection of precipitation falling on the roof or on the ground for productive purposes (like agricultural and human use related to water). Because the runoff water causes erosion, so it is harvested and utilized and considered as a rudimentary form of irrigation. RH is usually treated as an umbrella which describes the whole methods of collection and runoff forms such as rooftop runoff, overland flow, stream flow etc. from rainfall. From the past few years water harvesting (WH) has become essential because the surface water is inadequate to meet the growing demand of human beings..

II. INDIAN SCENARIO OF RAINWATER HARVESTING

A. Studies carried in India

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.

B. *Studies carried Globally*

Today due to rising population & economic 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 countries started harvesting rain.

III. Rainwater Harvesting System and Components

Rainwater Harvesting is a simple technique of catching and holding rainwater where its falls. Either, we can store it in tanks or we can use it to recharge groundwater depending upon the situation. A rainwater harvesting system comprises of components for - transporting rainwater through pipes or drains, filtration, and tanks for storage of harvested water. The common components of a rainwater harvesting system are

A. Catchments: The surface which directly receives the rainfall and provides water to the system is called catchment area. A roof made of reinforced cement concrete (RCC), galvanized iron or corrugated sheets can also be used for water harvesting.

B. Coarse Mesh: It prevents the passage of debris, provided in the roof.

C. Gutters: Channels which surrounds edge of a sloping roof to collect and transport rainwater to the storage tank. Gutters can be semi-circular or rectangular and mostly made locally from plain galvanized iron sheet.

D. Conduits: Conduits are pipelines or drains that carry rainwater from the catchment or rooftop area to the harvesting system. Commonly available conduits are made up of material like polyvinyl chloride (PVC) or galvanized iron (GI).

E. First Flushing: A first flush device is a valve which ensures flushing out of first spell of rain away from the storage tank that carries a relatively larger amount of pollutants from the air and catchment surface.

F. Filters: The filter is used to remove suspended pollutants from rainwater collected from rooftop water. The Various types of filters generally used for commercial purpose are Charcoal water filter, Sand filters, Horizontal roughing filter and slow sand filter.

G. Storage Facility: There are various options available for the construction of these tanks with respect to the shape, size, material of construction and the position of tank and they are Cylindrical, square and rectangular shape and Material of construction are Reinforced cement concrete, masonry, Ferro cement.

H. Recharge Structure: Rainwater Harvested can also be used for charging the groundwater aquifers through suitable structures like dug wells, bore wells, recharge trenches and recharge pits. Various recharge structures are possible, some which promote the percolation of water through soil strata at shallower depth (e.g., recharge trenches, permeable pavements) whereas others conduct water to greater depths from where it joins the groundwater (e.g. recharge wells). At many locations, existing structures like wells, pits and tanks can be modified as recharge structures, eliminating the need to construct any fresh structures. Some of the few commonly used recharging methods are recharging of dug wells and abandoned tube wells, Settlement tank, Recharging of service tube wells, Recharge pits, Soak ways ,Percolation pit , Recharge troughs, Recharge trenches, Modified injection well. Methods of Rainwater Harvesting System Are as follows

A. *Simple roof water collection systems*

While the collection of rainwater by a single household may not be significant, the impact of thousands or even millions of household rainwater storage tanks can potentially be enormous. The main components in a simple roof water collection system are the cistern itself, the piping that leads to the cistern and the appurtenances within the cistern. The materials and the degree of sophistication of the whole system largely depend on the initial capital investment. Some cost effective systems involve cisterns made with ferro cement, etc.

B. *Larger systems for educational institutions,stadiums,airports, and facilities*

When the systems are larger, the overall system can become a bit more complicated, for example rainwater collection from the roofs and grounds of institutions, storage in underground reservoirs, treatment and then use for non-potable applications.

C. *Roof water collection systems for high-rise buildings in urbanized areas*

The In high-rise buildings, roofs can be designed for catchment purposes and the collected roof water can be kept in separate cisterns on the roofs for non-potable uses.

D. *Land surface catchments*

Rainwater harvesting using ground or land surface catchment areas can be a simple way of collecting rainwater. Compared to rooftop catchment techniques, ground catchment techniques provide more opportunity for collecting water from a larger surface area. By retaining the flows (including flood flows) of small creeks and streams in small storage reservoirs (on surface or underground) created by low cost (e.g., earthen) dams, this technology can meet water demands during dry periods. There is a possibility of high rates of water loss due to infiltration into the ground, and because of the often marginal quality of the water collected, this technique is mainly suitable for storing water for agricultural purposes.

E. Collection of storm water in urbanized catchments

The surface runoff collected in storm water ponds, reservoirs from urban areas is subject to a wide variety of contaminants. Keeping these catchments clean is of primary importance, and hence the cost of water pollution control can be considerable[1].

F. Assessment of information and condition required for designing RWH:

- An climatic and Environmental phenomena
- Social aspects like Social structure, family structure and family size, daily consumption rate.
- Structural component of RWHS.
- Economic aspects [2].

G. Literature Review

Tejas D et al (2016) carried out study on **"***Study of Artificial Recharge Structure for Rain Water Harvesting"* Often, as a frantic response to problems of water scarcity and consequent hardships faced by both urban and rural communities, India has invested heavily in rainwater harvesting. Unlike investment in large water resource systems, these efforts, by and large, lack hydrological planning and sound economic analysis: research on the impact of local water harvesting/groundwater recharge activities in India is very sparse. This paper identifies six critical issues in rainwater harvesting efforts in water-scarce regions of India. First: there is no emphasis on potential local supplies and the demand they have to cater for: local supply potential is low in most water scarce regions, a fact compounded by poor reliability, and demand far exceeds the supply potential. Second: there are complexities in the economic evaluation of RWH, due to lack of scientific data on inflows, runoff collection and storage efficiency, beneficiaries, value of the incremental benefits generated and scale considerations. With higher degrees of basin development, the marginal benefit from water harvesting at the basin level reduces, while marginal cost increases. Third: in many basins, there is a strong 'trade-off' between maximizing hydrological benefits and improving cost effectiveness[3] .

M.K. Parmar et al (2016) carried out study on *" Rain Water Harvesting as Alternative in Water Scarcity Area: A Case Study of Takoli Gad Watershed, Garhwal Himalaya"* Water is the prime product of the forest and it is the basic human need which is felt more acutely in the drought condition being faced by the country. About 100 million people in 12 states of the country are facing sever water crises. Even the basic need of two and a half liters of water per day for drinking purpose, has become difficult to meet in these states. The other effect of drought is loss of agriculture, fodder, water for cattle and migration of people and cattle from the area in search of water. Present study emphasis on the rainwater harvesting problem in Takoli Gad watershed. Most of the villages are located over the spurs on the both side of the Takoli Gad catchment, most of the villages are suffer from the acute shortage of water. Takoli Gad watershed carry very little amount of water in dry season. However, these technologies have to be implemented systematically ensuring the participation of communities. According to the findings and recommendation the action research followed by ensuring the active participation of community can make the system successful[4] .

IV. Materials and Methodology

Chevella, Ranga Reddy Dist, Telangana. Ranga Reddy Dist occupies an area of 7500 sq km with a population 24, 46,265 (2011), density of 486/km^2.Chevella is located at 17.306^{0}N 78.1353^0 E. It has an average elevation of 623 m. The climate in Chevella is referred to as a local steppe climate. There is little rainfall throughout the year. The temperature here averages 26.1^{0}C. The average annual rainfall is 654.8mm (Fig: 1). the least amount of rainfall occurs in January. The average in this month is 2mm. The greatest amount of precipitation occurs in September, with an average of 199mm. The temperatures are highest on average in May, at around 32.5^{0}C. The lowest average temperature in the year occurs in December, when it is around 21.3^{0}C. The variation in the precipitation between driest and wettest months is 197mm. The variation in temperature throughout the year is 11.2^{0}C.

1) Various materials are used in the construction of the model of RWH

- Cardboards.
- Thermocol.
- PVC Pipes.
- Submersible motors.
- Handling Tools and Accessories.

2) Model of RWH of FIT Campus:

The visualization of the whole FIT Campus was carried out and accordingly the Model of the entire campus infrastructure was engineered(Fig:2) .

3) Methodology

On the basis of experimental evidence, Mr. H. Darcy, a French scientist enunciated in 1865, a law governing the rate of flow (i.e. the discharge) through the soils. According to him, this discharge was directly proportional to head loss (H) and the area of cross-section (A) of the soil, and inversely proportional to the length of the soil sample (L).

$$Q \propto \frac{H}{L} . A$$

Q = Runoff.

Here, H/L represents the head loss or hydraulic gradient (I), K is the co-efficient of permeability

Hence, finally, Q = K. I. A. Similarly, based on the above principle, water harvesting potential of the catchment area was calculated. The total amount of water that is received from rainfall over an area is called the rainwater legacy of that area and the amount that can be effectively harvested is called the water harvesting potential. The formula for calculation for harvesting potential or volume of water received or runoff produced or harvesting capacity is given as

Harvesting potential or Volume of water Received (m^3) = Area of Catchment (m^2) x Amount of rainfall (mm) x Runoff coefficient.

4) Design criteria of RWH structure:

Structures for RWH should be designed on the basis of availability of space, run-off, depth to water table and litho logy of the area. Two most important components which need to be evaluated for designing the RWH structures are:

1. Hydrology of the area including nature and extent of aquifer, soil cover, topography, depth to water levels and chemical quality of ground water.
2. Hydro-meteorological characters viz, rainfall duration, general position and intensity of rainfall.

V. Results and Disscussion

Determination of Volume of Water:

Volume of Water received (m^3) = Area of catchment x Amount of rainfall x run off coefficient

Total Catchment area (roof top) of FIT, Campus
= 15,568.07m^2

Average Annual rainfall at FIT= 654.

= 0.6548 m/year.

Run off Co eff = 0.85 (Assumed)
8mm /year.
Total Vol. of surface runoff supposed to be collected

= 15568.07 x 0.6548 x 0.85

= 8664.87 m^3 / year.

Population of FIT Campus:

Total Students	=	3000
Staff	=	200
Workers	=	50
Total	=	3250 persons

Water Demand:

Canteen	= 2500 liters
Gardening	= 2500 liters
Sanitation	= 3 x 2250 = 9750
Hostel (boys)	= 4000 liters
Total	= 18750 Liters / day

= 18750x365/ 1000

= 6843.75 m^3/year

= $\frac{6843.75}{12}$ m^3/month.

= 570.31 m^3 /month.

For 2 months 570.31 x 2= 1140.62 m^3.

Optimum Dimension of Tank:
Total Water Collected = 1140.62 m^3.
Taking height of tank = 4m
Area of Base=1140.62/4 =285.155m^2
=285 m^2
Dimensions of tank = 29x9.8x4.

Analysis and Design of Underground sump:

Ht of tank	= 4m
Area of base	= 285m^2

Angle of repose = 30^0

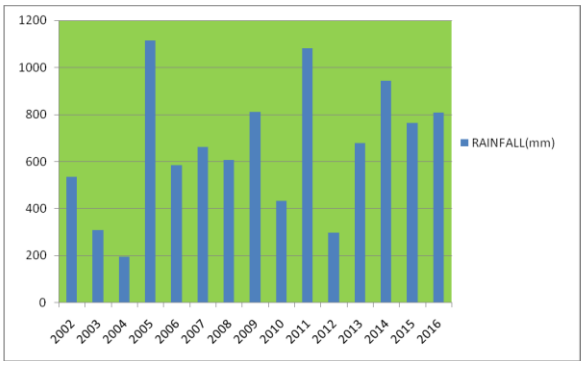

Fig 1: Graphical Representation of Rainfall in R.R Dist

Fig 2: Model of RWH

5. Gutter Design:

A channel which surrounds edge of a sloping roof to collect and transport rainwater to the storage tank is called gutter. Gutters can be semi-circular or rectangular and generally of PVC or galvanized iron sheet type of material. The efficiency of gutter is highly influenced by its choice of optimal size, width and position relative to the roof edge and its slope. Hence, this parameter is cautiously chosen. So, in order to collect maximum water, it is highly required to build the gutter with large dimensions. However, it is economical to make large gutter with reasonable dimension because the value of water collected from it is much higher than the cost of constructing the gutter. Considering the throw wind and pulsating effects, gutter width was frozen on the basis of the roof size and the ideal positioning was found out. Keeping the present case in mind, results of various studies were extensively analyzed, and a suitable gutter design was proposed. The final design recommendation is as follows. Design is made for trapezoidal shaped gutter whose angle was 30^0, and its sides are the same length as its base. The gutter has a slope of 0.5% in the first 2.3^{rd} portion of its length, and 1.0% slope in the last 1.3^{rd}. The gutter width is designed to be 160mm, of which 120mm is extending out from the roof edge and 40mm extending towards the inner side.

6. First flush Mechanisms:

In order to prevent entry of excess dirt from the catchment area from entry into tank and polluting the water, first flush mechanism is designed. And the order of this mechanism becomes highly important when water preserved is utilized for drinking purpose. The Turbidity factor was also considered while design first flush mechanism. After studying our requirement and prevailing condition, the design value of this mechanisms was fixed to be 8 liters /$10m^2$ and finally Ball valve design (Fig:3) was chosen. Ball valve design has a unique mechanism for controlling the flow of water into and outside of the tank. This system consists of ball inside the specially designed pipe which opens and closes the opening of outlet to the storage tank and diversion chamber according the level of water. When the water fills up to the brim, the water is diverted to the main tank from the side outlet. And when the water needs to be rejected is sent to the small diversion chamber where it fills the inlet pipe. Hence total volume of the diversion chamber and the pipe up to the Ball Valve are carefully designed to match the diversion volume that is calculated. The connection between the terrace water and storage tank rebuilds when water reaches the level of the ball making the ball to float and block the connection between the terrace water and diversion chamber, thus sending the water back again to main storage tank. In this way, small diversion chambers are designed for the downpipe from each terrace.

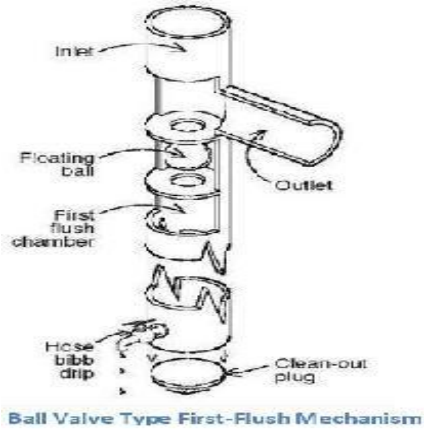

Fig 3: Ball Valve Type-Flush Mechanism

6. Design of Filtration Tank:

Filtration is designed for peak Discharged flow. The design rate of filtration is $200/m^2$/minute. The average rainfall obtained in FIT campus is 654.8mm/year.

Average annual Rainfall= 65.48cm

For 1 month,
= [65.48/(30x24x60x60)]
=0.0000025m/sec
Average Discharge Q= 0.0000025x0.85x15568
= 0.033 m^3/sec.
Peak Discharge = 2.5x0.033 m^3/sec.
= 0.075 m^3/
= 0.08 m^3/sec. (approx)
= 0.08x1000x60 liters/minute
Area of Filter required = Q/(Design Rate of Filtration)
(4800)/ (200) = 24m^2.

The size of 6m x 4m filter unit shall be provided

TABLE 1 TOTAL ESTIMATE OF THE RAIN WATER HARVESTING SYSTEM

Components	Cost (Rs)
Underground tank	1673125.115
Pipes	200000
Filtration unit	200000
Total	2073125.115
Grand total	2200000

VI. CONCLUSIONS

The following Conclusions were obtained from the study carried out on “Design of Rainwater Harvesting System in FIT Campus”.

1. The total rainwater harvesting infrastructure requires Rs.22 lakhs as per the cost analysis study. The college faces acute shortage of water during summer with large requirement for landscape, trees, canteen etc., hence with above investment it will be self sustaining during summer.

2. The designed infrastructure with all the dimensions and design values has long life with very minimal maintenance of filter media Therefore spending money on rainwater harvesting structure is highly economical taking in consideration life of facility for 30 years design period.

3. Excess exploitation of underground water source which has caused rapid depletion in water table can be avoided by this technique.

4. Avoids stagnation of rainwater in the college campus causing damage to roads and breeding of mosquitoes.

5. This rainwater is well used for gardening keeping our garden green and indeed college atmosphere green and clean and provides an alternative source of water for our college.

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