A manual for

Rain water Harvesting

TABLE OF CONTENTS

CHAPTER ONE: INTRODUCTION

1.1Introduction:

In spite of astonishing achievements in the field of Science & Technology, nature remains to be a mystery for human beings. Though water is also being obtained through desalination, artificial rain by cloud seeding etc. in some of the developed countries, the shortage of water even for drinking purpose is a perpetual phenomenon throughout the world, especially in developing and underdeveloped countries. India is likely to experience “Water Stress” from the year 2007 onwards. It will be pertinent to shift the thrust of the policies from “Water Development” to “Sustainable Water Development”. A vital element of this shift in strategy is the increasing importance of Water Harvesting and Artificial recharge of Ground Water.

Countries like Slovakia, Israel, use water about 4-5 times before disposing off. However, in India it is used only once before being disposed. This is certainly not a very encouraging situation.

The never-ending exchange of water from the atmosphere to the oceans and back again is known as the hydrologic cycle. This cycle is the source of all forms of precipitation (hail, rain, sleet and snow), and thus of all water. Water and moisture stored in streams, lakes, and soil evaporates while water stored in plants transpires to form clouds, which store the water in the atmosphere.

Making the most efficient use of our limited and precious resources is essential. This includes using appliances and plumbing fixtures that conserve water, not wasting water and taking advantage of alternative water sources such as grey water reuse and rainwater harvesting.

Water is essential for life and plays a major role in creating earth’s climate. By modifying land use, the proportion of the different pathways, evaporation, percolation and run off change. A change in evaporation from a region has impacts upon climate. Changes in percolation change ground water availability, both for humans, and natural springs and streams. Changes in run off will change stream flow and erosion patterns, which in turn modifies the sediment load of stream.

Rainwater harvesting is the activity of direct collection of rainwater. The Rainwater so collected can be stored for direct use or can be recharged into the ground water for future use. The main goal is to minimize flow of rainwater through drains / nallahas to the rivers and then to sea without making any use of the same. It is a known fact that the ground water level is depleting and going down day by day in the last decades. The rivers, lakes and ground water are the secondary sources of water. In absence of rainwater harvesting, we depend entirely on such secondary sources of water and in the process it is forgotten that rain is the ultimate source that feeds to these secondary sources. The value of this important primary source of water must not be lost. Rainwater harvesting means to understand the value of rain and to make optimum use of rainwater at the place where it falls.

The need: Rain Water Harvesting can be understood by the fact that even CHIRAPUNJI, which receives about 11000 mm rain fall annually, suffers from acute shortage of drinking water due to the reasons that Rain water is not harvested and is allowed to drain away.

The annual rainfall over India is computed to be 1170 mm, which is much higher than the global average of 800 mm. However, this rainfall in India occurs during short periods of high intensity. Such high intensity and short duration makes most of the rain falling on the surface to flow away leaving little scope for recharging of ground water. This results in lack of water in most part of the country even for domestic uses.

There are two types of rainwater harvesting:

- Storage of rainwater on surface
- Recharge to ground water

Roof top rainwater harvesting consists of collecting, storing and using rooftop rainwater from houses or any construction. Rainwater harvesting can also be collecting, filtering and recharging ground water through percolation pits, open wells or bore wells.

The artificial recharge to ground water is a process by which the ground water reservoir is augmented at a rate exceeding that obtained under natural conditions of replenishment. Any man made scheme or facility that adds water to an aquifer may be considered to be an artificial recharge system.

Artificial recharge techniques normally address to following issues:

- To enhance the sustainable yield in areas where over development has depleted the aquifer.
- To utilize the rainfall runoff, that goes to sewer or storm water drain.
- Storage of excess surface water for future requirements, since these requirements often change within a season or a period.
- Surface water is inadequate to meet the demand and it is met by ground water.
- Due to rapid urbanization, infiltration of rainwater into the sub soil has decreased drastically and recharge of ground water has diminished.
- To arrest seawater ingress.
- To improve the vegetation cover and reduce flood hazard.
- To raise the water levels in wells and bore wells those are drying up.
- To remove bacteriological and other impurities from sewage water and waste- water so that water is suitable for reuse.
- To improve the quality of existing ground water through dilution.
- To reduce power consumption used to withdraw water.

The basic purpose of artificial recharge of ground water is to restore supplies from aquifers depleted due to excessive ground water usage.

The sub-surface reservoirs are very attractive and technically feasible alternatives for storing surplus monsoon run off. They can store substantial quantity of water. The sub-surface geological formations may be considered as warehouse for storing water that come from sources located on the land surface. Besides suitable litho logical conditions, other considerations for creating sub-surface storages are favorable geological structures and physiographic units, whose dimensions and shape will allow retention of substantial volume of water in porous and permeable formations. The sub-surface reservoirs, located in suitable hydro geological situations, are environment friendly and economically viable proposition. The sub-surface storages have advantages of being free from the adverse effects like inundation of large surface area, loss of cultivable land, displacement of local populations, substantial evaporation losses and sensitivity, to earthquakes. No gigantic structures are needed to store water.

The storage of rainwater on surface is a traditional technique and structures used were underground tanks, ponds, check dams, weirs etc. Recharge to ground water is another concept of rain water harvesting and the structures generally used are:

- Pits
- Trenches
- Dug Wells
- Hand pumps
- Recharge wells
- Recharge shafts
- Lateral shafts with bore wells
- Spreading techniques

It is needed to implement measures to make sure that rainwater falling over a region is tapped to a maximum possible extent through rainwater harvesting, either by recharging it into the ground water resources or storing it for direct use.

CHAPTER TWO: RAIN WATER HARVESTING

2.1Introduction

Water scarcity is a serious problem throughout the world for both urban and rural communities. More and more water is required for domestic, construction and industrial use. The rate of withdrawal is far in excess of the rate of recharging the water table. In India, water is considered divine and referred to as thirtha. But, there is nothing holy in our treatment of our water sources. Pollution and overexploitation have shrunk the availability of clean and potable water to a trickle.

Urbanization has resulted in overexploitation of ground water, reduction in open soil surface and water infiltration rate and a resultant deterioration in water quality. Apartments and industrial units face acute water shortage forcing them to spend considerable amounts of money to purchase water from municipal and private water suppliers. The rural scenario is equally grim. The population explosion necessitates a proportionate increase in food production, which in turn demands more land, more fertilizers and pesticides and more water.

The water policy of the Government of India puts a norm of 180 litres per capita for our domestic needs. But it is not possible to supply even 100 litres per day even in urban areas. 30 million Indians spread out over an area of 7 lakh sq. km., mostly in the west and North West regions; face an acute scarcity of potable water especially in the summer months.

The main source is precipitation, in the form of rain or snow. The annual rainfall in India is 400 million hectare meter. This rainwater can be used to recharge the ground water, by adopting a simple technique called rainwater harvesting. Rainwater harvesting means making use of each and every drop of rainwater to recharge the groundwater, by directing the rainfall to go into the well or under the ground, without wasting the rainwater.

India uses only 10-20 percent of its annual rainfall. When it rains, only a fraction of the water percolates and reaches the ground water aquifers, while the major part of the rainfall drains out as run-off and goes unused into the ocean. Further, lack of adequate storage facilities necessitate water being let into the sea to prevent breaching and flooding. The increasing numbers and depth of bore wells and wells and their unrestricted use threaten India's ground water resources.

2.2 Advantages of using rainwater

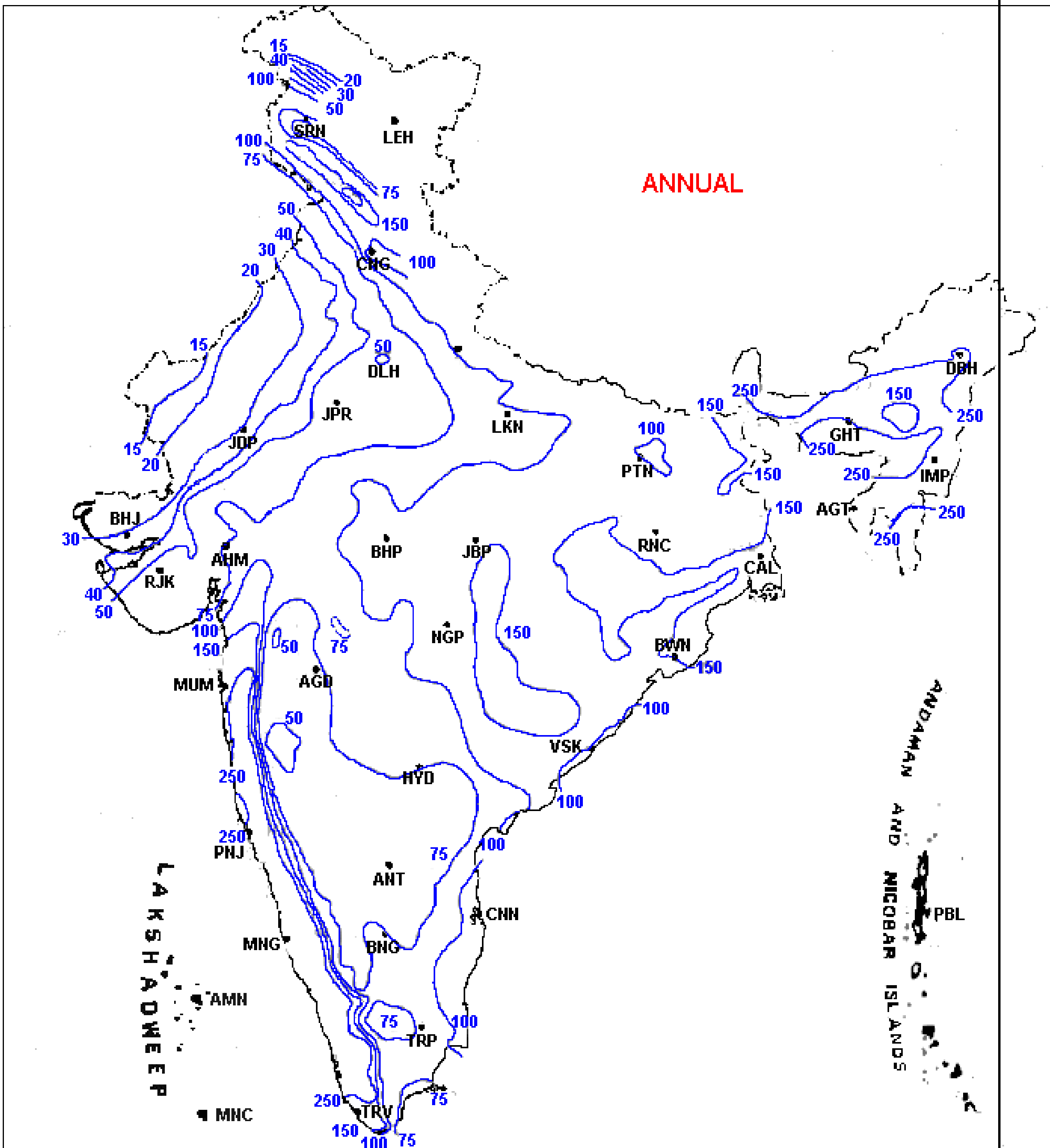
- Rainwater harvesting promotes self-sufficiency and fosters an appreciation for water as a resource. It also promotes water conservation.
- Rainwater harvesting also conserves energy as the energy input needed to operate a centralized water system is bypassed. Many systems require only a small pump to create water pressure in household pipes.
- Local erosion and flooding from impervious cover associated with buildings is lessened as a portion of local rainfall is diverted into collection tanks.
- Rainwater is one of the purest sources of water available. Its quality almost always exceeds that of ground or surface water.
- It does not come into contact with soil or rocks where it can dissolve minerals and salts nor does it come into contact with many of the pollutants that are often discharged into local surface waters or contaminate ground water supplies
- Rainwater is soft. It can significantly lower the quantity of detergents and soaps needed for cleaning. Soap scum and hardness deposits do not occur.

Table 2.1 Rainfall data for Major Cities in India

S.No.	City	Annual rain fall (mm) ®	S.No.	City	Annual rain fall (mm) ®
A-1 Class			29	Solapur	750..8
1	Mumbai	2146.6	30	Thiruvananthapuram	1827.7
2	New Delhi (Safdarjung)	797.3	31	Tiruchirappali	880.2

3	New Delhi (Palam)	794.0	32	Varanasi	1025.4
A- Class			33	Vishakhapatnam	968.8
4	Ahmedabad	803.4	34	Port Blair	3168.8
5	Bangalore	970.0	35	Dibrugarh	2588.7
C- Class			36	Tezpur	1768.3
6	Calcutta	1641.4	37	Chapra	1028.3
7	Chennai	1333.8	38	Jamshedpur	1320.7
8	Hyderabad	812.5	39	Muzaffarpur	1239.8
B-1 Class			40	Salem	1014.0
9	Bhopal	1146.7	41	Ranchi	1431.6
10	Indore	1008.3	42	Rajkot	726.9
11	Jaipur	673.9	43	Patna	1003.4
12	Kanpur	832.6	44	Bhuj	413.6
13	Lucknow	1021.5	45	Karnal	814.1
14	Ludhiana	752.3	46	Simla	1424.8
15	Nagpur	1112.7	47	Bidar	981.1
16	Amritsar	681.2	48	Imphal	1353.1
17	Aurngafbad	688.05	49	Shillong	2050.5
18	Bareli	1071.9	50	Kohima	1856.0
19	Chandigarh	1059.3	51	Bhubaneshwar	1542.2
20	Coimbatore	631.0	52	Cuttack	1475.3
21	Gorakhpur	1228.1	53	Pathankot	1319.0
22	Guwahati	1717.7	54	Alwar	774.6
23	Gwalior	899.0	55	Vellure	1004.4
24	Jabalpur	1331.6	56	Agartala	2178.6
25	Kochi	3228.3	57	Aligarh	781.6
26	Kota	761.4	58	Dehradun	2315.4
27	Madurai	873.3	68	Roorkee	1156.4
28	Meerut	901.0	69	Darjiling	2667.1

[Source: Climatological tables of observations in India (1951 – 1980) by Indian Metrological Department]



(Source: India Meterological Department)

Figure 2.1: Normal Annual Rainfall (cm) Map of India

2.3Artificial Recharging

Artificial recharging to augment ground water resources has become a necessity and we should therefore develop and popularize some of the cost effective rainwater harvesting methods in urban and rural areas. The main objectives of rainwater harvesting are

- To conserve the surface run-off during monsoons
- To recharge the aquifers and increase availability of ground water
- To improve the quality of ground water where required
- To overcome the problem of flooding and stagnation of water during the monsoon season
- To arrest salt water intrusion.

Various methods are available to recharge the water table by increasing the rate of infiltration. The artificial recharge can be achieved by obstructing the flow of water, by storing the water, by spreading the water or by injection through wells and bore wells.

The following are some methods used to recharge the ground water

- Pebble bed method
- Percolation pits
- Recharge wells
- Ridges and furrows
- Check dams
- Gully control/stone wall structures
- Contour bunding, trenching
- Land flooding

By using the existing well

The run-off water from rooftops can be led into the existing well through pipes and a small settling pit to filter the turbidity and other pollutants. In this cost-effective process we not only conserve the precious rainwater but also help to increase the local ground water table. Even an abandoned well can be used for this purpose.

Through percolation pits

Percolation pits (1m x 1m x 3m) may be dug a little away from the building. The pit is then filled with brick jelly/pebbles followed by river sand for the purpose of better percolation. The top layer of sand may be cleaned and replaced once in two years to remove the settled silt for improving the percolation.

Decentralized percolation trenches

This method can be adopted by those who reside in houses with large open areas. Run-off water from the rooftop can be diverted into bare soil/ garden in the premises. Apart from this a longitudinal trench of 1.0m depth and 0.5 m width may be dug at the periphery of the plot and filled with pebble stones and sand in order to store the excess run-off during rainy season that will eventually percolate into the ground.

Other methods of utilizing rain water

- Run-off should be diverted into suitably designed structures near pavements, parking lots, parks, play grounds, etc.
- Rainwater can also be stored in underground storage tanks (water sumps) for a few months and used directly for washing, flushing and other domestic purposes. Industries, multistoried buildings, various offices, etc., can implement this cost effective method, as they depend mostly on ground water for their needs.

Percolation tanks (PT) Spreading Basin

These are the most prevalent structures in India as a measure to recharge the ground reservoir both in alluvial as well as hard rock formations. The efficacy and feasibility of these structures is more in hard rock formations where the rocks are highly fractured and weathered. In the states of Maharashtra, Andhra Pradesh, Madhya Pradesh, Karnataka and Gujrat, the percolation tanks have been constructed to recharge deeper aquifers where shallow or superficial formations are highly impermeable or clayey with certain modification.

While taking decision on construction of percolation tanks following points should be kept in mind.

- In semi arid region the storage capacity of percolation tanks should be such that the water should percolate to ground water reservoir before onset of summer because during summer season evaporation losses would be higher.
- The percolation tank should be provided in the catchments where submergence area is smaller and such submergence area should be in un-cultivatable land.
- Percolation tank should be located in highly fractured and weathered rock for speedy recharge. In case of alluvium soil, the boundary formation (natural bunds) is ideal for locating percolation tank.
- The aquifer to be recharged should have sufficient thickness of permeable zone to accommodate the recharge.
- The percolation tank should be provided in a region where sufficient number of wells and cultivatable land is there, to take advantage of recharge water.
- Normally 50% of total quantum of rainfall in catchments area should be considered to decide the number and size of percolation tanks.
- Suitable provision in the form of waste weir or spillway to be made to allow the flow of surplus water which is in excess of maximum capacity of percolation tank in a particular day.
- To avoid erosion of embankment due to ripple action stone pitching to be provided up to high flood level in up stream side.

2.4Amount of water needed to satisfy the needs

If already connected to municipal water, rainwater collection for lawn and garden use may be the most cost-effective, since little or no treatment is required. If a well already exists, rainwater may be a good addition for washing or to augment water supplies when underground water supplies are low. If a new house is being built and municipal water is not available, rainwater collection may be cost-effective for all the needs.

If using rainwater is being used for all the needs, calculation of both indoor usage and outdoor usage is needed to determine how much water is needed to collect to meet the total needs.

- Household Needs
- Landscaping Needs
- Total Water Needs

Calculation of total water needs in a household

Household Needs

A rough estimate of indoor usage can be made by using either 75 gallons per day per person (GDP) for a house with older appliances and fixtures (or 55 GDP for a house with newer water saving appliances and fixtures) and multiplying the GDP by the number of people in the household. The water needs can be reduced. However, the need calculations based on water conservation should not be reduced unless water conservation techniques are actually practiced.

Example: Assume a family of four living in a new house with water-saving appliances and fixtures and not practicing water conservation techniques.

4 people x 55 gallons per day per person = 220 gallons of water per day used

220 gallons of water per day x 365 days per year = 80,300 gallons of water per year used

The following chart may be used to make more exacting calculations. To use the table, the **Use** and **Number of Users** columns are to be filled, then multiply the numbers in the **Use**, **Flow Rate**, and **Number of Users** columns to get the number for the **Total** column.

Fixture	**Use**	**Flow Rate**	**Number of Users**	**Total**
Toilet	________ #of flushes per person per day	1.6 gallons per flush *	________	________
Shower	________ #of minutes per person per day (5 min. max. suggested)	2.75 gallons per minute * (restricted flow head)	________	________
Bath	________ #of baths per person per day	50 gallons per bath average	________	________
Faucets	________ #of bathroom and kitchen sinks (excluding cleaning)	10 gallons per day per faucet	N/A	________
Washing Machine	________ #of loads	50 gallons per load	N/A	________

	per day	(average)		
Dishwasher	________ #of loads per day	9.5 gallons per load (average)	N/A	________
Total gallons per day ________				
Total gallons per day x 365 days per year = gallons per year ________				

* Flow rates are for new fixtures. Older toilets use 3.5 to 7 gallons per flush. Older shower heads may use as much as 10 gallons per minute.

Landscaping Needs

Calculating landscape watering needs is a little more complicated. Different types of grass need different amounts of water. To calculate landscaping water needs do the following:

1. The water demand (inches per year) is multiplied with the lawn size (square feet) and divided by 12 to determine the cubic feet of water needed.
2. For example, if a lawn of 1,800 (60 x 30) square feet of grass with 50 inches per year of water requirement is there, then (50 inches per year x 1,800 square feet of lawn) / 12 = 7,500 cubic feet of is water needed.
3. The number of cubic feet needed is multiplied by 7.48 to convert cubic feet needed to gallons needed.
   7,500 cubic feet of water x 7.48 = 56,100 gallons of water needed
4. the inches of natural rainfall for the area is multiplied by the lawn size (square feet) and divide by 12 to determine the cubic feet of rain received. For example (32 inches of rainfall per year x 1,800 square feet of lawn) / 12 = 4,800 cubic feet of rainfall.
5. The cubic feet of rainfall are multiplied by 7.48 to convert cubic feet of rainfall to gallons of rainfall.
   4,800 cubic feet of rainfall x 7.48 = 35,904 gallons of rainfall

6. The gallons of natural rainfall is subtracted from (line 4) from the gallons of water needed (line 2) to determine how much rainfall must be harvested and stored to meet landscape watering needs.
   56,100 gallons of water needed - 35,904 gallons of rainfall = 20,196 gallons to be collected and stored

The landscape watering needs can be reduced by xeriscaping.

Total Water Needs

For a family of four with an 1,800 square feet lawn, the yearly water consumption is 80,300 gallons for household use + 20,196 gallons for landscape use =100,496 gallons of water for use each year

The amount of water needed is not equal to the amount of water that must be stored**.** Enough water is to be stored to get through the driest parts of the year. First, the amount of water that can be collected is calculated and then the maximum size of storage needed is calculated to carry through the driest part of the year.

2.5Amount of rain water that can be collected

- How much rainfall can *possibly* be collected?
- How much rainfall can *really* be collected?
- How much rain will fall?

Rainfall that can possibly be collected

An amazing amount of water can be collected. The rule of thumb is 600 gallons of water per inch of rain per thousand square feet of catchment area. Here is the basic formula for calculating the potential amount that can be collected:

$$\frac{\text{Catchment area of building}^{1} \times \text{inches of rain} \times 600 \text{ gallons}}{1000}$$

Catchment area is calculated using the footprint of the building plus the length of the overhangs. In other words if the building is 25 feet by 50 feet the catchment area is 1,250 square feet.

Sample calculation

$$\frac{1{,}250 \text{ sq ft of catchment area} \times 3 \text{ inches of rain} \times 600 \text{ gallons per inch}}{1000}$$

$$= \frac{2{,}250{,}000}{1000}$$

= 2,250 gallons of water collected from three inches of rain

Amount of rainfall that can be really collected

Not all the rain that falls can actually be collected. Several factors affect collection efficiency:

- A small amount of rain, 3/100s to 1/10th of an inch, will be needed to wet the roof and fill the roof washer.
- Some of the rain will overshoot the gutters or spill out of gutters during heavy downpours.
- Once storage tanks are full any additional rain will not be collected.

Efficiency is usually presumed to be 75% to 90% depending on system design and capacity.

The amount of rain that will fall

How much rain will fall in a given year is unknown. Rainfall data for previous years can be used to predict how much rain may fall.

The first step in determining reliability of rainfall is to find out the average rainfall in the area. This may be all that is needed to be known if relying on rainwater as a supplement to another source.

If rainwater is the sole source of water, the least amount of rainfall in a year and the period of the year when the rain falls is to be known. If part of the year is very dry, then it is to be seen if enough water can be collected during the rainy months to last through the dry months. If only the minimum amount of rain falls in a year, then it is to be known whether that will be enough to meet needs.

Least Amount of Rainfall

It is important to examine the worst case scenario. A handy rule of thumb to determine the likelihood of low rainfall is to take the average amount of rainfall for an area and divide it by two.

This below calculation can be used to calculate a worse case scenario for collecting rain water.

- Assume 1,250 square feet of catchment area
- Assume 16 inches of rain in the year
- Assume 75% collection efficiency

$$\frac{1{,}250 \times 16 \times .75 \times 600}{1000} = 9{,}000 \text{ gallons of water a year}$$

On the other hand in a year of average rainfall (32 inches) the water that can be collected is

$$\frac{1{,}250 \times 32 \times .75 \times 600}{1000} = 18{,}000 \text{ gallons of water a year}$$

If more water than that provided by the worst case scenario is needed , then supplemental water supply for those years should be planned for. This means having enough storage capacity to carry through the dry years.

Variations in Rainfall during the Year

Rain does not fall evenly throughout the year. Some months are drier than others. The amount of water that is needed each month is to be known compared to the amount of water that can be collected and stored each month. A monthly balance is to be calculated. It's best to calculate the balance using the amount of rain that is expected at least 50 percent of the time and the amount of rain coming at least 75 percent of the time.

If the rainfall of a particular area based on the last 50 years of data is as follows;

- **Min** is the least amount of rain that has fallen in that month in the last 50 years
- **10%** is the amount of rain that falls in that month at least 90% of the time
- **25%** is the amount of rain that falls in that month at least 75% of the time
- **50%** is the amount of rain that falls in that month at least 50% of the time
- **Avg** is the average amount of rain that falls in that month
- **Max** is the highest amount of rain that has fallen in that month in the last 50 years

Month	**Min**	**10%**	**25%**	**50%**	**Avg**	**Max**
Jan	0.02	0.35	0.60	1.23	1.79	9.14
Feb	0.23	0.59	1.13	2.28	2.40	6.48
Mar	0.00	0.25	0.81	1.66	1.84	5.97

Apr	0.03	0.53	1.38	2.18	2.89	9.85
May	0.77	1.17	1.60	3.89	4.40	9.90
Jun	0.00	0.66	1.51	2.63	3.41	14.87
Jul	0.00	0.11	0.44	1.10	1.75	10.50
Aug	0.00	0.25	0.60	1.19	2.03	8.84
Sep	0.09	0.80	1.50	3.15	3.22	7.41
Oct	0.00	0.56	0.87	2.78	3.50	12.25
Nov	0.00	0.32	0.74	1.71	2.05	7.28
Dec	0.00	0.32	0.74	1.24	2.18	14.05

Sample Calculation

- Assume 1,250 square feet of catchment area
- Assume 16 inches of rain in the year
- Assume 75% collection efficiency
- Assume 8,320 gallons of water used each month
- Assume 0 gallons in storage in January
- Assume 20,000 gallon storage tank

1. Calculation of the amount of rain that can be collected in January at the 50% level

$$\frac{1,250 \times 1.23 \times .75 \times 600}{1000}$$

= 692 gallons of water collected

2. The amount already in storage is added to the amount collected and subtracted from the monthly demand to determine the balance.

0 gallons in storage + 692 gallons collected - 8,320 gallons needed

= (7,628) or 0 gallons in storage at the end of January

3. This calculation is continued for each month to get a picture for the year.

Month	Monthly Use gal/mo	50% Rain inches	Rainfall Collected gallons	End of Mo. Storage gallons	25% Rain inches	Rainfall Collected gallons	End of Mo. Storage gallons
				0			0
Jan	8,375	1.23	692	0	0.60	338	0
Feb	8,375	2.28	1,283	0	1.13	636	0
Mar	8,375	1.66	934	0	0.81	456	0
Apr	8,375	1,226	2.18	0	1.38	776	0
May	8,375	3.89	2,188	0	1.60	900	0
Jun	8,375	2.63	1,479	0	1.51	849	0
Jul	8,375	1.10	619	0	0.44	248	0
Aug	8,375	1.19	669	0	0.60	900	0
Sep	8,375	3.15	1,772	0	1.50	844	0
Oct	8,375	2.78	1,564	0	0.87	489	0
Nov	8,375	1.71	962	0	0.74	416	0
Dec	8,375	1.24	698	0	0.74	416	0
Totals	100,496	25.04	11,898		11.92	6,706	

In years when the amount of rain is only what it gets 75% of the time an insufficient amount of water is collected to meet needs. In years when the amount of rain is what it gets 50% of the time enough water is still not collected. In this example, rainwater collection can only be a supplement.

The collection efficiency accounts for the facts that all the rainwater falling over an area cannot be effectively harvested because of evaporation, spillage etc. Runoff coefficient as stated for various types of roof and land surfaces are shown in Table. The first flush wastage i.e. first spell of rain is flushed out, evaporation and spillage does not enter the system so a constant co-efficient of 0.80 may be adopted for all situations. This is done because the first spell of rain carries with it a relatively larger amount of pollutenants from the air and catchments surface.

Table 2.2 Runoff Coefficients of Various Surfaces

1.	Roof Catchment			Co-efficient
	1.1	Tiles		0.8-0.9
	1.2	Corrugated metal sheets		0.7-0.9
2.	Ground Surface Covering			
	2.1	Untreated Ground Catchments		
		2.1.1	Soil on slope less than 10%	0.0-0.3
		2.1.2	Rocky material catchment	0.2-0.5
		2.1.3	Business Area	
			2.1.3.1 Down town	0.70-0.95
			2.1.3.2 Neighborhood	0.50-0.70
	2.2	Residential Complexes in urban Areas		
		2.2.1	Single family	0.30-0.50
		2.2.2.	Multi units, detached	0.40– 0.60
		2.2.3	Multi units, attached	0.60- 0.75
	2.3	Residential Complexes in Suburban Areas Apartments		0.50-0.70
	2.4	Industrial		
		2.4.1	Light	0.50-0.70
		2.4.2	Heavy	0.60-0.90
	2.5	Parks, cemeteries		0.10-0.25
	2.6	Play grounds		0.20-0.35
	2.7	Railroad yard		0.20.-0.35
	2.8	Unimproved Land Areas		0.10- 0.30
	2.9	Asphalt or concrete pavement		0.70 –0.95
	2.10	Brick Pavement		0.70-0.85
	2.11	Lawns, sandy soil having slopes		
		2.11.1	Flat 2%	0.05-0.10

	2.11.2 Average 2 to 7%	0.10-0.15
	2.11.3 Steep 7%	0.15-0.20
2.12	Lawns, clayey soil having slopes	
	2.12.1 Flat 2%	0.13- 0.17
	2.12.2 Average 2 to 7%	0.18-0.22
	2.12.3 Steep 7%	0.25- 0.35
2.13	General Driveways and walls	0.15-0.30

(Source ASCE and WPCF 1969)

Where the use of the runoff coefficients implies there is constant ratio of rainfall to run off, the actual ratio will vary over the course of a storm due to condition of the area and at the variability of the rainfall pattern. A common practice is to use average coefficients for various types of areas and assume that the coefficients will be constant throughout the duration of the storm.

CHAPTER THREE: ROOF TOP RAINWATER HARVESTING

3.1 Introduction

Domestic rainwater harvesting or Rooftop rainwater harvesting is the technique by which rainwater is captured from roof catchment and is stored in tanks/reservoirs/ ground water aquifers. It consists of conservation of rooftop rainwater in urban areas and utilizing it to augment ground water storage by artificial recharge. It requires connecting the out let pipe from rooftop to divert collected water to existing tank/well/tube well/bore well or a specially designed well.

The approximate volume of water available for harvesting with respect to roof top area and annual rainfall of that area has been shown in Table 3.1 for designing the rainwater harvesting structures.

Rooftop rainwater harvesting systems, both small and large are comprised of six basic components as described below:

- *Catchment Area/ Roof:* Surface upon which rainfalls.
- *Gutters and Down Spouts:* Transport channels from catchment surface to storage.
- *Leaf Screens and Roof Washers:* Systems that remove contamination and debris.
- *Cisterns or Storage Tanks:* Where collected rainwater is stored.
- *Conveying:* The delivery system for treated rainwater, either by gravity or pump.
- *Water treatment:* Filters and equipment and additives to settle, filter and disinfect.

The system involves collecting water that falls on the roof (made-up of galvanized iron sheets/ asbestos sheets or brick tiles) of a house during rain storms, and conveying it by an Aluminium, PVC wood or plastic drain or collector to a nearby covered storage unit or cistern. Rainwater yield varies with the size and texture of the catchment area. A smoother, cleaner and more impervious roofing material contributes to better water quality and greater quantity.

The broad idea about the particular diameter of pipe which will be required to cater the certain roof surface area for given average rate of rainfall in millimeter per hour is shown in Table 3.2.

Table 3.1 Availability of Rain Water by Roof Top Rain Water Harvesting

Rainfall (mm) / Roof top Area (Sqm)	100	200	300	400	500	600	800	1000	1200	1400	1600	1800	2000
	Harvested Water from Roof Top (cum)												
20	1.6	3.2	4.8	6.4	8	9.6	12.8	16	19.2	22.4	25.6	28.8	32
30	2.4	4.8	7.2	9.6	12	14.4	19.2	24	28.8	33.6	38.4	43.2	48
40	3.2	6.4	9.6	12.8	16	19.2	25.6	32	38.4	44.8	51.2	57.6	64
50	4	8	12	16	20	24	32	40	48	56	64	72	80
60	4.8	9.6	14.4	19.2	24	28.8	38.4	48	57.6	67.2	76.8	86.4	96
70	5.6	11.2	16.8	22.4	28	33.6	44.8	56	67.2	78.4	89.6	100.8	112
80	6.4	12.8	19.2	25.6	32	38.4	51.2	64	76.8	89.6	102.4	115.2	128
90	7.2	14.4	21.6	28.8	36	43.2	57.6	72	86.4	100.8	115.2	129.6	144
100	8	16	24	32	40	48	64	80	96	112	128	144	160
150	12	24	36	48	60	72	96	120	144	168	192	216	240
200	16	32	48	64	80	96	128	160	192	224	256	288	320
250	20	40	60	80	100	120	160	200	240	280	320	360	400
300	24	48	72	96	120	144	192	240	288	336	384	432	480
400	32	64	96	128	160	192	256	320	384	448	512	576	640
500	40	80	120	160	200	240	320	400	480	560	640	720	800
1000	80	160	240	320	400	480	640	800	960	1120	1280	1440	1600
2000	160	320	480	640	800	960	1280	1600	1920	2240	2560	2880	3200
3000	240	480	720	960	1200	1440	1920	2400	2880	3360	3840	4320	4800

(Source: Central Ground Water Board Guide)

The graph shown in Figure 3.1 gives fair idea about amount of peak precipitation may likely happen for different duration of rainfalls shown on curved lines with respect to recurrence intervals shown in years. This will give idea about peak rainfall intensity for a particular station for which settlement tanks are to be designed for 15 minutes duration of peak rainfalls.

Table 3.2 Sizing of Rain Water Pipes for Roof Drainage

S.No.	Diameter of pipe (mm)	Roof Area (Sqm)					
		50	75	100	125	150	200
		Average rate of Rain Fall (mm per hour)					
1	50	13.4	8.9	6.6	5.3	4.4	3.3
2	65	24.1	16.0	12.0	9.6	8.0	6.0
3	75	40.8	27	20.4	16.3	13.6	10.2
4	100	85.4	57.0	42.7	34.2	28.5	21.3
5	125	-	-	80.5	64.3	53.5	40.0
6	150	-	-	-	-	83.6	62.7

(Source: National Building, SP –35)

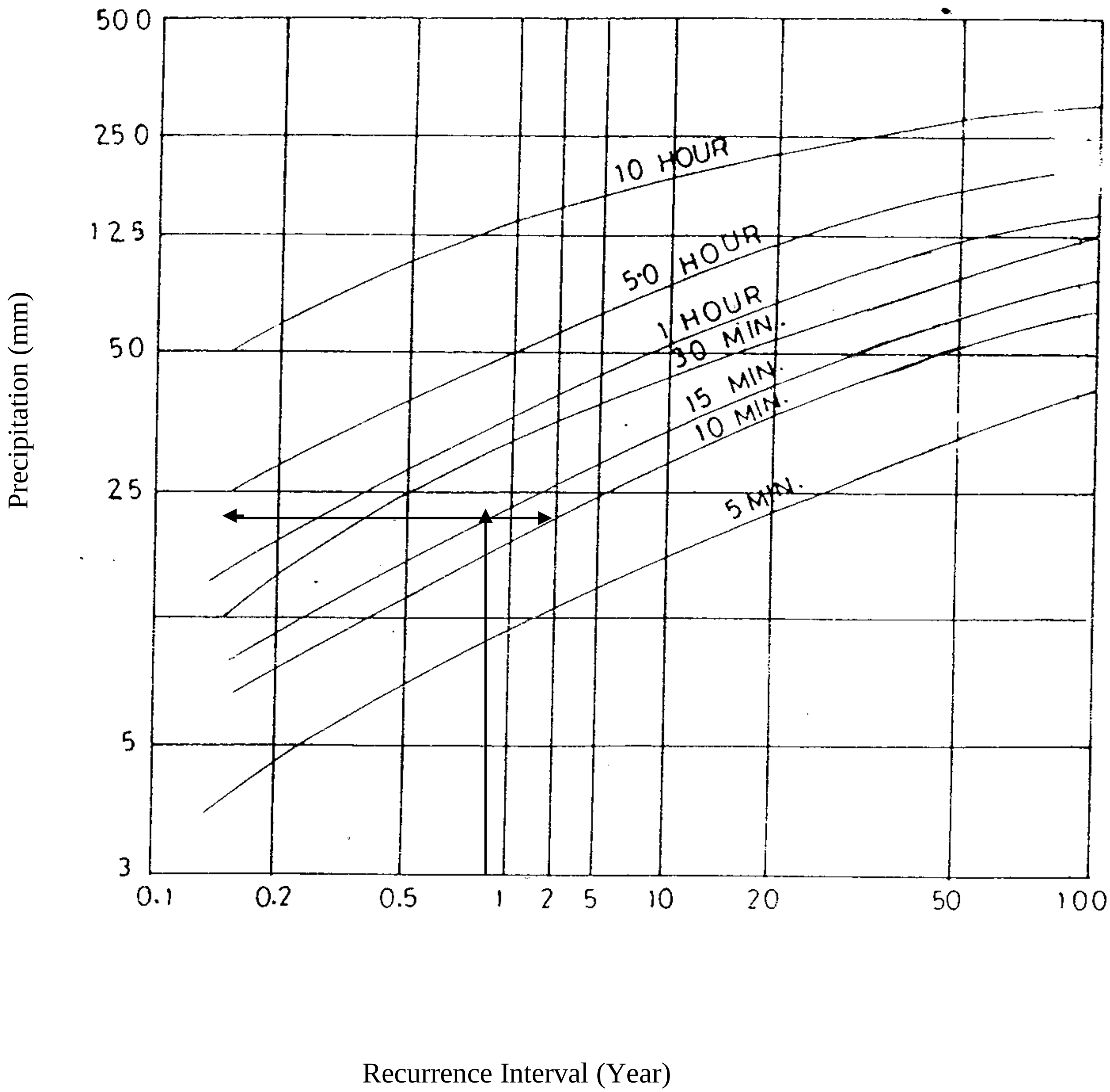


Figure 3.1 Rainfall Intensity, Duration and Frequency Relationship (Source: National Building, SP –35)

3.2Water quality considerations

Primary water quality criteria –health concerns

Once rain comes in contact with a roof or collection surface, it can wash many types of bacteria, molds, algae, protozoa and other contaminants into the cistern or storage tank. Indeed, some samples of harvested rainwater have shown detectable levels of these contaminants. Health concerns related to bacteria, such as salmonella, e-coli and legionella, and to physical contaminants, such as pesticides, lead, and arsenic, are the primary criteria for drinking water quality analysis. Falling rain is free of most of these hazards. Common sense takes a lot of the guess work out of proper treatment procedures.

For example, if the rainwater is intended for use *inside* the household, either for potable uses such as drinking and cooking or for non-potable uses including showering and toilet flushing, appropriate filtration and disinfection practices should be employed. If the rainwater is to be used *outside* for landscape irrigation, where human consumption of the untreated water is less likely, the presence of contaminants may not be of major concern and thus treatment requirements can be less stringent or not required at all. Depending on where the system is located, the quality of rainwater itself can vary, reflecting exposure to air pollution caused by industries such as cement kilns, gravel quarries, crop dusting, and a high concentration of automobile emissions.

Secondary water quality criteria – aesthetic concerns

Aesthetic concerns such as color, taste, smell, and hardness comprise the secondary testing criteria used to evaluate publicly supplied water. When assessed according to these characteristics, rainwater proves to be of better quality than well or municipal tap water. Inorganic impurities such as suspended particles of sand, clay, and silt contribute to the water's color, and smell. Proper screening and removal of sedimentation help to decrease problems caused by these impurities.

Rainwater is the softest natural occurring water available, with a hardness of zero for all practical purposes. As mentioned above, a benefit of the soft water is that faucets and water heaters last longer without the build-up of mineral deposits.

Rainwater contains almost no dissolved minerals and salts and is near distilled water quality. For people on restricted salt diets, this represents a decisive advantage over other water sources.

The pH of rainfall would be 7.0 if there were nothing else in the air. However, as rain falls through the air, it dissolves carbon dioxide that is naturally present in the air and becomes slightly acidic. The resultant pH is 5.6; however, any sulfates or nitrates dissolved from the air will lower this number below pH 5.6.

Although the pH of rain is below neutral, it is only slightly acidic, and the smallest amount of buffering can neutralize the acid. The low total dissolved salts and minerals levels found in rainwater permit even very small amounts of something like baking soda (one level tablespoon per 100 gallons) to adjust the pH to near neutral.

WATER QUALITY PROPERTIES RELATED TO SPECIFIC USES

Domestic	**Industrial**	**Irrigation**
Taste	pH	Boron
Odor	Acidity	Alkalinity
Poisons	Alkalinity	Sodium-Calcium Ratio
Fluoride	Silica	Dissolved solids
Nitrate	Hardness	
Iron	Sediment	
Hardness	Dissolved solids	
Sediment		
Dissolved solids		

CHAPTER FOUR: METHODOLOGY OF A RAIN WATER HARVESTING SYSTEM

4.1System components

Whether the system you are planning is large or small, all rainwater harvesting systems are comprised of six basic components:

- **Catchment Area/Roof:** The surface upon which the rain falls
- **Gutters and Downspouts:** The transport channels from catchment surface to storage
- **Leaf Screens and Roof washers:** The systems that remove contaminants and debris
- **Cisterns or Storage Tanks:** Where collected rainwater is stored
- **Conveying:** The delivery system for the treated rainwater, either by gravity or pump
- **Water Treatment:** Filters and equipment, and additives to settle, filter, and disinfect

Catchment area

The catchment area is the surface on which the rain that will be collected falls. While in this text the main focus is on roofs as catchment areas, channeled gullies along driveways or swales in yards can also serve as catchment areas, collecting and then directing the rain to a french drain or bermed detention area. Rainwater harvested from catchment surfaces along the ground, because of the increased risk of contamination, should only be used for lawn watering. For in-home use, the roofs of buildings are the primary catchment areas, which, in rural settings, can include outbuildings such as barns and sheds. A “rainbarn” is a term describing an open-sided shed designed with a large roof area for catchment, with the cisterns placed inside along with other farm implements.

Rainwater yield varies with the size and texture of the catchment area. A smoother, cleaner, and more impervious roofing material contributes to better water quality and greater quantity. While loss is negligible for pitched metal roofs, concrete or asphalt roofs average just less than 10% loss, and built up tar and gravel roofs average a maximum of 15% loss. Losses can also occur in the gutters and in storage. Regardless of roofing material, many designers assume up to a 25% loss on annual rainfall. These losses are due to several factors: the roofing material texture which slows down the flow; evaporation; and inefficiencies in the collection process.

Type of roofing material

If you are planning a new construction project, metal roofing is the preferred material because of its smooth surface and durability. Other material options such as clay tile or slate are also appropriate for rainwater intended to be used as potable water. These surfaces can be treated with a special painted coating to discourage bacterial growth on an otherwise porous surface. Because composite asphalt, asbestos, chemically treated wood shingles and some painted roofs could leach toxic materials into the rainwater as it touches the roof surface, they are recommended only for non-potable water uses. For systems intended as potable water sources, no lead is to be used as roof flashing or as gutter solder as the slightly acid quality of rain can dissolve the lead and thereby contaminate water supply. Existing houses and buildings should be fully examined for any lead content in the planning stages of any rainwater collection project.

Catchment area size

The size of a roof catchment area is the building's footprint under the roof. The catchment surface is limited to the area of roof which is guttered. To calculate the size of your catchment area, multiply the length times the width of the guttered area (See Chapter II for more detail).

Gutters and downspouts

These are the components which catch the rain from the roof catchment surface and transport it to the cistern. Standard shapes and sizes are easily obtained and maintained, although custom fabricated profiles are also available to maximize the total amount of harvested rainfall. Gutters and downspouts must be properly sized, sloped, and installed in order to maximize the quantity of harvested rain.

Materials and sizes

The most common material for off-the-shelf gutters is seamless aluminum, with standard extrusions of 5 inch and 6 inch sections, in 50 foot lengths. A 3 inch downspout is used with a 5 inch gutter and a 4 inch downspout is used with a 6 inch gutter. Galvanized steel is another common material which can be bent to sections larger than 6 inches, in lengths of 10 feet and 20 feet. A seamless extruded aluminum 6 inch gutter with a 4 inch downspout can handle about 1,000 square feet of roof area and is recommended for most cistern installations. For roof areas that exceed 1,000 square feet, larger sections of gutters and downspouts are commonly fabricated from galvanized steel or the roof area is divided into several guttered zones. Downspouts are designed to handle 1.25 inches of rainfall during a 10 minute period.

Copper and stainless steel are also used for gutters and downspouts but at far greater expense than either aluminum or galvanized steel. Downspouts are typically the same material as the gutters but of a smaller cross section. The connection between the downspout to the cistern is generally constructed of Schedule 40 PVC pipe. To keep leaves and other debris from entering the system, the gutters should have a continuous leaf screen, made of 1/4 inch wire mesh in a metal frame, installed along their entire length, and a screen or wire basket at the head of the downspout. Gutter hangers are generally placed every 3 feet. The outside face of the gutter should be lower than the inside face to encourage drainage away from the building wall. Where possible, the gutters should be placed about 1/4 inch below the slope line so that debris can clear without knocking down the gutter. As with the catchment surface, it is important to ensure that these conduits are free of lead and any other treatment which could contaminate the water. Check especially if you are retrofitting onto older gutters and downspouts that may have lead solder or lead-based paint.

Roof washers

Roof washing, or the collection and disposal of the first flush of water from a roof, is of particular concern if the collected rainwater is to be used for human consumption, since the first flush picks up most of the dirt, debris, and contaminants, such as bird droppings that have collected on the roof and in the gutters during dry periods. The most simple of these systems consists of a stand pipe and a gutter downspout located ahead of the downspout from the gutter to the cistern. The pipe is usually 6 or 8 inch PVC which has a valve and clean out at the bottom. Most of these types of roof washers extend from the gutter to the ground where they are supported. The gutter downspout and top of the pipe are fitted and sealed so water will not flow out of the top. Once the pipe has filled, the rest of the water flows to the downspout connected to the cistern. These systems should be designed so that at least 10 gallons of water are diverted for every 1000 square feet of collection area. Rather than wasting the water, the first flush can be used for nonpotable uses such as for lawn or garden irrigation. Several types of commercial roof washers which also contain filter or strainer boxes are available.

Storage tanks

Other than the roof, which is an assumed cost in most building projects, the storage tank represents the largest investment in a rainwater harvesting system. To maximize the efficiency of your system, your building plan should reflect decisions about optimal placement, capacity, and material selection for the cistern.

Siting

Cisterns can be placed both above and below ground. While above ground installations avoid the costs associated with excavation and certain maintenance issues, cisterns that are below ground benefit from the cooler year-round ground temperatures. To maximize efficiency, cisterns should be located as close to both the supply and demand points as possible. And, to facilitate the use of gravity or lower stress on a pump, the cistern should be placed on the highest level that is workable.

While the catchment area (roof) should not be shaded by trees, the cistern can benefit from the shade since direct sunlight can heat the stored rainwater in the tank and thereby encourage algae and bacterial growth, which can lower water quality. To ensure a safe water supply, cisterns should be sited at least 50 feet away from sources of pollution such as animal stables, latrines, or, if the tank is below ground, from septic fields.

Tank placement should also take into consideration the possible need to add water to the tank from an auxiliary source, such as a water truck, in the event your water supply is depleted due to over-use or drought conditions. For this reason, the cistern should be located in a site accessible to a water truck, preferably near a driveway or roadway, and positioned to avoid crossing over water or sewer lines, lawns or gardens.

Design features

Regardless of the type of tank material you select, the cistern should have a durable, watertight exterior and a clean, smooth interior, sealed with a non-toxic joint sealant. If the water is intended for potable use, the tank should be legally approved (food and drug administration), as should any sealants or paints used inside the tank. A tight-fitting cover is essential to prevent evaporation, mosquito breeding, and to keep insects, birds, lizards, frogs and rodents from entering the tank.

If the cistern is your only water source, an inflow pipe for an alternate water source is advisable. All tanks, and especially tanks intended for potable use, should not allow sunlight to penetrate or algae will grow in the cistern. A settling compartment, which encourages any roof run-off sediment that may enter the tank to settle rather than be suspended in the tank, is an option that can be designed into the bottom of the cistern.

Designing a system with two tanks provides some flexibility that may be of value. In most cases, an additional tank represents added cost, regardless of whether it represents increased capacity. This is because two smaller tanks of, for example, 1,500 gallons each are generally more expensive than a single 3,000 gallon tank. The primary benefit of a multi-tank system is that the system can remain operational if one tank has to be shut down due to maintenance or leaking.

Regardless of tank type chosen, regular inspection and proper maintenance are imperative to ensure reliability and safe, efficient operation. Water is heavy. A 500 gallon tank of water will weigh more than two tons, so a proper foundation and support are essential.

Conveying

Water only flows downhill unless you pump it. The old adage that gravity flow works only if the tank is higher than the kitchen sink accurately portrays the physics at work. The water pressure for a gravity system depends on the difference in elevation between the storage tank and the faucet. Water gains one pound per square inch of pressure for every 2.31 feet of rise or lift.

Many plumbing fixtures and appliances require 20 psi for proper operation, while standard municipal water supply pressures are typically in the 40 psi to 60 psi range. To achieve comparable pressure, a cistern would have to be 92.4 feet (2.31 feet X 40 psi = 92.4 feet) above the home's highest plumbing fixture. That explains why pumps are frequently used, much in the way they are used to extract well water.

Pumps prefer to push water, not pull it. To approximate the water pressure one would get from a municipal system, pressure tanks are often installed with the pump. Pressure tanks have a pressure switch with adjustable settings between 5 and 65 psi. For example, to keep your in-house pressure at about 35 psi, set the switch to turn off the pump when the pressure reaches 40 psi and turn it on again when the pressure drops down to 30 psi.

Water treatment

Before making a decision about what type of water treatment method to use, have your water tested by an approved laboratory and determine whether your water will be used for potable or non-potable uses.

The types of treatment discussed are filtration, disinfection, and buffering for pH control. Dirt, rust, scale, silt and other suspended particles, bird and rodent feces, airborne bacteria and cysts will inadvertently find their way into the cistern or storage tank even when design features such as roof washers, screens and tight-fitting lids are properly installed. Water can be unsatisfactory without being unsafe; therefore, filtration and some form of disinfection is the minimum recommended treatment if the water is to be used for human consumption (drinking, brushing teeth, or cooking). The types of treatment units most commonly used by rainwater systems are filters that remove sediment, in consort with either an ultraviolet light or chemical disinfection.

Filters

Filtration can be as simple as the use of cartridge filters or those used for swimming pools and hot tubs. In all cases, proper filter operation and maintenance in accordance with the instruction manual for that specific filter must be followed to ensure safety. Once large debris is removed by screens and roofwashers, other filters are available which help improve rainwater quality. Most filters on the market are designed to treat municipal water or well water. Therefore, filter selection requires careful consideration. Screening, sedimentation, and prefiltering occur between catchment and storage or within the tank. A cartridge sediment filter, which traps and removes particles of five microns or larger is the most common filter used for rainwater harvesting.

Sediment filters used in series, referred to as multi-cartridge or in-line filters, sieve the particles from increasing to decreasing size. These sediment filters are often used as a pre-filter for other treatment techniques such as ultraviolet light or reverse osmosis filters which can become clogged from large particles. Unless you are adding something to your rainwater, there is no need to filter out something that is not present. When a disinfectant such as chlorine is added to rainwater, an activated carbon filter at the tap may be used to remove the chlorine prior to use.

Activated carbon filters are subject to becoming sites of bacterial growth. Chemical disinfectants such as chlorine or iodine must be added to the water prior to the activated carbon filter. If ultraviolet light or ozone is used for disinfection, the system should be placed after the activated carbon filter. Many water treatment standards require some type of disinfection after filtration with activated carbon. Ultraviolet light disinfection is often the method of choice. All filters must be replaced per recommended schedule rather than when they cease to work; failure to do so may result in the filter contributing to the water's contamination.

Disinfection

Ultraviolet Light (UV) water disinfection, a physical process, kills most microbiological organisms that pass through them. Since particulates offer a hiding place for bacteria and microorganisms, prefiltering is necessary for UV systems. To determine whether the minimum dosage is distributed throughout the disinfection chamber, UV water treatment units should be equipped with a light sensor. Either an alarm or shut-off switch is activated when the water does not receive the adequate level of UV radiation. The UV unit must be correctly calibrated and tested after installation to insure that the water is being disinfected. Featured in the case studies are several systems which utilize ultraviolet light.

Ozone. Ozone is a form of oxygen (0_3) produced by passing air through a strong electric field. Ozone readily kills microorganisms and oxidizes organic matter in the water into carbon dioxide and water. Any remaining ozone reverts back to dissolved oxygen (0_2) in the water. Recent developments have produced compact ozone units for home use. Since ozone is produced by equipment at the point of use with electricity as the only input, many rainwater catchment systems owners use it to avoid having to handle chlorine or other chemicals. Ozone can also be used to keep the water in cisterns "fresh". When used as the final disinfectant, it should be added prior to the tap, but after an activated carbon filter, if such a filter is used.

Chlorine or iodine for disinfecting. Private systems do not disinfect to the extent of public water systems where the threat of a pathogenic organism such as e.coli can affect many households. If the harvested rainwater is used to wash clothes, water plants, or other tasks that do not involve direct human consumption or contact, treatment beyond screening and sedimentation removal is optional. However, if the water is plumbed into the house for general indoor use such as for drinking, bathing, and cooking, disinfection is needed.

Chlorine is the most common disinfectant because of its dependability, water solubility, and availability. Granular or tablet form is available (calcium hypochlorite), but the recommended application for rainwater disinfecting is in a liquid solution (sodium hypochlorite). Household bleach contains a 5.0% solution of sodium hypochlorite, and is proven to be reliable, inexpensive and easily obtained. A dose is one liquid ounce of bleach for each 100 gallons (one and a quarter cups of bleach per 1,000 gallons) of rainwater collected will most likely be sufficient to disinfect the collected rainwater. When disinfecting, never overdose with bleach. Mixing occurs naturally over a day or so, but a clean paddle may be used to accelerate the process. When chlorine bleach is added directly to the storage tank or cistern as described above, the chlorine will have a longer time to kill bacteria thus achieving a better rate of disinfection.

Chlorine feed pumps which release small amounts of solution while the water is being pumped can also be used. Chlorine metering pumps inject chlorine into the water only at the time of use. Chlorine concentrations are easily measured with a swimming pool test kit. A level of between 0.2 mg/L (milligrams per liter) and 1.5 mg/L is recommended. If the level is below 0.2 mg/L, add one liquid ounce of chlorine bleach per 100 gallons of the volume of water in storage (one and a quarter cups per 1,000 gallons) if you are using bleach or adjust the chemical feed pump in accordance with the pump's instructions.

Testing should occur outside the tank. Chlorine is more effective at higher water temperatures and lower pH levels than iodine. Iodine is another water disinfectant that is less soluble than chlorine although it is effective over a pH range of 5 to 9 and displays greater antibacterial activity in water temperatures of 75 to 98.6 degrees Fahrenheit.

Prolonged presence of chlorine where organic matter may be present may cause the formation of chlorinated organic compounds. If chlorine is used as a disinfectant, all organic material from the tank should be screened.

Buffering

Baking soda for buffering. The composition and pH of rainwater differs from chemically treated municipal water and mineral rich well water. Controlling the pH of rainwater by buffering can be easily accomplished by adding one level tablespoon of baking soda to the storage tank for each 100 gallons of water collected. (About four ounces by weight of baking soda for every 1,000 gallons of water collected.) An easy method is to mix this amount of baking soda in a jar of water and pour it into the tank. Mixing will occur naturally over a day or two or a clean paddle may be used to hasten the process, but avoid disturbing materials that have settled at the bottom of the cistern.

CHAPTER FIVE: DESIGN OF STORAGE, SETTLEMENT TANKS AND RECHAGE STRUCTUTES

5.1Design of Storage Tanks

The quantity of water stored in a water harvesting system depends on size of the catchment area and the size of the storage tanks. The storage tank has to be designed according to the water requirements, rainfall and catchment availability.

Basic Data

i. Average annual rainfall
ii. Size of catchments
iii. Drinking water requirements

Suppose the system has to be designed for meeting drinking & cooking water requirement of a 5 member family living in a house in Pilani, with a roof top area of 100 Sqm. Average annual rainfall is 417 mm. Daily drinking & cooking water requirement per person is 10 liters.

Table 5.1 Details of Domestic Consumption

Purpose	Water consumption (liters/capita/day)
Drinking	5
Cooking	5
Ablution	10
Cleaning of utensils and houses	10
Washing Clothes	30
Flushing water closets	45
Bathing	70
Others	25
Total	200

(Source: Code of Basic Requirements for Water Supply, Drainage and Sanitation, Is: 1172, 1983)

We shall first calculate the maximum amount of rainfall that can be harvested from rooftop.

Area of Rooftop	= 100 Sqm.
Average annual rainfall	= 417 mm
Runoff co-efficient for tiles surface (typical case)	= 0.85 (Ref Table 2.3)
Co-efficient for evaporation, spillage and first flush etc.	= 0.80 (Ref. Para 2.7)

Annual water harvesting potential from 100 Sqm. roof top = (Area of roof top) x (Annual rain falls in meter) x (Run off coefficient to be obtained from Table 2.3) X (Constant co-efficient Refer Para 2.7)

= 100 x 0.417 x .85 x .80

= 28.356 cum = 28,356 liters

The tank capacity has to be designed for dry period i.e. the period between two consecutive rainy seasons. With monsoon extending over 4 months the dry season is of 245 days has been considered.

Drinking water requirement for family of 5 persons for dry season

= 245 x 5 x 10

= 12,250 liters

As a safety factor, the tank should be built 20% larger than required i.e.

= (1.2 x 12250)

= 14700 liters

This tank can meet the basic drinking & cooking water requirement of a 5-member family for the dry period. Quantity of rainwater harvested is more than the requirement so surplus quantity may be used for recharging the groundwater acquifer.

5.2Design parameters for settlement tank

Settlement tanks are used to remove silt and other floating impurities from rainwater. Settlement tank is like an ordinary container having provision for inflow, outflow and over flow. Settlement tank can have an unpaved bottom surface to allow standing water to percolate into the soil. Apart from removing silt from water the desilting chamber acts like a buffer in the system.

For designing the optimum capacity of the tank following aspects have to be considered:

i. Size of catchments
ii. Intensity of rainfall
iii. Rate of recharge

Since the desilting tank also acts as buffer tank, it is designed such that it can retain a certain amount of rainfall, since the rate of recharge may not be comparable with the rate of runoff. The capacity of tank should be enough to retain the runoff occurring from conditions of peak rainfall intensity. The rate of recharge in comparison to runoff is a critical factor. However, since accurate recharge rate are not available without detailed geo-hydrological studies. The rates of ground recharge have to be assumed.

The capacity of recharge tank is designed to retain runoff for at least 15 minutes of rainfall of the peak intensity (for Pilani 22.5 mm/per 15 minutes say 25 mm per 15 minutes)

Suppose the following data is available:

Surface area of rooftop catchment (A)	= 100 Sqm.
Peak rainfall in 15 min (r)	= 25 mm
Runoff co-efficient (C)	= 0.85
Then capacity of tank	= A x r x C
	= 100 x 0. 025 x 0.85
	= 2.125 cum
	= 2,125 liters

To obtain indicative peak rainfall for various stations the basic rainfall data for that station may be collected from Indian Metrological office and refer paragraph 3.5 and Figure 3.1 (from which peak rainfall for different duration of rainfall can be obtained for given recurrence interval in years and this recurrence interval can be related to the expected life of settlement tank structure.

5.3Design of recharge structures

Recharge Structures

In places where the withdrawal of water is more than the rate of recharge an imbalance in the groundwater reserves is created. Recharging of aquifers is undertaken with the following objectives:

- To maintain or augment natural groundwater as an economic resource.
- To conserve excess surface water underground.
- To combat progressive depletion of groundwater levels.
- To combat unfavorable salt balance and saline water intrusion.

To achieve the objectives it is imperative to plan out an artificial recharge scheme in a scientific manner. Thus it is imperative that proper scientific investigations be carried out for selection of site for artificial recharge of groundwater.

Detailed knowledge of geological and hydrological features of the area is necessary for adequately selecting the site and type of recharge structure. In particular, the features parameters and data to be considered are; geological boundaries, hydrological boundaries, inflow of water, storage capacity, porosity, hydraulic conductivity, transmissivity, natural discharge of springs, water resources available for recharge, natural recharge, water balance litho logy, depth of aquifer, tectonic boundaries. The aquifers best suited for artificial recharge are those aquifers, which absorb large quantity of water and do not release the same too quickly.

The proper design will include the following considerations

Selection of site

Recharge structures should be planned out after conducting proper hydro-geological investigations. Based on the analysis of this data (already existing or those collected during investigation) it should be possible to:

- Define the sub-surface geology.
- Determine the presence or absence of impermeable layers or lenses that can impede percolation.
- Define depths to water table and groundwater flow directions.
- Establish the maximum rate of recharge that could be achieved at the site.

Source of water used for recharge

Basically the potential of rainwater harvesting, quantity and quality of water available for recharging, have to be assessed.

Engineering, construction and costs

Sound engineering and construction practices are exercised so that construction costs are affordable and projects are economical viable.

Operation, maintenance and monitoring

The rainwater harvesting structures should be replicable and sustainable. These should be free from maintenance as far as possible. Also these should be easy to maintain and operate. There should be arrangements for monitoring the elements of the whole system including the ground water table levels.

Types of Recharge Structures

- Recharge through abandoned Dug Well
- Recharge through abandoned/running Hand Pump
- Recharge through Trench
- Recharge through gravity head Recharge Well
- Recharge through Shaft

Abandoned Dug Well

- A dry or unused dug well can be used as a recharge structure.
- The recharge water is guided through a pipe to the bottom of well or below the water level to avoid scouring of bottom and entrapment of air bubbles in the aquifer.
- Before using the dug well as recharge structure, its bottom should be cleaned and all the fine deposits should be removed.
- Recharge water should be silt free as far as possible.
- It should be cleaned annually preferably.
- It is suitable for large building having the roof area more than 1000 Sqm.
- The run off of first rain should not be allowed to go percolate to the rain water harvesting structure and is allowed to go to the drain by making suitable by-pass arrangement in water carrying pipe systems.

Abandoned/Running Hand Pump

- An abandoned / running hand pump can be used for recharge.
- The structures are suitable for the small building having the roof area up to 150 Sqm.
- Water is diverted from rooftop to the hand pump through pipe of diameter 50 to 100 mm.

- For running hand pump a closing valve is fitted in conveyance system near hand pump to avoid entry of air in the suction pipe.
- Recharge water should be silt free.
- The run off of first rain should not be allowed to go percolate to the rain water harvesting structure and is allowed to go to the drain by making suitable by-pass arrangement in water carrying pipe systems.

Recharge Trench

- It is constructed when a permeable stratum of adequate thickness is available at shallow depth.
- It is a trench of shallow depth filled with pebbles and boulders.
- These are constructed across the land slope.
- The trench may be 0.5 to 1 m wide 1 to 1.5 m deep and 10 to 20 m long depending upon the availability of land and roof top area.
- It is suitable for the buildings having the roof area of 200 to 300 Sqm.
- Cleaning of trench should be done periodically.

Gravity Head Recharge Well

- Bore wells/tube wells can be used as recharge structures.
- This technique is suitable where
    - Land availability is Limited
    - When aquifer is deep and over laid by impermeable strata
- The rooftop rainwater is conveyed to the well and recharged under gravity flow condition.
- Recharge water should be silt free as far as possible.
- The well can also be used for pumping.
- Most suitable for the areas where ground Water levels are deep

- The number of recharging structures can be determined in limited area around the buildings depending upon roof top area and aquifer characteristics.
- The runoff of first rain should not be allowed to go percolate to the rain water harvesting structures and is allowed to go to the drain by making suitable by-pass arrangement in water carrying pipe systems.

Recharge Shaft

- A recharge shaft is dug manually or drilled by the reverse/direct rotary method.
- Diameter of recharge shaft varies from 0.5 to 3 m depending upon the availability of water to be recharged.
- It is constructed where the shallow aquifer is located below clayey surface.
- Recharge shaft is back filled with boulders, gravels and coarse sand.
- It should end in more permeable strata (sand).
- Depth of recharge shaft varies from 10 – 15 m below ground level.
- Recharge shaft should be constructed 10 to 15 m away from buildings for the safety of building.
- It should be cleaned annually preferably by scraping the top layer of sand and refilling it accordingly.

Maintenance of Recharge Structures

Roof Top Rain Water Harvesting for ground water recharge involves injection of rainwater into the aquifer through recharge trench cum tube wells under gravity flow. The surface water although treated through the filter bed may cause clogging after comparatively short periods of injection. In this case though the precaution is taken, there is a probability of silt being injected into the recharge wells and may cause clogging. Short periods of pumping quickly remove the clogging particles and improve the recharge capacity. Annual redevelopment of recharge wells by air compressor is recommended for improving the recharge capacity of trench cum recharge wells. Moreover silt deposited on sand bed also reduces the recharge rate. This also needs periodic removal of the finer material by scraping.

Selection of Recharge Structure

The types of Recharge structures to be considered for different areas (Alluvial areas or Hard Rock areas) for various roofs are shown in Table 5.1.

The Whole complex/colony can be suitably divided in various clusters and one of the above systems appropriate to the roof size and underground characteristics may be selected for use.

General Recommendations for Rain Water Harvesting

Guidelines for action plan for artificial recharge project.

- Collect basic data on topography, rainfall pattern of that area, hydrogeology aquifer situation, and land-source water availability. Identify the methods, which are most suitable.
- With reference to the local conditions of the area further identify the most appropriate techniques of artificial recharge suitable at various sites/ locations on the basis of total available volume of rainwater that can be harvested and the location of available aquifer. Whether it is at shallow depths i.e. 6 to 8 meters from ground level or at sufficient depths i.e. more than 8 meters from ground level.
- Determine the number of each type of artificial recharge structure needed to achieve the quantitative targets. The recharge structure should be designed with volume of water it may store for equivalent of 24 hours rainfall and surface area of run-off for which the recharge structure has been considered, without giving any allowance for percolation during this period of 24 hours.

- For individual structure at different locations, finalize the design the design specifications from the details given in case studies. If required, the necessary advice from local Geological Department or Central Ground Water Board may be obtained.

Table 5.2 Summary for Selection of Recharge Structures

Roof Area Sqm	Total Rainfall Volume for considering Delhi (Cum)	Volume Available for recharge 80 % Cum	Type of Structure recommended for recharge	
			Alluvial Area	Hard Rock Area
50	30	24	Recharge pit/hand pump	Recharge pit/hand pump
100	60	48	“	“
150	90	72	“	“
200	120	96	Trench	Trench/ hand pump
300	180	144	“	“
400	240	192	Gravity head recharge well	Gravity head recharge well
500	300	240	“	“
600	360	288	“	“
800	480	384	“	“
1000	600	480	“	“
1500	900	720	“	Recharge Shaft/dug well
2000	1200	960	“	“
2500	1500	1200	Recharge shaft/dug well	“
3000	1800	1440	“	“
4000	2400	1920	“	“

5000	3000	2400	“	“

(Source: Central Ground Water Board)

- Finalize the design of the conveyance system required to bring the source water to the recharge structure site and the treatment required in the form of settlement tanks.
- Plan the required monitoring system to evaluate the efficiency of recharge scheme and ensure regular maintenance of recharge structures before onset of monsoon every year.

In a given plot attempt should be made to keep the maximum plot area as katcha area which allows rainwater for percolation to ground water.

The rainwater from season’s first rain should normally not be used for percolation to recharge structure because it contains pollutants from the air and catchment surface. For such water suitable arrangement for by pass in pipe system should be introduced.

A suitable provision should be made if possible to allow rain water to percolate to ground water after passing it through settlement tank because such rain water contains silt which is deposited on sand bed and reduces the percolation rates.

The recharge structure should be made on a plot at the places of lower levels elevations so that rainwater may flow towards it under normal gravitation flow.

On a vast and sloppy land patch, the contour bunds preferably of mud with height varying from 15 cm to 30 cm should be made to store run off temporarily over the katcha land area, thus allowing more time for percolation of water to the ground water and arresting the flow of run off to the drains / sewers.

For recharge of run off from roads suitable arrangements in the footpath by introducing some katcha area should be made.

In large residential and office complexes the drive ways, pucca path and areas should hand some katcha area which may facilitate rain water to percolate to ground water.

Ideal conditions for rain water harvesting and artificial recharge to ground water artificial recharge techniques are adopted where:

- Adequate space for surface storage is not available specially in urban areas.
- Water level is deep enough (more than 8 mtr) and adequate sub-surface storage is available.
- Permeable strata are available at shallow/ moderate depth up to 10 to 15 mtr.
- Where adequate quality of surface water is available for recharge to ground water.
- Ground water quality is bad and our aim is to improve it.
- Where there is possibility of intrusion of saline water especially in coastal area.
- Where the evaporation rate is very high from surface water bodies.

The decision whether to store or recharge rain water depends on the rainfall pattern of a particular region.

- If the rain fall period between two spells of the rain is short i.e. two to four month, in such situation a small domestic size water tank for, storing rain water for drinking and cooking purpose can be used.
- In other regions where total annual rain fall occurs only during 3 to 4 months of monsoon and the period between two such spells is very large i.e. 7 to 8 months, so it is feasible to use rain water to percolate to the ground water aquifers rather than for storage which means that huge volumes of storage container are required.

CHAPTER SIX: CASE STUDIES

Central Ground Water Board, Western Region, Jaipur has prepared an Conceptual plan for schematic design and implementation of Roof Top Rain Water Harvesting Structure for FD III building at Birla Institute of Technology and Science, Pilani, Rajasthan. This case study deals with rooftop/ Pavement Rain water run-off harvesting structure. Birla Institute of Technology and Science, Pilani has experienced sharp decline in water level due to excessive withdrawal of ground water to cater down the water supply demands for domestic as well as irrigation. This may lead to complete drying up of the aquifers. Hence the situation needs to develop and implement suitable management strategy. This needs to make artificial recharge to ground water by various feasible techniques. The proposed Roof Top Rain Water Runoff Harvesting for artificial recharge to ground water is one of the available management options which will help in this perspective.

Base Information of Problem Area

1.	Location	Birla Institute of Technology and Science, Pilani, FD-3 Building Latitude-28^0 21’ 30” Longitude-75^0 36’ 30”
2.	Area	Pilani Urban (Surajgarh Block)
3.	Agriculture	Top soil-Sand fine to medium with kankar
4.	Climate	Type of climate: Semi arid Rainfall: • Normal annual monsoon rainfall- 353.4 mm • Average annual rainfall (1963-2001)- 417.0 mm • Rainfall distribution- 90% of rain during monsoon • Average monsoon rainy days- 25 Temperature: • Mean maximum temp- 46 ^{0}C

		• Mean minimum temp- 1.5 ^{0}C Average Humidity: • 77% (8.30 hrs) 37% (17.30 hrs) Potential Evapotranspiration: • 1744.7 mm (Jaipur Station) Max wind speed: • 11.6 kmph

Justification of the Scheme

S. No.	Nature of problem requiring Artificial Recharge of Ground Water	Description
1.	Quantity Problem	• Extent of area showing water level decline and depleting ground water resources. The alluvial aquifers of Pilani urban area covers an area of 779 sq. km are under the category of "over exploited" (as in 01.01.2001). Excessive withdrawal of ground water of the magnitude of 41.5429 MCM/yr may lead to complete drying of the alluvial aquifers with in 10-15 yrs. • Average decline in water levels is- 0.65 m/yr. • Drying up of wells • Declining of water level needs regular deepening of bore holes and lowering of additional pipes in tube wells/hand pumps. • Higher cost for pumping of ground water from various structures due to more energy from deeper

		water level.

Hydrogeology Information

1.	Geological Formation	95 m thick quaternary formations (fluvial as well as Aeolian) underlain by the quartzite of Delhi super group.
2.	Nature of unsaturated zones	Older alluvium of quaternary age, moderately porous and permeable, saturated below 60 m downward.
3.	Aquifer system	Unconfined to semi confined
4.	Hydraulic characteristics of aquifers	Transmissivity- 318 m^2/day Storativity- 3.4 x 10^{-3}
5.	Depth to water level	60.85 mbgl (2001)
6.	Elevation of ground with respect to msl	275 meters above MSL
7.	Long term fluctuation in water level	Decline in water level of about 5.20 m from 1993-2001, i.e. 0.65 m/yr
8.	Ground water flow direction	North westerly
9.	Existing ground water structures	Dug cum bore well = 9 Bore well = 8
10.	Ground water resources as on 01.01.2001 (Surajgarh block)	• Annual recharge- 33.8751 MCM • Annual irrigation draft- 55.6080 MCM • Annual domestic draft- 7.9672 MCM • Allocation of domestic and industrial requirement as projected for the

		year- 19.8100 MCM • Ground water balance- -41.5429 (mining of ground water annually) • Stage of ground water development-187.68 % category- over exploited.
11.	Ground water level trend	significant long term decline in pre-monsoon as well as in post monsoon water level
12.	Hydrochemistry	concentration of chemical constituents in ground water EC-1600 micromhos/cm at 25 ^{0}C Cl- 232 ppm F- 0.80 mg/liter NO_3- 49 ppm SO_4- 58 ppm Total hardness- 160 ppm
13.	Sub surface potential for ground water recharge	thickness of unsaturated zone (below 4 mbgl)- 56 m alluvium surplus water available for recharge

mbgl: Meter below ground level

Availability of Surplus Runoff Information

1.	Roof top run-off area	3600 sq. meter
2.	Pavement/road run-off area	nil
3.	Total considered run-off area	3600 sq. meter
4.	Availability of surplus rain water run-off which can be harvested for artificial recharge	1278 m^3/annum
5.	Rain water run-off at 30 mm/hr rainfall intensity	91.80 m^3/hr

Artificial recharge structure proposed

Structure proposed	Number
Silting pit	1
Filter pit cum reservoir	1
Tube well chamber	1
Tube well	1

Design and Dimension of Structure proposed

Details of structure/work	Dimensions
Silting pit (brick masonry 0.35 m)	2.5(L) x 2.0(W) x 3.25(D) mtrs for 0.25 Magl
Filter pit cum reservoir (brick masonry 0.35 m)	3.00(L) x 2.00(W) x 3.50(D) mtrs for 0.25 Magl
Tube well chamber	2.60(L) x 1.5(W) x 4.00(D) mtrs for 0.25 Magl
Construction of recharge tube well at the bottom of the tube well chamber	0.254 mtr diameter tube well with 90 m depth (well assembly as per site condition)
Providing porous filter media in the filter pit	Providing the porous media in the filter pit for 1.0 m height from bottom upward as below Sand 0.5-1.0 mm (0.33 m) Sand 1.0-2.0 mm (0.33 m) Gravel 3-5 mm (0.33 m)
Laying of inlet pipe from silting pit to filter pit	RCC non pressure pipe of 300 mm diameter
Installation of floating material retention cage towards the run off inlet side portion of the silting pit	Below 0.2 m depth level (MS flat beds of 20 mm x 3 mm and welded mesh of 16 gauge steel wire with 5 x 5 mm openings)
Installation of overflow pipe from recharge trench to road side	RCC pressure pipe of 300 mm diameter

A provision for adding bleaching powder is to be kept for prevention of pollution in roof top rainwater harvesting structure.

Optimum storage and recharge capacity of the system designed

Rain fall intensity for which the system has been designed 30 mm/hr	30 mm/hr
Quantum of run off to be available for artificial recharge from the concerted area taken into consideration at rain fall intensity 30 mm/hr	91.8 m3/hr
Storage capacity of the harvesting system	
Silting pit	15 m^3
filter pit cum reservoir	15 m^3
tube well chamber	9 m^3
storage of water in tube well	6 m^3
total storage	45 m^3
Anticipated recharge rate for the structure designed	30 m^3/hr
Anticipated life of recharge scheme	20 yrs
Expected benefits	
Quantity of water likely to recharge annually	1278 m^3/anum
Quantity of water likely to recharge during life span	25560 m^3

Lithological Graph of Bore Hole Drilled at Pilani

Lithology	Depth range (m)		Depth (m)
	From	To	
Surface soil	0	6	6
Sand, fine	6	9	3
Sand with kankar	9	12	3
Clay, with kankar	12	18	6

Sand, fine to medium	18	27	9
Sand, with clay and kankar	27	33	6
Sand, fine	33	42	9
Sand, fine with little clay and kankar	42	48	6
sand, fine to medium	57	63	6
Sand, and kankar	63	66	3
Sand with clay & kankar	66	69	3
Sand, fine with kankars	69	75	6
Sand, with clay and kankars	75	78	3
Clay, with pieces of flaky minerals	78	84	6
Pieces of quartz, feldspar and flaky minerals	84	95	11

(Static water level: 50 m; Discharge: 3000 gph)

Depth to Water Level Data of Piezometer Located at Pilani

Aquifer- older alluvium; Total depth 69.69 m bgl.

Table 6.1: Depth to water level data

Year	Pre-monsoon (mbgl)	Post monsoon (mbgl)	Fluctuation (m) +rise, -fall
1993	-	55.20	-
1994	55.40	55.90	-0.50
1995	56.60	56.72	-0.12
1996	55.50	55.90	-0.40
1997	56.75	56.56	+0.19
1998	59.50	59.22	+0.28
1999	59.40	60.10	-0.70
2000	59.72	60.20	-0.48
2001	60.85	60.40	+0.45

Average decline – 0.65 m/yr

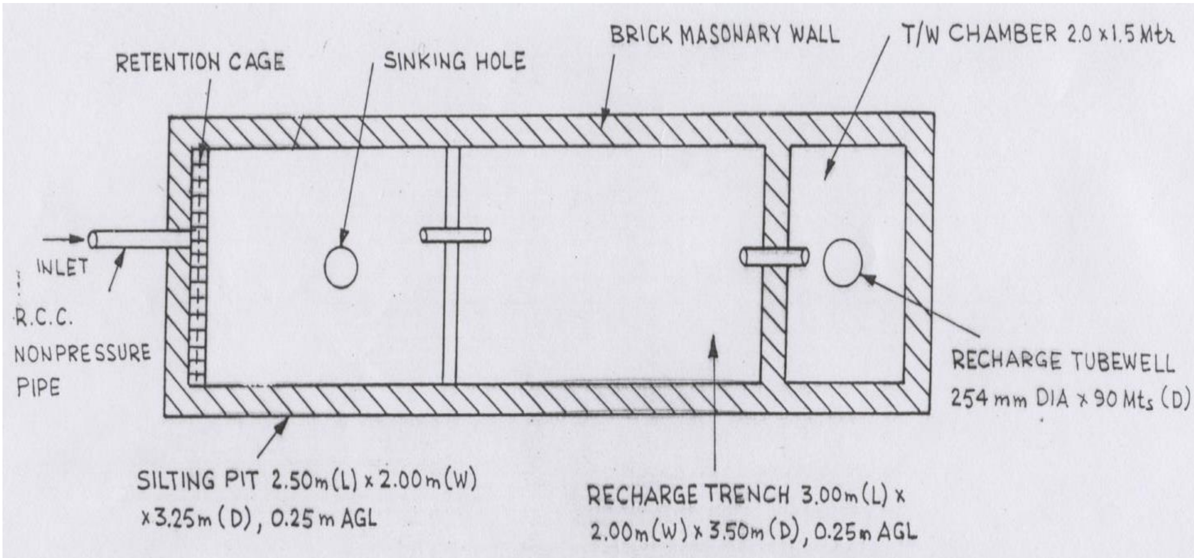


Figure 6.1 Desilting Unit with Recharge well structure (Plan)

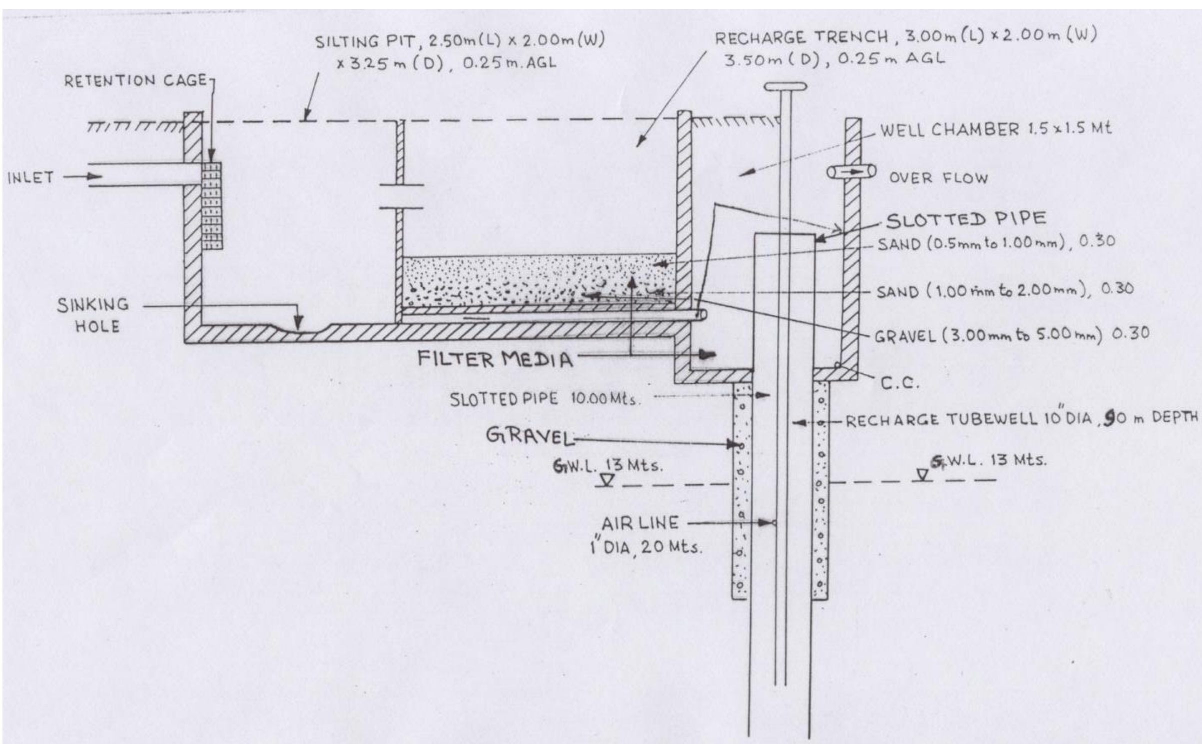


Figure 6.2 Desilting Unit with Recharge well structure (section)

Forecasting Estimate for Recharge Structure

S. No.	Particulars	Amount (Rs.)
1.	Supplying and fixing P.V.C. pipe of 110 mm. diameter including laying and jointing with accessories like tee, band etc, 300.00 meter @ Rs. 280/ per meter.	84,000/-
2.	Supplying and fixing P.V.C. pipe of 160 mm. diameter etc. 500.00 meters. @ Rs. 350/meter.	1,75,000.00
3.	Supplying and fixing P.V.C. pipe of 200 mm. diameter etc. 200.00 meter @ Rs. 500/- per meter.	1,00,000.00
4.	Lump Sum provision for scaffolding required for lying pipes and construction of small pillars.	60,000.00
5.	Construction of man holes etc. 40 Nos. @ Rs. 2700/ each	1,08,000.00
6.	R.C.C. non pressure pipe of 300 mm. dia 20.00 mt. including harvesting etc. @ Rs.455 per meter.	9,100.00
7.	Silting pit 2.50x2.0 = 5 Sqm. @ Rs. 4000/Sqm.	20,000.00
8.	Construction of filter pit cum reservoir 3.0 x 2.0 = 6 Sqm. @ Rs. 4000/Sqm.	24,000.00
9.	Construction of recharge tube well chamber 2.0 x 2.0 = 4.0 Sqm. @ Rs. 6000/Sqm.	24,000.00
10.	Construction tube well 254 mm diameter 90 meter @ 1238/m.	1,11,420.00
11.	Pipe assembly 90 meter. @ Rs. 1112 meter.	1,00,080.00
12.	Assembly lowering with gravel packing 90 meter @ Rs. 295 per mt.	26,550.00
13.	Development of tube well 90 meter @ 295/mt.	26,550.00
14.	Retention cage/fine screening below filter media 1800 kg. @ Rs. 40 per kg.	72,000.00
15.	G.I. slotted pipe 25 mm. diameter for air line 90 m. @ Rs. 150/mt.	13,500.00

16.	M.S. ladder 10.0 meter @ Rs. 500 per mt.	5,000.00
17.	Gravel 3 mm. to 5 mm. 3.0 cum. @ Rs. 2500/cum	7,500.00
18.	Filter media 0.50 mm. to 2.0 mm. 4.0 cum. @ Rs. 2000/Cum.	8,000.00
19.	R.S. Joist for filtration chamber 300 kg. @ Rs. 30 per kg.	9,000.00
20.	Lump sum provision for disinfecting agent.	2,000.00
21.	Lump Sum. Provision for un seen item	50,000.00
	Total	10,35,700.00
	Add 4.5% for contingency charge	46,606.00
	Add 1% for quality control	10,357.00
	Add 10% for prorate	1,03,570.00
	Grand Total	11,96,233.00

Rainwater Harvesting and Well Replenishing project at Raila

This case study shows the Rainwater Harvesting and Well Replenishing (RHWR) project at *Raila* Village 5 km from campus of BITS, Pilani. In fact it will build a network of water storage clusters. A cluster may consist of several tanks attached to a group of houses. In turn, these clusters will be connected to a community tank. The proposed scheme presented for rainwater harvesting is based on four types of rain water collection tanks. Let us denote the tanks by A, B, C and D. Storage capacity and over flow from each type of tank is shown in Table 6.2. Surplus water from each type of tanks will be overflowed to the next type of tank and at last to the community tank from where it will recharge the groundwater. These are shown in Figure 6.3. To find the capacity of various tanks, calculation (Table 6.2) were carried out to meet the desired capacities, requirements and supply at different locations.

Proposed scheme

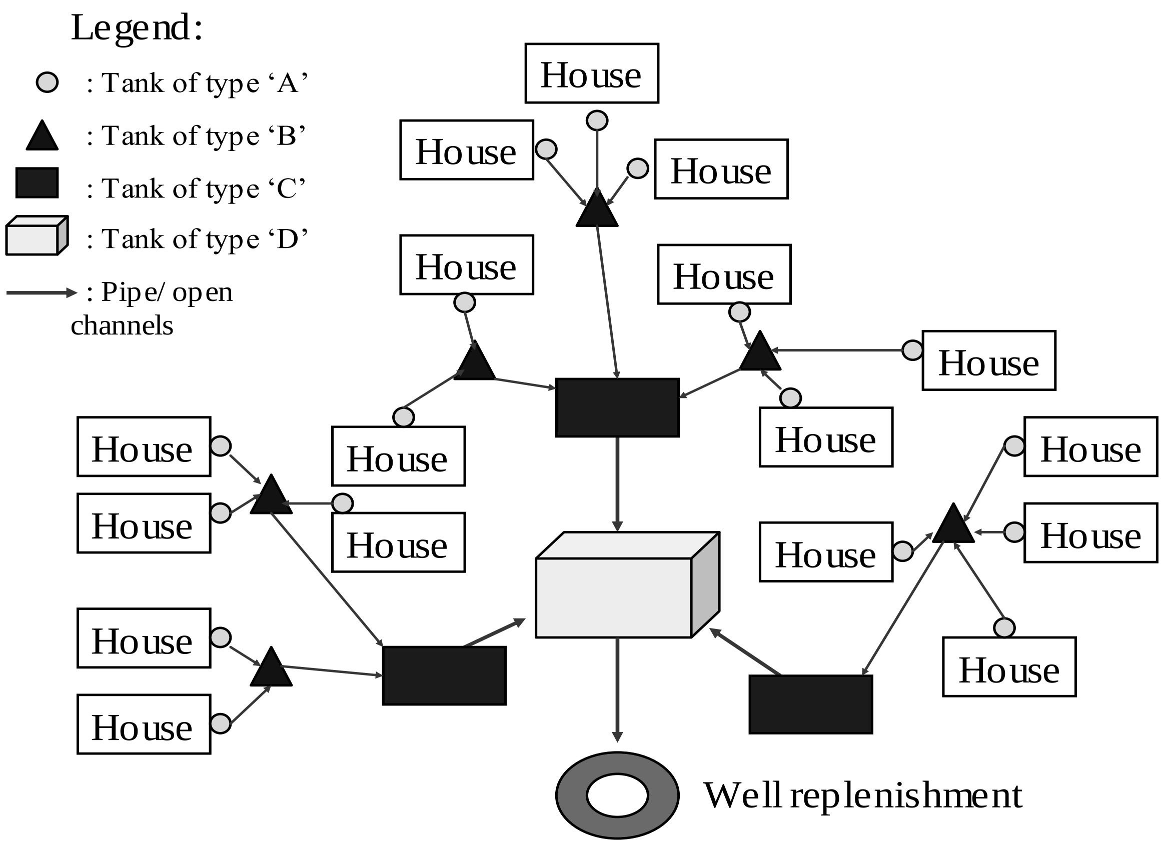


Figure 6.3 Proposed scheme of Rainwater harvesting system

- **Type A tank:** This tank is built for household level, intended to collect roof top water. These tanks will be built at each house and their capacity will be dependent upon roof top area. There will be 80 tanks of this type and each will be of 22000 liters capacity.

- **Type B tank:** This tank is fabricated for a community purposes. The community will be defined by a cluster of houses in a town/village. Its capacity will be decided by number of connecting house. This tank will be collecting ground intercepted water passing through a filter media. Filter media will be running over a perforated pipeline that in turn will be connected to tank. Filter media will be made of sand and gravel layer. The stored water can be used for bathing and washing purposes.

- **Type C tank:** This type of tank will be collecting overflow from Type B tank and also from ground intercepted water through filter media. Its use is mainly for agricultural purposes.

- **Type D tank:** Overflow from type C tank will be directed to a larger capacity tank, Type D tank. Overflow from here can be used for ground recharge through a ground recharge well. Water from this tank can be used for agricultural tanks.

- **Filter Media:** The filter media will be composed of different layers of sand and gravel (grain size from 0.15-20 mm). The topmost layer is of large aggregates of grain size 12 to 20 mm followed by finer particles of grain size 0.15 to 2 mm. The last two layers are of particle size 2-6 and 6-12 mm respectively. Finer particle layer plays the most important role in removing smaller contamination and also effects infiltration rate.

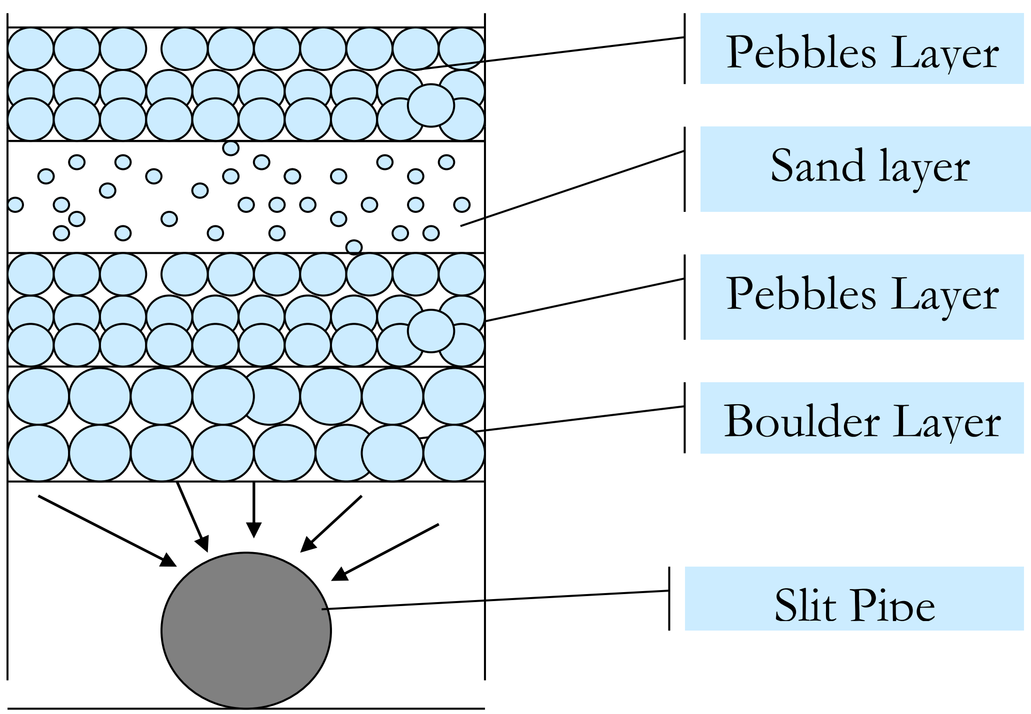


Figure 6.4 Cross Section of Perforated Pipe with Filter Media

Table 6.2: Calculation of capacity of tanks to be installed in Raila village based on demand and supply at different location of tanks

S.No.	Supply from	Demand at	Balance
1.	Rooftop of 80 houses = 80(houses)X100(sqmt)X0.417(mt) X0.85(coeff) = 2836 cum	A type tanks = 80(houses)X22(cum) + 80(houses)X5(persons)X365(days)X 10(liters)/1000 = 3220 cum	2869-1760 = -384.4 cum
2.	Balance of A type tanks + pipe network from A type tanks to B type tanks = ()+4(mt)X746(mt)X0.417X0.3 = 373 cum	B type tanks = 21X50 = 1050 cum	373-1050 = -677 cum
3.	Balance of B type tanks + pipe network from B type tanks to C type tanks = ()+4X1995X0.417X0.3 = 998 cum	C type tanks = 3X100 = 300 cum	998-300 = 698 cum
4.	Balance of C type tanks + pipe network from C type tanks to D type tanks = 698+4X500X0.600X0.3 = 948 cum	D type tank = 1X675 = 675 cum	948-675 = 273 cum = 2,73,000 liters

- **Perforated pipe:** This is a perforated pipe lying below filter media collecting filtered water and passing it to a storage tank. Slit size in pipe is determined keeping in mind filter media constituents.

Construction Methodology

Simple construction technology is suitable for rainwater harvesting projects. The type of technology and materials used at Raila village for different components are discussed here.

Storage Tanks

- **A Type Tank**:Storage tanks at individual houses are under ground tanks constructed in Brick masonry with cement sand (1:4) mortar. It is finished with 15mm cement plaster (1:3) and by neat coat of cement. Bottom of the tank is of 6" thick PCC (1:3:6) and is finished with 40 mm CC flooring (1:1.5:3). Tank is covered with 5" thick RCC slab. It is having a opening of size 450mmX450mm to take out water and also to clean the tank. At the inlet of the tank a filter unit is provided. This filter unit is made up of 20 liters steel drum filled with filter media. Filter unit bottom is perforated to allow the water to enter the tank after getting filtered through it. The materials used in filter unit are discussed above. An outlet is there for taking the overflow water from the tank to the next tank i.e. B type tank.
- **B, C, D Type Tanks**: These tanks are also under ground tanks but these will be of completely RCC tanks. These tanks will be having cover for cleaning as well as for taking out water. These are circular tanks covered by dome shaped roofs. One opening will be at top for the purpose of ventilation.

Water Conveyance System

- **At House Level:** PVC pipes are provided to convey the water from rooftop to the tanks. Vertical pipes are plain pipes but under ground horizontal pipes are one third perforated at the top side. Under ground pipes are laid in slope of 1:100 and 1.0' feet deep from ground level. These pipes are covered with the filter media as discussed above. Care should be taken while laying and jointing the pipes so that there should be no leakage in future.

- **At Village Level:** Here only under ground pipes will be there and all other things are similar to the house level pipes.

Proposed Methodology of Rainwater harvesting system using GIS

Manual surveying was done and the map of the village was created using AUTOCAD. After creation of the map GIS software's ARC GIS 8.3 and ARC VIEW 3.1 were used for the analysis part. Georeferencing was done to match with the real world coordinates and then digitization was done. Potential points for construction of tanks were identified. The catchment area was decided according to the place available and buffers were created accordingly. Lengths of the pipes required were calculated from the analysis and cost was worked out. The different phases of the analysis is shown below

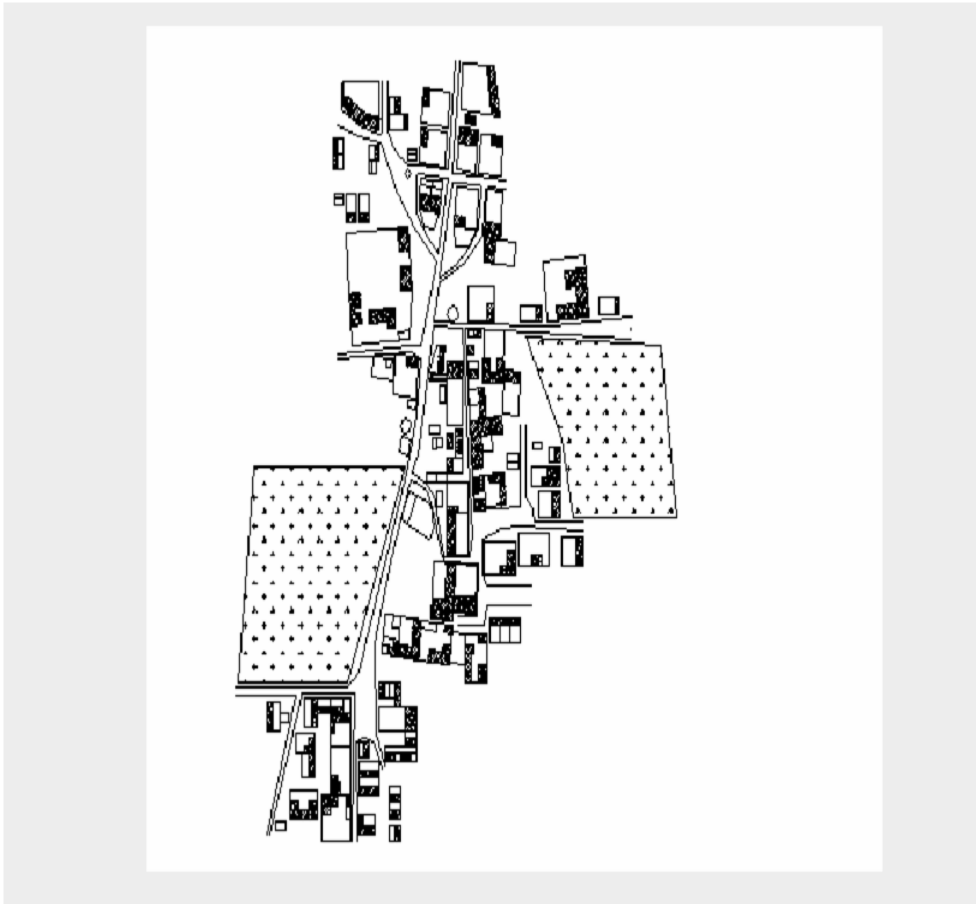


Figure 6.5: A picture showing Raila village's housing plan

- **Creation on map of the village**

  Surveying was done and then the map of the village was drawn using AUTOCAD. The village has 80 buildings including one school building. There are two wells in the village out of which one well is abandoned.

- **Analysis for catchment areas (Figure 6.6)**

Potential points for location of tanks were identified and then analysis for different catchment areas was done.

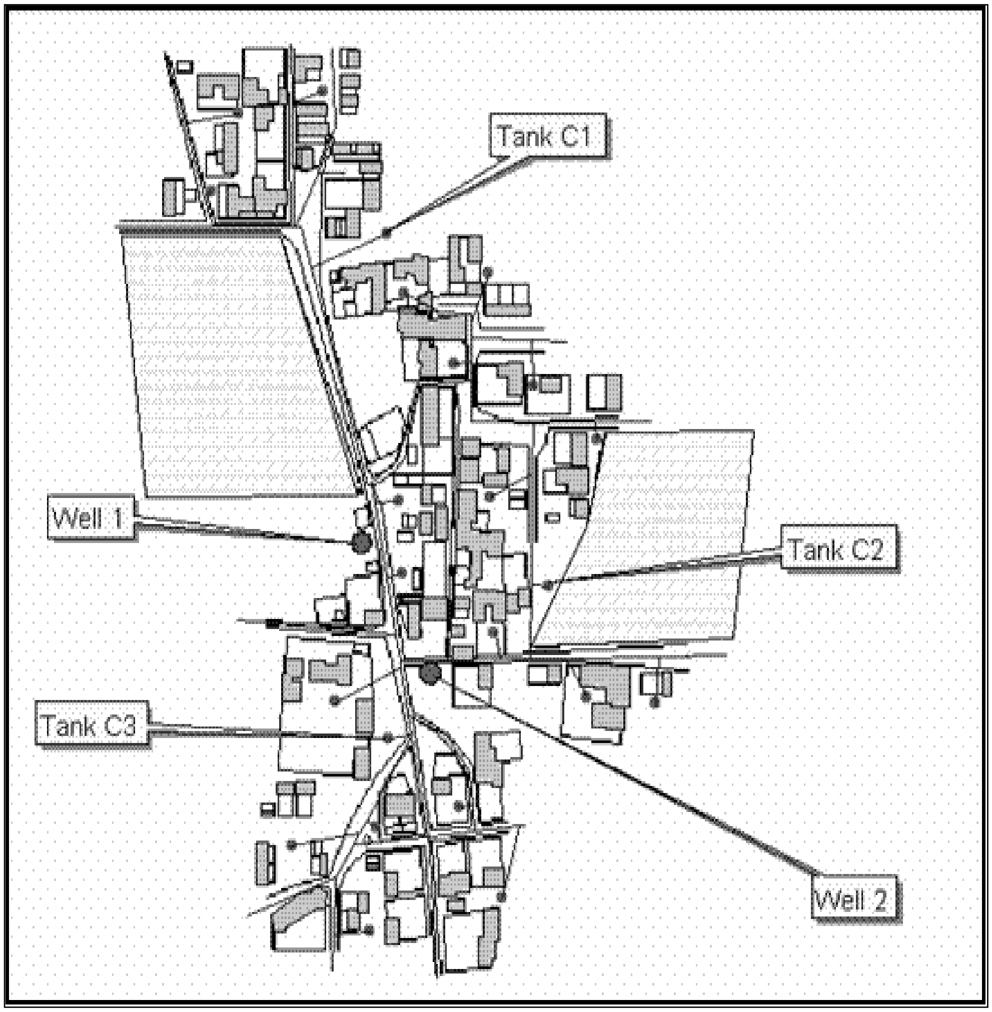


Figure 6.6

- **Analysis for 20m catchment area (Figure 6.7)**

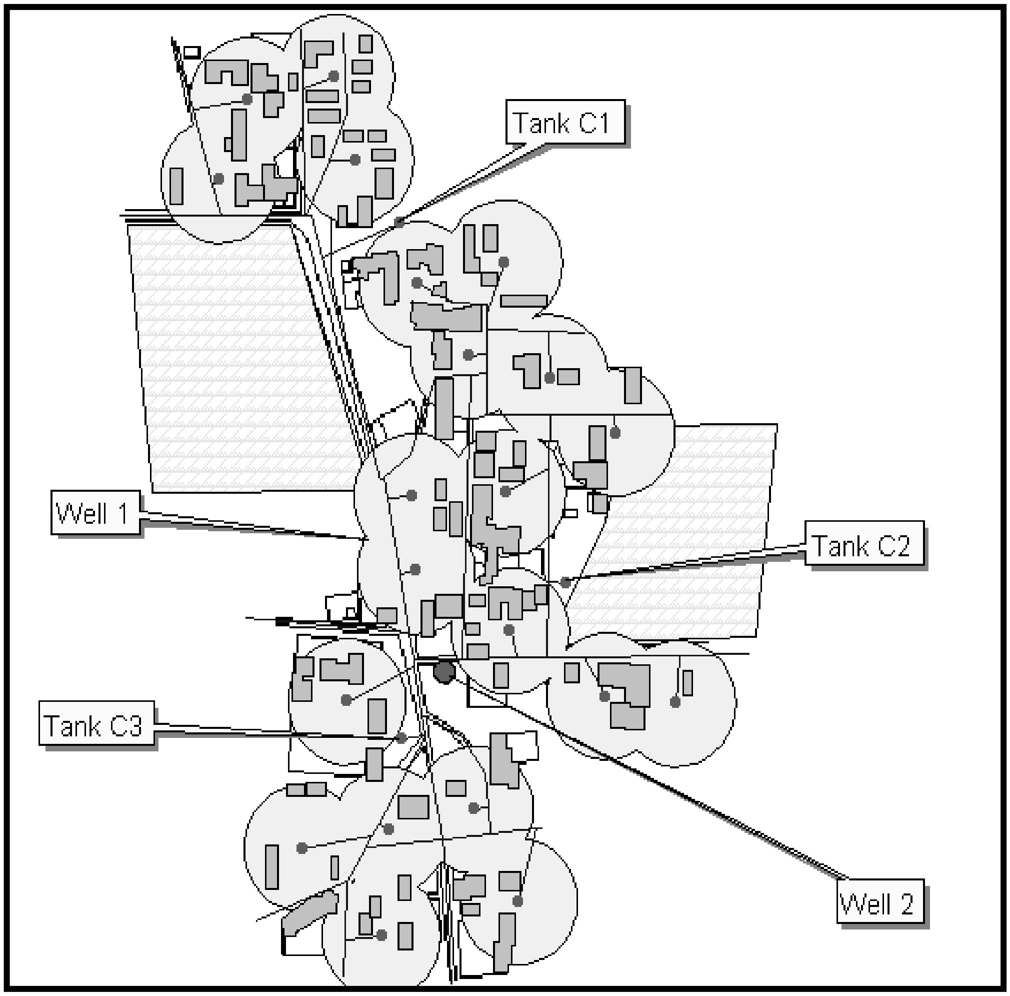


Figure 6.7

- **Analysis for 15m catchment area (Figure 6.8)**

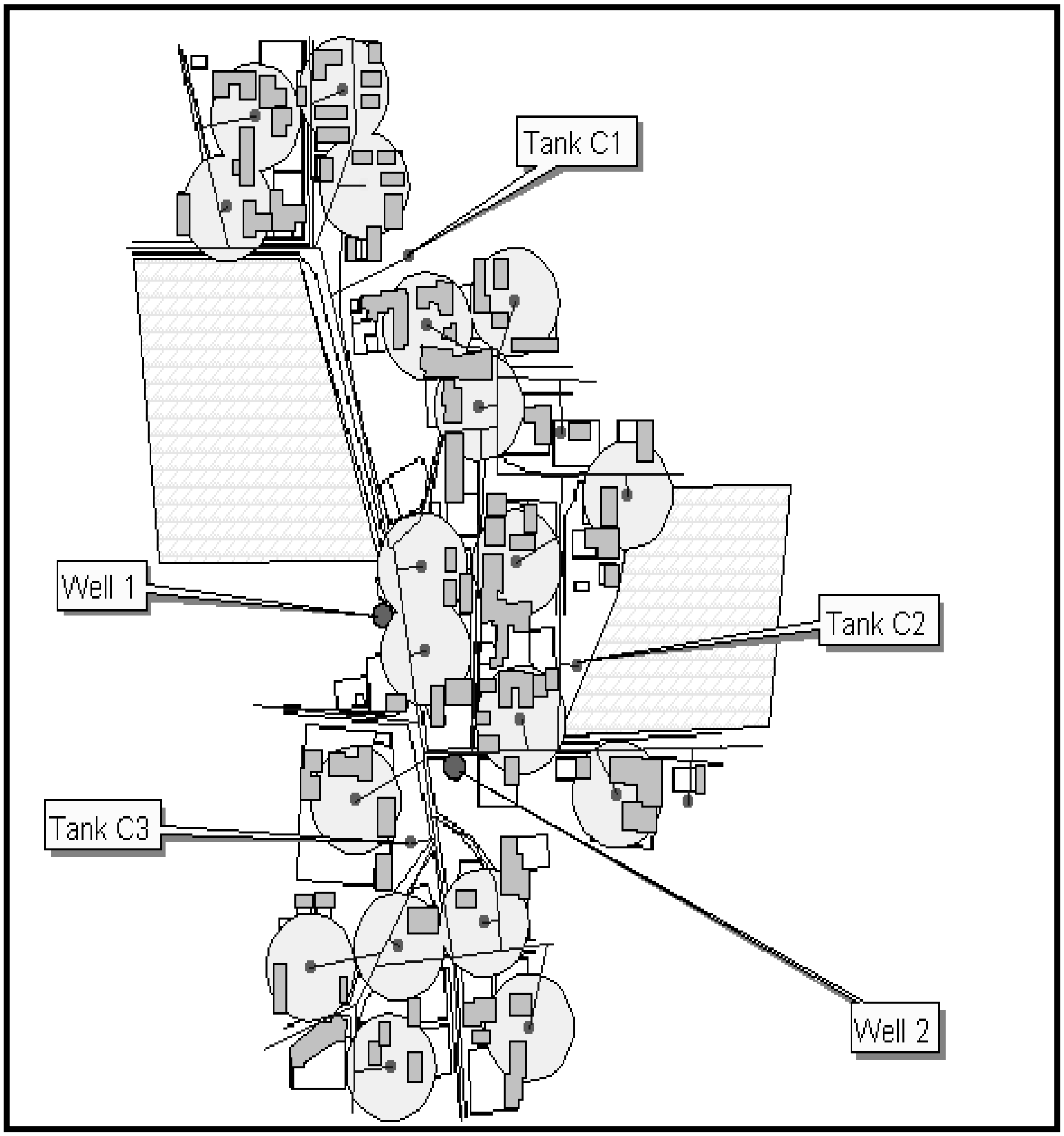


Figure 6.8

- **Combined analysis for catchment areas (Figure 6.9)**

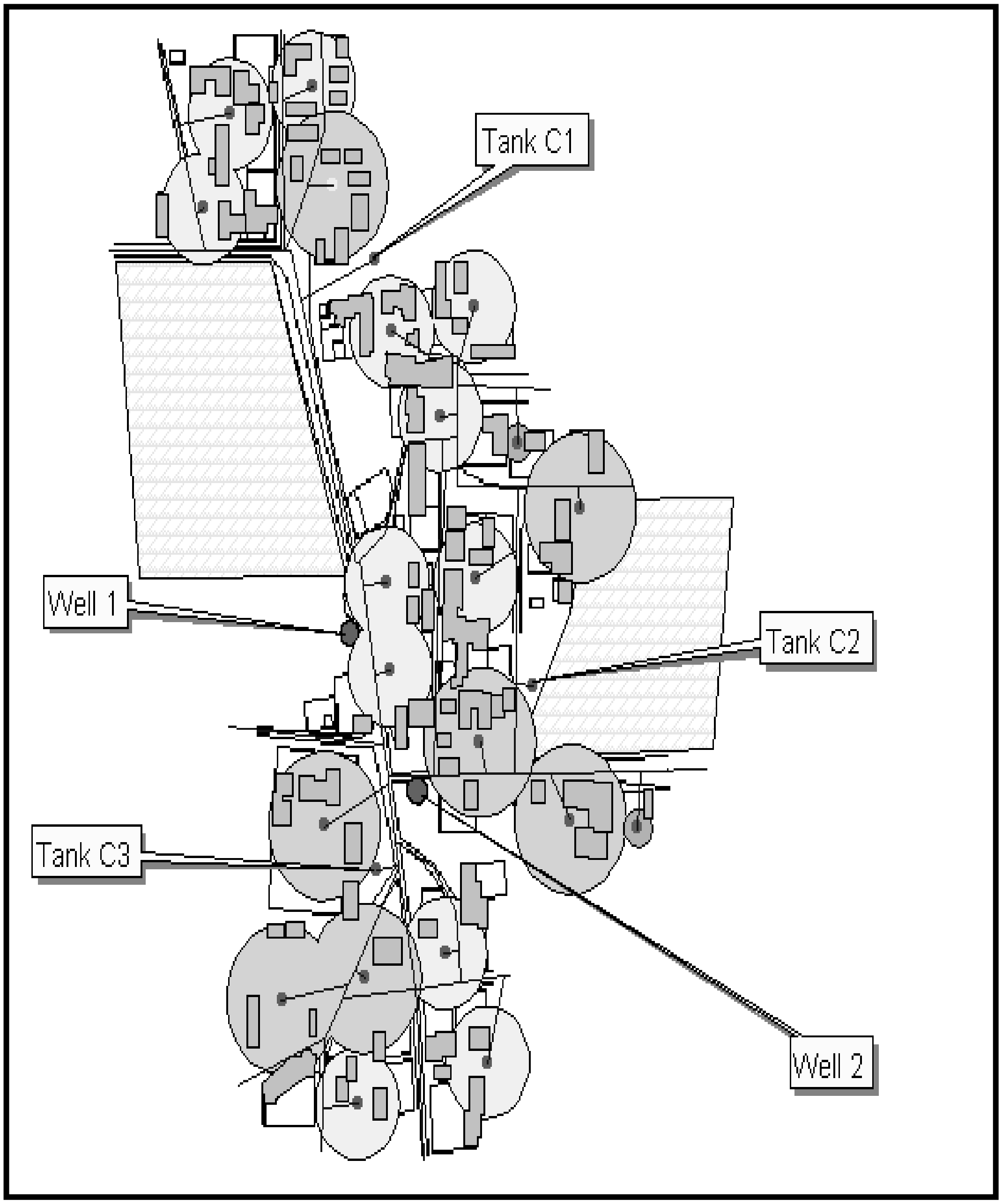


Figure 6.9

From the above three figures we choose 15m catchment area and designed the tank capacity accordingly. The reason for choosing 15m area is that as we can see from the figures 15m buffer covers almost all the houses so 20m doesn't give any advantage and also it unnecessarily increases the cost. Also if we go for combined catchment areas then we have to design tanks accordingly which unnecessarily increases our cost.

- **Pipe network from each house to Tank B**

The figure below shows the pipe network from each house to tank B. The lengths for the pipes were calculated from the analysis using ARC GIS 8.3.The lengths required are shown in Table 6.3.

Figure 6.10

- **Location of Tank C**

After finding suitable locations for Tank B, we have to find suitable locations for tank B and based on the catchment area available we have to design the tank capacity accordingly.

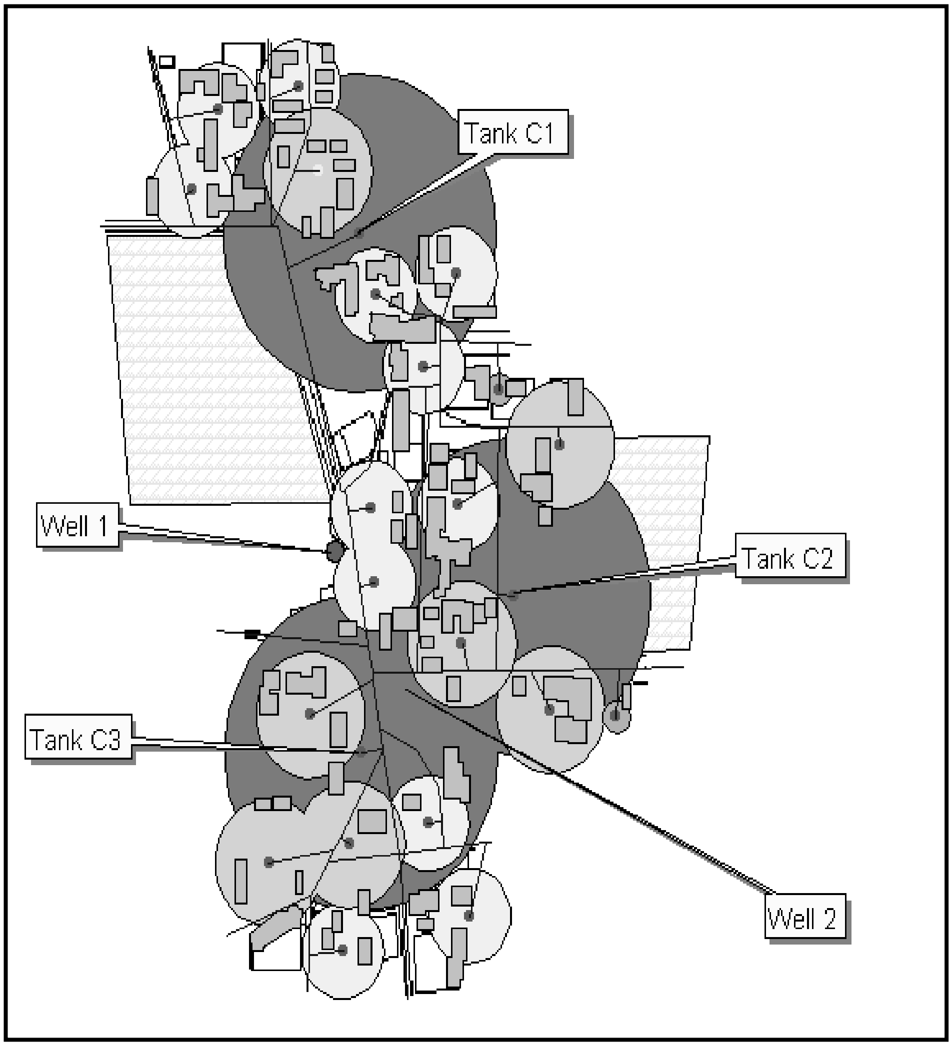


Figure 6.11

- **Length of pipe required for connecting tanks of Type B to Tank C**

Table 6.3:

Tank C 1	117.26
	78.86
	93
	67.88
	187.51
	163.3
	196.34
Tank C2	136.95
	83.37
	56.39
	129
	102.38
	47.50
	53.33
	83.32
Tank C3	52.80
	42.63
	56.21
	64.53
	89.37
	92.58
Total length (m)	***1994.51***

- **Length of pipes required from each houses to Tank B:**

Table 6.4:

S.No	Length of pipe (m)	S.No	Length of pipe (m)
1	6.69	45	8.61
2	3.93	46	7.17
3	5.14	47	11.21
4	3.95	48	14.14
5	11.65	49	10.73
6	9.50	50	10.89
7	15.66	51	7.34
8	5.85	52	11.26
9	11.94	53	4.09
10	4.62	54	10.21
11	5.82	55	15.18
12	7.71	56	11.07
13	14.24	57	10.81
14	14.84	58	4.74
15	11.67	59	4.47
16	6.79	60	4.1
17	15.85	61	16.18
18	10.64	62	7.37
19	6.43	63	11.44
20	8.29	64	6.84
21	6.07	65	17.33
22	5.32	66	8.56
23	4.48	67	17.71
24	5.61	68	9.83
25	6.44	69	17.43
26	4.43	70	17.63

27	7.85	71	5.79
28	10.05	72	15.83
29	5.46	73	5.69
30	8.44	74	16.11
31	5.17	75	3.34
32	10.27	76	6.93
33	3.57	77	5.93
34	3.33	78	10.6
35	22.16	79	11.85
36	10.77	80	4.78
37	11.52	**Total**	**746.48**

Cost Model for Raila Village

Here cost estimation for the proposed scheme is given. The estimation is done for the required components given below.

- Total No. Houses= 80 Houses
- Roof Top Area (App.) = 100 Sqmts.
- Capacity & No. of Tank Type A= 22000 Liters X 80
- Capacity & No. of Tank Type B= 50000 Liters X 21
- Capacity & No. of Tank Type C= 100000 Liters X 3
- Capacity & No. of Tank Type D= 675000 Liters X 1
- Pipe Network Length From A To B = 746 Mts.
- Pipe Network Length From B To C = 1995 Mts.
- Pipe Network Length From C To D = 500 Mts.

Table 6.5: Cost estimation for Tank type A, B, C, and D made up of brick masonry as well as filter media

S.No	Item Description	Quantity	Unit	Rate (Rs.)	Amount (Rs.)
A	*Storage Tank*				
1.	Earth work in Excavation	23.35	Cum	29.95	699.33
2.	PCC in foundation (1:3:6)	1.11	Cum	1060+ 130	1320.90
3	Brick masonry in foundation with bricks of class designation 75 in cement mortar 1:4 (1 cement : 4 coarse sand)	7.17	Cum	970+130	7890.00
4.	RCC work by M15 grade mix 1:2:4 for tank roof.	0.83	Cum	1500+ 161	1378.63
5.	20 mm thick plaster on new surface on wall in cement sand mortar 1:3	36.50	Sqm	35+20	2007.50
6.	Steel reinforcement for RCC	70.00	Kg	1.00+ 17.50	1295.00
	Total sum				14591.00
B	Pipe Network for connecting various tanks				
1.	Earth work in Excavation	740.07	Cum	29.95	22165.10
2.	PVC rigid pipe (IS:4985 mark) Class II (Kg./Sqcm) 160 mm dia	2741	Mtr.	168+12	493380.00
3.	Filter media refilling in trenches	370.04	Cum	143.01	52919.42
	Total Sum				568464.00

Table 6.6: Cost estimation for Tank type D of capacity 6,75,000 liters at gram level made up of stone masonry.

S.No.	Item Description	Quantity	Unit	Rate (Rs.)	Amount (Rs.)
1.	Earth work in Excavation	675.00	Cum	29.95	20216.25
2.	PCC in foundation (1:3:6)	35.80	Cum	1060+130	42602.00
3	Stone masonry in foundation with cement mortar 1:6 (1 cement : 6 coarse sand)	81.00	Cum	350+140	39690.00
	Sum Total				Rs. 102508

Table 6.8 Cost estimation for Tank type A at individual house of capacity 22,000 liters made up of stone masonry

S.No.	**Item Description**	**Quantity**	**Unit**	**Rate (Rs.)**	**Amount (Rs.)**
1.	Earth work in Excavation	37.59	Cum	29.95	1125.82
2.	PCC in foundation (1:3:6)	1.50	Cum	1060+130	1785.00
3	Stone masonry in foundation with cement mortar 1:6 (1 cement : 6 coarse sand)	15.34	Cum	350+140	7516.60
4.	RCC work by M15 grade mix 1:2:4 for tank roof.	1.41	Cum	1500+161	2342.01
5.	Steel reinforcement for RCC	70.00	Kg	1.00+ 17.50	1295.00
	Sum Total				14064.00