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Design of rainwater harvesting system at Shilpa Hostel in JNTUA College of Engineering Ananthapuramu: A case study from Southern India

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Abstract:- This article evaluates the potential for water saving by using rainwater in Shilpa Hostel a residential building at JNTUA College of Engineering in Ananthapuramu town located in the southern state of Andhra Pradesh in India. The building houses on an average 211 girl students every year. The roof top of the hostel is the catchment area. Using average rainfall data, calculations for rainwater endowment and water harvesting potential were made. Volume of water that can be collected in one year was calculated. Suitable hydrocyclone for removing suspended particles and reducing turbidity has been proposed. The project cost was calculated making use of prices prevailing currently in India. Annual monetary savings were calculated based on the volume of water collected by rain water harvesting and payback period was arrived at**.**

Keywords:- water conservation; rainwater harvesting potential; rainwater endowment, run-off coefficient; hydrocyclone.

I. INTRODUCTION

Many cities in India and all over the world are dealing with depleting water supply, marked by falling groundwater levels, vanishing water bodies, severe pollution and urban floods. With their own supplies drying up, cities are forced to source water from further and further away. This is expensive. City planners usually ignore a powerful source of water that they can access to - rain. Rainwater and run-off can be harvested . It can be collected and stored, or conveyed to the aquifer to recharge groundwater [1].

A. Rainwater harvesting system and its features

Rainwater harvesting is a simple technique of catching and holding rainwater where it falls. Either, one can store it in tanks or can use it to recharge ground water depending upon the situation. The system is economically cheaper in construction compared to other sources like dams, diversions etc. It is ideal for areas where there is inadequate ground water supply or surface resources. The system helps in utilizing the primary source of water and prevents the runoff from going into sewer or storm drains, thereby reducing the load on treatment plants.

Rainwater harvesting systems used in housing schemes can provide water for potable and non potable uses. The potable uses include drinking, bathing, cooking and dish wash. Usually the rain water used for this purpose must be treated to remove the contaminants and generally the main required treatment processes are filtration and disinfection unless the rainwater contains heavy metals, then special treatment is needed. Non-potable uses of rain water harvesting include flushing toilets, watering garden, and washing floors and for such uses treatment is not required [2].

The rain water harvesting system recharges water into aquifers which help in improving the quality of existing ground water through dilution.

B. Components of a typical rain water harvesting system

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 catchment surface, delivery system, and storage reservoirs. Figure below shows different components of residential rain water harvesting cistern system [3].

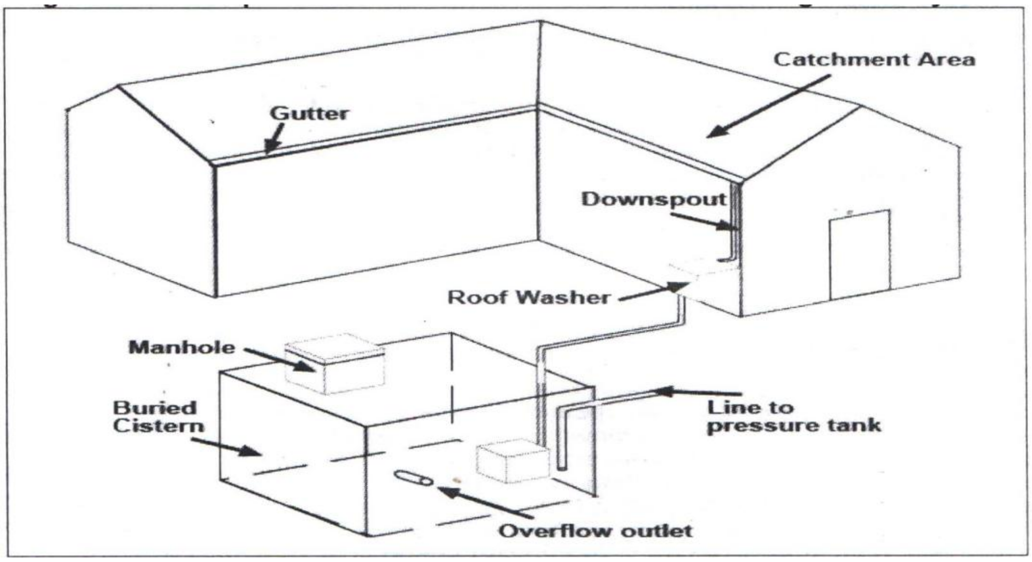

Fig. 1. Components of residential rain water harvesting cistern system

The catchment of a water harvesting system is the surface that receives rainfall directly and drains the water to the system. Surface water is however in most cases not suitable for drinking purposes since the water quality is not good enough. Any roofing material is acceptable for collecting water. However water to be used for drinking should not be collected from thatched roofs or roofs covered with asphalt. Also lead should not be used in these systems. Galvanized corrugated iron sheets, corrugated plastic and tiles make good roof catchment surfaces. Flat cement or felt covered roofs can also be used provided they are clean. Undamaged asbestos cement sheets do not have negative effect on the water quality. Coarse mesh prevents the passage of debris, provided in the roof.

The delivery system from the rooftop catchment usually consists of gutters hanging from the sides of the roofs sloping towards a downpipe and tank. This delivery system or guttering is used to transport the rain water from the roof to the storage reservoir.

For the effective operation of the rain water harvesting system, well designed and carefully constructed gutter system is crucial because the guttering is often the weakest link in a rain water harvesting system. As much as 90% or more of the rain water collected on the roof will be drained to storage tank if the gutter and downpipe system is properly fitted and maintained. Common material for gutters and downpipes are metal and poly vinyl chloride (PVC). Cement based products, bamboo and wood may also be used [4].

With high intensity rains in tropics, rain water may shoot over the conventional gutter, resulting in rain water loss and low harvesting production. Splash guards can prevent this spillage. Conduits are pipelines or drains that carry rainwater from the catchment or roof-top area to the harvesting system. Commonly available conduits are made up of material like polyvinylchloride (PVC) or galvanized iron (GI).

The water storage tank usually represents the biggest capital investment element of an urban RWH system. It therefore usually requires the most careful design to provide optimal storage capacity and structural strength while keeping the costs as low as possible. For storing large quantities of water the system will usually require a tank above or below the ground. Round shaped tanks are generally stronger than square shaped tanks.

There are two categories of storage reservoirs: surface tanks and subsurface tanks. Surface tanks are most common for roof collection. Materials for surface tanks include metal, wood, plastic, fiber glass, brick, interlocking blocks, compressed soil or rubble stone blocks, ferro-cement and reinforced concrete. The choice of material depends on local availability and affordability.

Surface tanks are generally more expensive than underground tanks but also more durable. The material and design for the walls of subsurface tanks or cisterns must be able to resist the soil and soil water pressures from outside when the tank is empty. Tree roots can damage the structure below the ground. Careful location of the tank is therefore important. Local material such as wood, bamboo and basket work can be used as alternatives to steel for reinforcing concrete tanks. A subsurface tank or cistern requires a water lifting device such as pump or bucket-rope system. Safe water lifting device and regular maintenance and cleaning are important for prevention of contamination of the stored water.

Regular cleaning and inspection of the catchment area and gutter are important to ensure good water quality. To protect water quality, good system design, operation and maintenance are essential. The first rains should flush away the dust, leaves etc. that lie on the roof surface. In practice, preparation and cleaning of the roof surface before the first rains hardly ever happens. To prevent these pollutants and contaminants from getting into the storage tank, the first tank water containing the debris must therefore be diverted or flushed away. Many RWH systems therefore incorporate a system to divert this 'first flush' water so that it does not enter the tank. A coarse filter, preferably made up of nylon or a fine mesh, can also be used to remove dirt and debris before the water enters the tank. Further treatment through boiling, exposure to sunlight and chlorination can be undertaken if there are concerns about the water quality [2].

C. Factors affecting rainwater harvesting and quality of harvested rainwater

Run off coefficient is a factor that affects the amount of rainwater harvested. It is the ratio of the volume of water that runs off a surface to the volume of rainfall that falls on the surface. More water runs off smooth and impervious surfaces such as roofs or paved areas than soils and unpaved areas. Different catchment materials absorb water to different extents [1].

Table I. Run-Off Coefficients for Different Catchment Areas

Type	Run-off coefficient
Well-constructed roof	0.9
Galvanized iron sheets	>0.9
Tiles (glazed)	0.6-0.9
Aluminum sheets	0.8-0.9
Flat cement roof	0.6-0.7
Organic (e.g. thatched)	0.2

Factors that influence the water quality of roof runoff are chemical characteristics, roughness, surface coating, age of the roof material, catchment parameters viz. size, inclination, exposure, precipitation events - intensity, wind, duration, local weather and chemical properties of pollutants [5].

The roofing material effects the quality of harvested rainwater. The conventional roofing materials are asphalt, fiberglass, wood, metal, and concrete tiles. Rainwater harvested from these roofs require treatment for potable and non potable use for meeting standards.

The rainwater harvested from the metal roof showed lower concentration of fecal indicator bacteria than did the other roofing material. This is because of lower emissivity of metal, resulting in higher surface temperatures of the roof.

Concentration of the tested water quality parameters decreased as a result of diverting a first-flush of at least 38 liters for every 93 m^2 of collection area [6].

Roof run-off contamination was found to be strongly influenced by both local wind speed and direction. Evans et al. reported that the bulk of the contamination for rainwater catchment systems at an urban housing development in Newcastle, Australia was not due to random animal activity occurring on the catchment area but was more heavily influenced by the microorganisms deposited by the local wind [7].

D. Benefits of rainwater harvesting

As rainwater is very soft there is less consumption of washing and cleaning powder. Rainwater harvesting saves high quality drinking water sources and relieves the pressure on sewers and environment by mitigating floods, soil erosions and replenishing groundwater levels [4].

Rainwater harvesting is cost effective from a financial perspective because of exemption from water tax. Avoids public rationing through self management. It integrates one with environment by reducing waste giving satisfaction. Mandatory rainwater harvesting could increase societal well-being [8].

"Applications of Rainwater Harvesting Scheme in Shimla Region" paper discusses about the prospects and the possibilities of rainwater harvesting in Shimla region of Himachal Pradesh, which experiences water shortages in summer periods due to increase in population and climatic conditions. The study showed that the sanitation water requirements for a family can be met for two months with storage of rainwater for one single month only.

The benefit cost ratio analysis shows that within a minimum period the installation cost of the rainwater harvesting system can be easily recovered. Added advantages would be exemption of paying bill or tanker charges as well as making potential savings on any changes in the rate of water pricing or additional taxes charged by the local municipal corporations if rain water is daily used for washing and sanitation facilities [9].

Compared with most unprotected traditional water sources, drinking rainwater from well-maintained roof catchment usually represents a considerable improvement [10].

Houses fitted with rainwater harvesting system are less affected by water restrictions. Rainwater harvesting systems add security to urban water supply system in the event of unforeseen failure of urban water supply system [11].

E. Limitations of rainwater harvesting

Rainwater collected from ground catchment systems was generally subjected to high levels of microbial contamination and its consumption without treatment is not recommended [4].

Rainwater harvested from any the roofing materials would require treatment if the consumer wanted to meet drinking water standards or non-potable water reuse guidelines [6].

Rainwater harvesting is site specific and depends on local rainfall and hence it is difficult to give a generalized idea and make it successful. Problems may arise due to chemical microbiological contamination. Stagnant water can pose hazards such as mosquito breeding. Household based rainwater harvesting meets some of the water demand needs but it rarely manages to satisfy the full daily water requirement demands [7].

Urban areas with high impervious surfaces and centralised stormwater drainage infrastructure, rainwater quickly turns from a valuable resource into a societal cost in the form of flooding, stream erosion, aquatic habitat destruction, and toxic loadings on receiving environments [8].

The rainwater harvested may contain pathogens if it is sourced from sources which are poorly located, constructed or maintained [10].

II. OBJECTIVES OF RAIN WATER HARVESTING

Water availability is a matter of concern all over the world. This work describes the water availability scenario in J.N.T.U.A College of Engineering Ananthapuramu located in a drought prone district Ananthapuramu in the state of Andhra Pradesh in southern India and suggests method to harvest rainwater in the campus.

The economy of Ananthapuramu is agro-based and the farmers depend mostly on rains for growing crops such as rice, groundnuts etc. The shortage in annual rainfall year after year has created drought like conditions continuously. Also the people in the villages and towns face severe shortage of water for drinking during summer. Hence there arises an urgent need to think of simple and effective method which is economical to catch rain water as it falls for meeting the daily demand of water. Rain water harvesting (RWH) is one such method. Water is the natural resource which is always in high demand by human beings and is indispensable part of the life. If this demand is not met, then it will lead to water scarcity. Water scarcity has become the most common problem in every part of India. This problem is also profoundly seen in the residence halls inside the campus hostels. If not dealt with proper care then this problem will become a major hurdle in the development of campus and the standard of living will decline. Keeping in view of the above the college should focus on the water scarcity problem. Rainwater harvesting system (RWH) can be considered as a solution for scarcity of water. Moreover owing to simple technology, ease of construction and installation and low cost of investment, RWH system deserves implementation in the campus.

This article focuses on harvesting rain water in ‘Shilpa’ hostel of JNTUA College of Engineering. The rain water is collected from roof top which is the catchment area for the hostels. Rainwater harvesting can meet potable and non-potable water demands and also control flooding of the buildings. The non-potable harvested rainwater can be best utilized for purpose of constructing new infrastructure building, gardening, etc. which reduces the investment to be made for water. Campus can easily meet the potable water demand and also able to save money which is being spent for procuring potable-water. Rainwater harvesting also helps in increasing the soil moisture condition and fertility of soil for plantation. This improves the greenery surrounding the campus, increasing aesthetic factor needed for a residential campus.

III. METHODOLOGY

The different steps involved in designing RWH system are listed in the following table:

Table II. Different steps in design of RWH system

Different steps in designing a RWH system	
1	Obtaining the rainfall data
2	Obtain the number of students supplied with water
3	Estimation of water demand
4	Calculation of total roof area
5	Determination of volume of water that can be harvested
6	Sizing and selection of filter
7	Design of delivery system
8	Cost Estimation
9	Calculation of annual savings and payback period

A. Obtaining rainfall data:

For the design of rainwater harvesting system, rainfall data is required preferably for a period of at leas ten years. The more reliable and specific data is for the location, the better the design will be. The table below describes about overall rainfall data for a period of fourteen years in Ananthapuramu. The data is taken from the Telugu daily Eenadu.

Table III. Rainfall data for ananthapuramu for past 14 years

Year	Rainfall(mm)
2000-2001	614.3
2001-2002	702.1
2002-2003	290.4
2003-2004	523.4
2004-2005	433.5
2005-2006	791.2
2007-2008	407.04
2008-2009	816.0
2009-2010	713.9
2010-2011	615.6
2011-2012	722.4
2012-2013	495.7
2013-2014	538.7
2014-2015	517.0

From the above table, the highest and lowest average rainfall values are in 2008-2009 and 2002-2003 respectively.

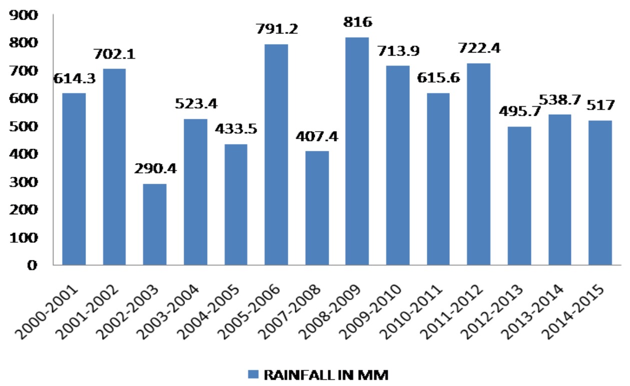

Fig. 2. Rainfall data for Ananthapuramu district for the past 14 years

From the above data it is clear that rainfall (mm) in any year cannot be predicted. The average rainfall for the past 14 years has been calculated using the above data as 584.37 mm.

B. Number of students supplied with water in the hostel:

On an average, the number of students residing in Shilpa hostel is 211.

C. Estimation of water demand:

Water consumption for one person per day for different acitivities is 135 liters. Average water consumed for different acitivities by a person per day is given in the table below:

Table IV. WATER CONSUMPTION FOR DIFFERENT ACTIVITES

S.No	Activity	Water Consumption
1	Bathing	55 liters
2	Toilet flushing	30 liters
3	Washing of clothes	20 liters
4	Washing of room	10 liters
6	Washing of utensils	10 liters
7	Cooking	5 liters
8	Drinking	5 liters
	Total	135 liters

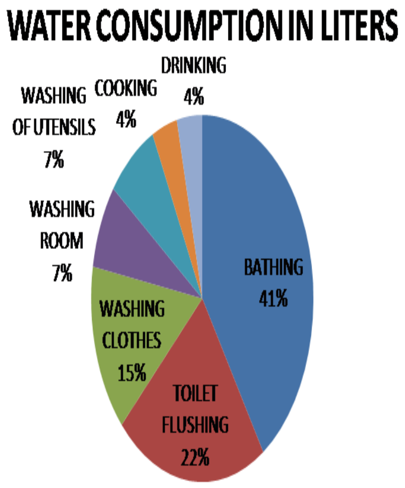

Fig. 3. Water consumption for different activities

Number of students in Shilpa hostel = 211

Demand = water use × number of students ×365

= 135 liters × 211×365

= 10397025 litres/year.

D. Calculation of total roof area:

Study Area

To increase the potential benefits of RWH system and draw maximum advantages from it, it is important to have large rooftop areas which will be going to act as catchment areas. More the catchment areas more will be the surface runoff and thus more will be the amount of harvested water. Shilpa hostel has large rooftop area and has been considered for the present study.

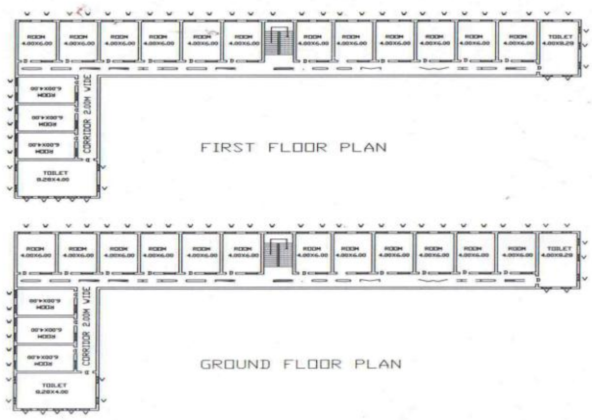

Fig. 4. Plan of Shilpa hostel

Length of the catchment area = 28.6 m
Breadth of the catchment area = 24.0 m
Catchment area = length × breadth = 28.6×24.0 = 686.4 m^2

E. Determination of volume of water that can be harvested in a year:

Rainwater endowment:

The total amount of water that is received in the form of rainfall over an area is called the rainwater endowment of that area.

$$\begin{aligned} \text{Rainwater endowment} &= \text{rainfall}\times\text{catchment area} \\ &= 584.37\times10^{-3}\ \text{m} \times 686.4\ \text{m}^2 \\ &= 401.111\ \text{m}^3 \end{aligned}$$

Run-off coefficient:

Present case run off coefficient is taken as 0.9 because type of catchment area is a well constructed roof.

Rainwater harvesting potential:

Out of rainwater endowment that can be effectively harvested is called water harvesting potential.

$$\begin{aligned} \text{RWH Potential} &= \text{Rainwater endowment}\times\text{run-off coefficient} \\ &= 401.111\times0.9 \\ &= 361\ \text{m}^3 \end{aligned}$$

F. Sizing and Selection of Filter

Filters are needed to remove fine particles of dust or bacteria from water. Selection of a filter depends on: purpose of use, quality of run off, type of catchment, amount of silt load and type of recharge structure.

The type of filter medium selected here is a hydrocyclone (Rainy filter FL 200) which is a low carbon galvanised steel cylinder with a mesh size of 250 microns. The filter is enclosed in an outer casing of polyethylene and the filter can withstand a rainfall intensity of 75 mm/hour. The working of the filter is based on the principles of cohesive and centrifugal force. A hydrocyclone is a static, continuous particle size separation device. It is used for phase separations, including solid-liquid, liquid-liquid and liquid-gas separations. Hydro cyclones are attractive as a filter in a rain water harvesting system as they have no moving parts, a small foot print, relatively low capital and operating costs. Also they are simple to operate [1].

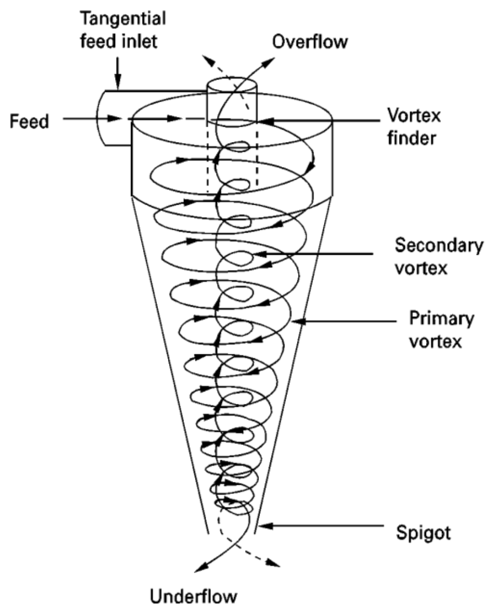

Fig 5. Schematic diagram of a hydrocyclone

Characteristic features of Rainy Filter (FL 200) hydrocyclone:

The characteristic features of FL 200 dual intensity rain water harvesting filter is its capacity to take up the load up to 10 to 225 square meters of roof area with variable intensity of rainfall of 5 to 75 mm/hour with a discharge capacity of 10 to 225 litres per minute. This filter can be conveniently used for harvesting rainwater for individual households, schools, apartments, institutions, and commercial buildings of medium sizes. Three numbers of these filters will be suitable for the present rain water harvesting system since the catchment area is 686.4 m^2.

TABLE V. FEATURES OF RAINY FILTER FL-200

Suitable up to area:	225 SQMTRS
Max. Intensity of Rainfall:	75 mm/hr
Working Principle :	Cohesive Force & Centrifugal force
Operating Pressure:	Less than 2 feet of head (0.060kg/cm^2)
Capacity:	225 LPM
Filter Element:	SS-304 Screen
Mesh Size:	250 Microns
Inlet:	110 MM
Clean Water Outlet:	75 MM
Drain Outlet:	90 MM
Housing:	High Density Polyethylene
Efficiency of Filter:	Above 90%
Source of Power:	Gravity

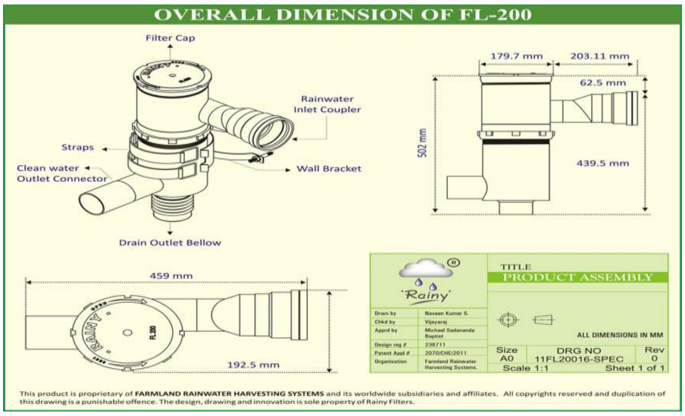

Fig 6. Schematic diagram showing the dimensions of hydrocyclone FL 200

G. Designing delivery system:

The proposed pipe routing is shown in the schematic diagram below. The parts are listed and cost estimation is made.

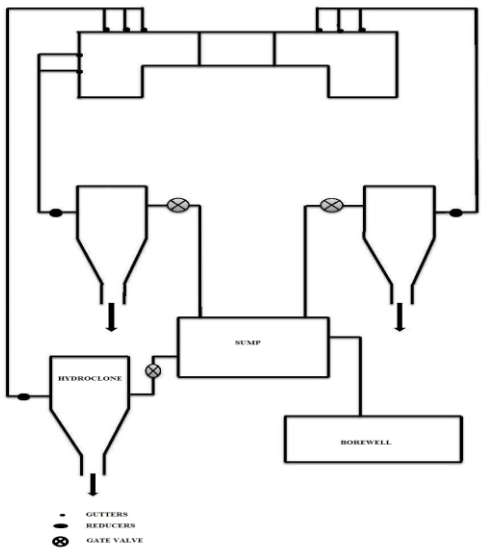

Fig 7. Schematic diagram of RWH system showing the pipe routing and filters

H. Cost Estimation:

Table vi. Cost estimation for rwh system

S. No	Part	Number Required	Cost per part (Rs)	Total cost(Rs)
1	PVC Pipes(4´´)	20	380	7600
2	Common heads	3	450	1350
3	Bends	15	400	9000
4	Enlarge, reducers	6	500	3000
5	Gate valves	3	400	1200
6	Hydro cyclones	3	13,000	39,000
7	Labour cost	-	-	15,000
8	Total cost	-	-	76,150

I. Calculation of annual savings and payback period:

Potential /volume of tank = 3, 61, 000/8, 000 = 45.125
Cost of 8,000 liters = Rs. 800
Cash in flow per period or annual savings = 45.125 × 800
= Rs.36,100.00
Payback period = initial investment/cash in flow per period
= 76,150/36,100= 2.11 years.

IV. CONCLUSIONS

This project deals with aspect of improving the rain water availability in the JNTUACE, Ananthapuramu campus by implementing rain water harvesting (RWH). This implementation of RWH system can last for many years providing water for drinking and other uses. A little maintenance and manual work is needed to clean the catchment area, storage tanks and hydrocyclones. This work focused on implementing rainwater harvesting (RWH) for the ladies hostel 'Shilpa' which houses around 211 girl students every year.

- The water demand per year has been calculated and found to be 1,03,97,025 liters.
- Catchment area for Shilpa hostel was calculated as 686 m^2.
- Rainwater endowment for the area has been computed to be 401.111 m^3.
- Assuming a run off coefficient 0.9, rain water harvesting potential is calculated as 3,61,000 liters/year.
- A layout (piping diagram) has been proposed which includes three hydrocyclones for separation of suspended particles. List of parts have been identified and cost estimation was made. The total cost for implementing RWH system worked out to be Rs. 76, 150.00.
- Considering the amount of water collected annually through the rain water harvesting system, annual savings is found to be Rs. 36,100.00. The payback period for project calculates to be 2.11 years. It is a worthwhile investment since the payback period is near the ideal payback period range of 3 to 5 years. Hence it is strongly recommended for implementation of RWHS project which will result in monitory savings and will help in increasing the water availability and recharging the ground water.
- Amount of rainwater harvesting potential is 3.47% of the total demand for the hostel. This percentage can be higher if there is a greater rainfall in the year than the average. The water can be effectively used for non potable uses which does not need any further treatment.
- Also more catchment area can be brought into use by considering other buildings such as administrative building, library, departmental blocks and other hostels. This will improve the overall rainwater harvesting potential of the institution.
- This project does not require power for its operation or maintenance.

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REFERENCES

[1]. Catch water where it falls. Toolkit on urban rainwater harvesting. Published by Center for Science and Environment, New Delhi, 2013.

[2]. Mohammed, Thamer Ahmed, Megat Johari Megat Mohd Noor, and Abdul Halim Ghazali. "Study on potential uses of rain water harvesting in urban areas." *Proceedings of the colloquium on rainwater utilisation, Putrajaya, Malaysia, 19&20 April 2007*.

[3]. Low impact development stormwater management planning and design guide. Published by Credit Valley Conservation Authority and Toronto and Region Conservation Authority Ontario Canada 2010.

[4]. Khoury-Nolde, Norma. "Rainwater Harvesting." (2006).

[5]. Förster, Jurgen. "Patterns of roof runoff contamination and their potential implications on practice and regulation of treatment and local infiltration." *Water science and technology* 33.6 (1996): 39-48.

[6]. Mendez, Carolina B., J. Brandon Klenzendorf, Brigit R. Afshar, Mark T. Simmons, Michael E. Barrett, Kerry A. Kinney, and Mary Jo Kirisits. "The effect of roofing material on the quality of harvested rainwater." *water research*45, no. 5 (2011): 2049-2059.

[7]. Evans, Craig A., T. Harrison, Peter J. Coombes, Hugh R. Dunstan, and RHugh Dunstan. "Identifying the major influences on the microbial composition of roof harvested rainwater and the implications for water quality." (2006): 245.

[8]. Gabe, Jeremy, Sam Trowsdale, and Diveshkumar Mistry. "Mandatory urban rainwater harvesting: learning from experience." *Water Science and Technology*65.7 (2012): 1200.

[9]. Ganguly, Rajiv, A. Bansal, M.Mishra, and A. Kumar. "Application of Rain Water Harvesting Scheme in Shimla Region." *Hydrology: Current Research* 5, no. 3 (2014): 1.

[10]. Gould, John. "Is rainwater safe to drink? A review of recent findings." *9th International Rainwater Catchment Systems Conference*. 1999.

[11]. Rahman, A., J. Dbais, and M. Imteaz. "Sustainability of rainwater harvesting systems in multistorey residential buildings." (2010).