BUILDING WATER RESILIENCE

A Practitioner’s Guide for Community-Based RAIN WATER HARVESTING
Disclaimer
This report is made possible by the generous support of the American People through the USAID. The contents are the responsibility of The Centre for Urban and Regional Excellence (CURE) and do not necessarily reflect the views of USAID or of the United States Government.

Team Members:
Dr. Renu Khosla, Director CURE
Siddharth Pandey, Associate Director, CURE
Trishubh Singh, Project Coordinator, CURE
Jivantika Satyarthi, Project Coordinator, CURE
Rajeev Kumar Project Coordinator, CURE
Durgesh, Ashok Prajapati, Prakash and Mukut Singh, Field Facilitators, CURE

Donors:
USAID for supporting the development of this document and scaling up of the rainwater harvesting initiative in Agra
Frank Water and Arghyam for supporting the development rainwater harvesting model in Agra

Acknowledgement
This practitioner’s guide for Rain Water Harvesting is made possible by the generous support of the American people through the United States Agency for International Development (USAID), Frank Water and Arghyam. It would also like to acknowledge the contribution and support of Agra Nagar Nigam and East Delhi Municipal Corporation in providing relevant rainfall and site specific data for implementing the rainwater harvesting systems in different parts of Agra and providing the necessary permissions for the same.
This document has immensely benefitted from the work of community groups in Agra and Delhi region who have willingly shared their knowledge and participated in the rainwater harvesting initiatives within their own communities along with the tireless efforts of the field team. The efforts of the project team in supervision and meticulous document have been instrumental in putting this document together. The team at CURE would like extend a special thanks to:
1. Municipal Commissioner, Agra Nagar Nigam
2. East Delhi Municipal Corporation, Delhi
3. Jalkal Vibhag, Agra
4. Primary Education Department, Agra, Uttar Pradesh
5. Education Department, east Delhi Municipal Corporation, Delhi
6. School Management Committee, teachers and school staff of Ambedkar Nagar School, Agra
7. Ambedkar Nagar Sewa Sudhar Samiti, Youth Group, Agra
8. Saheli Swaym Sayata Samooh, Ambedkar Bagichi, Agra
9. Thakur Mandan Mohan Mandir Trust, Dalhai, Agra
10. Delhi Urban Shelter Improvement Board, Delhi (DUSIB)
TABLE OF CONTENTS

Preface ........................................................................ 8

1  ........................................................................ 10
INTRODUCTION
A. COMMUNITIES FOR RAIN WATER HARVESTING 12
B. THE LEGISLATION 13

2  ........................................................................ 16
2: COMMUNITY-BASED RAIN WATER HARVESTING: THE PROCESS

3  ........................................................................ 22
PLANNING AND DESIGN
A. SITE SELECTION 24
B. MEASURING THE SITE 27
C. DECIDING RWH TANK CAPACITY 28
D. PREPARING A CONCEPTUAL PLAN 31
E. DEVELOPING THE SITE PLAN 31
F. RAIN WATER HARVESTING OPTIONS FOR COMMUNITIES 35
   i. Rainwater harvesting in homes 36
   ii. Rainwater harvesting in Government complexes, schools and panchayats 39
   iii. Rainwater harvesting in Religious complexes 40
   iv. Rainwater harvesting in open spaces and play grounds 40
   v. Recharging 41
   vi. Preserving ponds, pokhars and wells 41

4  ........................................................................ 46
CONSTRUCTION
A. CIRCULAR TAN CONSTRUCTION 48
B. MATERIAL REQUIREMENT AND COST ESTIMATION 50

5  ........................................................................ 54
MAINTENANCE AND SUSTAINABILITY

Case Studies .................................................................... 56
LIST OF FIGURES

Figure 1: Urban Water Crisis 12
Figure 2: Advantages of Rainwater Harvesting 13
Figure 3 Community Rainwater Harvesting Process 18
Figure 4: Measurement of site 28
Figure 5: Conceptual Plan 31
Figure 6: Conceptual Plan of RWH System in Shikarvar Temple Kolhai, Tajganj 32
Figure 7: Site Plan preparation 33
Figure 8: Guttering in building 33
Figure 9: First Flush water diversion system 33
Figure 10: Concept of Silt Trap 34
Figure 11: Location of chamber and circular drain 34
Figure 12: Overflow drain construction from tank to recharge boring 34
Figure 13: Rain water harvesting options based on catchment area and community needs 35
Figure 14: Preparing a Charcoal Filter 37
Figure 15: Sand Filter in Retrofit Structures 37
Figure 16: Concept of Retrofit RRWH Systems in House with Porch 38
Figure 17: Concept of Retrofit RRWH Systems in House with Courtyard 39
Figure 18: Home Retrofit RWH Systems 40
Figure 19: Concept of Household Brick/Stone RRWH System 41
Figure 20: Concept of underground Household Brick/Stone RRWH System 41
Figure 21: One Shared Tank between many households 42
Figure 22: Concept of more than one Shared Tanks between households 42
Figure 23: Concept of RRWH from roof catchments in a compound 43
Figure 24: Concept of RWH System from surface catchments in a compound 43
Figure 25: Recharging Techniques for Large, Medium and High Rise Buildings 35
Figure 26: Tank line out 48
Figure 27: Manual Excavation of circular tank 48
Figure 28: Base preparation through brick bat and concrete cement 49
Figure 29: Tank wall construction and tank top preparation 49
Figure 30: Roof levelling and piping-fitting along parapet 50
Figure 33: Fittings in RWH System 50
LIST OF TABLES

Table 1: Summary of rainwater harvesting legislations in select states of India 14
Table 2: Things to remember: Planning and selection
Table 3: Site Analysis Parameters to be discussed with Community 25
Table 4: Indicative parameters for selection of rainwater harvesting system options
   for individuals/cluster of households
Table 5: Tank capacity determination from RWH Potential and Demand for cemented roof top 27
Table 6: Runoff Coefficient for type of catchment material 29
Table 6: Cost Estimation in Retrofit Systems 30
Table 7: Material Requirement for retrofit systems 40
Table 8: Material Requirement and costing of 5,000L-10,000L RWH tanks 51
Table 9: Material Requirement and costing of tanks of varying capacities 51
Table 10: Material Requirement and Costing of Tanks of Varying Capacities 52

ABBREVIATIONS

RWH  Rain Water Harvesting
RRWH  Roof top Rain Water Harvesting
HRWH  Household Rain Water Harvesting
lpcd  liters per capita per day
mbgl  Meters below ground level
O&M  Operation and Maintenance
ANN  Agra Nagar Nigam
This practitioner's guide on Rain Water Harvesting (RWH) is an outcome of the work of the Centre for Urban and Regional Excellence (CURE). The work that began at Agra with the support of Frank Water and Arghyam and in partnership with the Agra Municipal Corporation was later expanded to Delhi and Rourkela in partnership with communities and local governments - East Delhi Municipal Corporation, Delhi Urban Shelter Improvement Board and Rourkela Municipal Corporation; and with the financial support of Tata Trusts and Moody’s. These activities contributed to the leveraging effort of USAID supported water and sanitation project.

The Protocol is more than a guide to cities to Rain Water Harvesting. It is a pathway for cities to become water resilient through active engagement and participation of communities. It is about communities in action to ensure better water use behavior, conservation practices, harvesting and using rainwater, restoring groundwater by recharging excess water into the ground and treating and reusing wastewater.

There are three key reasons for developing this protocol; the drying of cities because of climate change, the deterioration of the water infrastructure of cities and local governments’ mandate to implement rainwater harvesting solutions. These learnings have been distilled from our Agra work and the Agra experience is being used to exemplify the imagination behind this Protocol.

Our cities are staring a water crisis because of rising demand and changing climate patterns. In all cities, water sources are drying up and or highly polluted. Unpredictable and scantily rainfall is insufficient to recharge the groundwater. Over exploitation of the re-
source and unmanaged construction over the recharge areas has only deepened the crisis. Cities are drawing water from farther and farther off at huge and unsustainable costs. Agra city’s primary water source - the Yamuna River, is dirty from wastewater discharges, both from the city’s own untreated sewers and sewage from upstream cities. It is reportedly “close to death” – its high toxicity making the water unfit for use even after treatment. Its other source - groundwater is ‘over exploited’ and declining rapidly at the rate of 4cm/year. Its current depth is 250 ft, which has dropped a 100 ft since 1985. Its quality is dangerously poor as evident from the rising incidence of dental-skeletal fluorosis, gastric cancer, kidney stones, hair whitening, etc. because of high water hardness (more than 250mg/l), high TDS (approx. 4000mg/l), high nitrate levels (over 45mg/l) and other high elements (Ground Water Test by AES Laboratories, 2016 and CPCB’s report on Status of Ground Water Quality in India, 2007). Lack of water to treat means Agra maintains an inadequate and unreliable piped water supply system, forcing people to use their own unsustainable arrangements to fill the gap. This has created a vicious cycle of the water crisis.

Most cities, especially Agra, were traditionally water resilient with water bodies, wells, water Baolis, ponds, etc. These are deteriorating, drying and being built over. Besides being on the banks of River Yamuna, historically, Agra reportedly had many water bodies and wells. The Imperial Gazetteer of India (1884) counted 70,622 irrigation wells, 4991 drinking water wells, Hauze (manmade tanks), Baoli (step wells), Tal (lakes). Recent data from the Agra Municipal Corporation (ANN, Agra Nagar Nigam) suggests that 13 of the city’s 41 water bodies are fully or partially encroached, dumped with earth/waste and incapable of either storing or recharging water. Just 34% of the city’s 68 water wells exist, but are filled with waste and largely non-functional.

Cities understand the crisis. That is why they have changed the building bylaws to make rainwater harvesting mandatory. Agra in its Master Plan 2021 has mandated all residential and commercial buildings with an area over 300 sqm to build rainwater harvesting systems together with groundwater recharging. It has also mandated that all new buildings with a ground area larger than 1000 sqm shall also harvest rainwater and recharge into the ground. Despite enacting these provisions, few buildings are harvesting rainwater or recharging water into the ground because of lack of knowledge and skills to build these systems. This Protocol is an aid to all those cities, communities and households that are keen to build Rainwater Harvesting Systems in their neighbourhoods, institutions, public spaces and homes and be water resilient.

This is a practitioner’s guide on rainwater harvesting. Its purpose is to provide detailed, systematic information on building rainwater-harvesting systems with groundwater recharging. The thought is to put cities on the path of water resilience and restoration of the ecological balance of the area. It will help local government officials and households for setting up rainwater harvesting systems in community spaces, buildings and homes.
Introduction

Rain Water Harvesting is the conscious collection and storage of rainwater for human consumption.
A. COMMUNITIES FOR RAIN WATER HARVESTING

Cities in India are facing a water crisis and are running out of water. The groundwater aquifers are being destroyed, groundwater tables are dropping rapidly because of unchecked extraction and surface water sources are too polluted to be treated for drinking purposes. Demand for water in cities is growing because of rising populations. Cities are also experiencing the impacts of climate change as rainfall patterns are changing. A concerted effort led by local government and citizens for harvesting rainwater can help cities become water resilient, restore the natural ecology and perhaps generate sufficient drinking water to fulfill its current needs and help save for the future.

Rapid urbanization, construction of roads and paving, is reducing the absorbent surface area drastically. As a result, very little water percolates into the ground, depleting and damaging the groundwater resource. Rainwater harvesting by individuals and communities can add to water availability and preserve the natural ecology of the area.

Depending on the local environmental conditions, collective action on rainwater harvesting can supplement the existing supply, serve as an alternative to municipal supplies or be the only feasible way to improve supplies, especially in the urban areas. Rainwater harvesting at a neighborhood level using common open spaces can help decentralize water supply in cities and reduce the overall burden of water demand on local authorities. Communities can benefit from rainwater harvesting as it is one of the purest forms of water. It is qualitatively better than groundwater in its physical and chemical...
composition. If collected properly, it is also less likely to be contaminated. Rainwater is therefore potable and good for drinking and cooking. It results in fewer illnesses and associated health costs.

Rainwater harvesting is key to building water resilience. Historically, communities have always collected stored and managed rainwater for use and in the desert regions of Rajasthan this was one of the important means of survival and each member of the community played a role in the management of these common water facilities. It is a 4000-year-old practice that was a response to seasonal variability in water availability. Rainwater was collected from rooftops, land surfaces, rock catchments, and stored within accessible distance for future use. Excess rainwater was recharged into the ground, to renew the groundwater aquifers.

In recent times rooftop RWH systems linked to individual properties are more common. A typical rainwater harvesting system will have a catchment area which is linked to a means of conveyance and filtration leading to storage or a recharge mechanism. Rooftop rainwater harvesting is a guttering and downpipe system that collects rainwater from rooftops of houses, transports it to an RWH tank and stores it for future use.

Water from rooftops can also be channelled to an existing well or tube well or a percolation pit. Rainwater is potable and therefore it is critical that its storage and transportation is kept clean and clear of all contaminants. Rooftop RWH systems can be built in individual houses or in community spaces such as schools, temples, mosques, community centers, government buildings, commercial centers, institutional areas, and large catchments. It can also be undertaken in open areas such as parks and playgrounds.

B. THE LEGISLATION

The Central Ground Water Authority (CGWA) has made rainwater harvesting mandatory in all institutions and residential areas in all cities and towns of the country. Further, all states and many cities have issued their own legislations with rules relevant to their specific contexts. Often, communities are unaware of the existing norms and regulations regarding rainwater harvesting relevant for their neighbourhood. Community meetings should be used as a means of disseminating information on existing regulations. Demonstrations and pamphlets in local languages can help bring about awareness among communities on the regulations.

Sites lying in protected areas of protected heritage site have certain restrictions on construction of infrastructure. Permission from concerned authority is required to carry out the work. However, those areas where RWH is mandatory in large buildings/complexes are easy to scale up. Local harvesting and recharging norms should be followed before planning the system.
## Table 1: Summary of rainwater harvesting legislations in select states of India

<table>
<thead>
<tr>
<th>States/ Cities</th>
<th>Eligible Properties for RWH</th>
<th>Wells/Percolation/Recharge</th>
<th>Penalties/ Incentives</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mumbai, Kanpur, Maharashtra</td>
<td>All buildings being constructed on plots more than 1,000 sqm in size</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tamil Nadu</td>
<td></td>
<td>Disconnection of water connection if RWH not implemented</td>
<td></td>
</tr>
<tr>
<td>New Delhi</td>
<td>All institutional, residential buildings in notified areas</td>
<td>Drilling of tube wells is banned</td>
<td></td>
</tr>
<tr>
<td>Indore</td>
<td>New buildings with an area of 250 sqm or more</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kerala</td>
<td>All new construction</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Agra</td>
<td>All residential and commercial and government buildings over 300 sqm, both new and old</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gujarat</td>
<td>All new buildings</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ahmedabad</td>
<td>All buildings covering an area of over 1,500 sqm</td>
<td>One percolation well mandatory for over 1,500 sqm cover area; for every additional 4,000 sqm cover area, another well to be built</td>
<td></td>
</tr>
<tr>
<td>Haryana</td>
<td>All new buildings irrespective of roof area</td>
<td>Drilling of tube wells banned</td>
<td></td>
</tr>
<tr>
<td>Himachal Pradesh 7</td>
<td>All commercial and institutional buildings, tourist and industrial complexes, hotels, etc., new or old and having a plinth area of more than 1000 m²</td>
<td></td>
<td>No objection certificates not to be issued for properties unless satisfactory compliance of the RWH is shown</td>
</tr>
<tr>
<td>Rajasthan</td>
<td>All public and commercial establishments and all plots covering more than 500 m² in urban areas</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Madhya Pradesh</td>
<td>All new buildings with an area of 250 sqm or more</td>
<td></td>
<td>6 percent rebate on property tax as incentive for implementing RWH systems</td>
</tr>
</tbody>
</table>

Legislation on rainwater harvesting, available at

* [http://cpcbenvis.nic.in/envis_newsletter/RWH%20in%20India%20-%20An%20Appraisal%20of%20CPCBENVIS.pdf](http://cpcbenvis.nic.in/envis_newsletter/RWH%20in%20India%20-%20An%20Appraisal%20of%20CPCBENVIS.pdf)
COMMUNITY-BASED RAIN WATER HARVESTING: THE PROCESS

Capitalising on Community wisdom in setting up rain water harvesting systems ensures sustainability
Community-based rainwater harvesting is a four-step process. It begins with an understanding of the site and its social and physical setting with respect to the communities that live there. The end user of the rainwater harvesting system will determine the effectiveness of it and therefore engaging with the community at the beginning of the process is critical.

Second, with a basic understanding of the physiological factors, the communities can be introduced to the various design options for the rainwater harvesting system. This will also include an understanding of community preferences with respect to shared and/or individual rainwater harvesting systems. Not all communities can have common rainwater harvesting tanks even though it may be more economical, as this also means that communities have to work together to maintain the system. The third stage of the construction requires an understanding of local construction techniques and locally available materials. Traditional materials and construction techniques are more economical and communities may contribute through labour and bring down the cost of construction. Fourth, is the setting up of maintenance system which is critical for shared/community rainwater harvesting systems. Active engagement of the community in site selection, design and construction of the system helps build ownership of the system among communities and they are more willing to maintain the system as a community asset.
Not all communities can have common rainwater harvesting tanks even though it may be more economical, as this also means that communities have to work together to maintain the system.
The city wide benefits of a community based rain water harvesting system:

**The Case of Agra**

**THE PROBLEM**
Agra city is running out of groundwater rapidly. Its surface water source - River Yamuna is highly polluted and untreatable. Water supply in the city is thus inadequate, unreliable and of poor quality. The impact of insufficient and poor-quality water is disproportionately felt by the poor, affecting their health, schooling, productivity, savings, etc.; exacerbating poverty. The project on community led rainwater harvesting was aimed at building socially coherent water resilient neighbourhoods.

**PROJECT APPROACH**
The project approach was communitarian - responding to a felt need for water in the community. Communities were mobilized and organized to participate in the planning, implementation and management of water resilient solutions and systems, at the community and household level. Community wisdom and local/traditional construction techniques were used in the design and implementation of leakage and waste reduction, community rainwater harvesting and, groundwater recharging using local resources and environmentally appropriate techniques. Partnership with the Agra Municipal Corporation (ANN) was focussed on creating knowledge and capacity for producing scale and enabling Agra to access resources for expansion.
COMMUNITY ENGAGEMENT
Communities especially women were organized in 6 low-income settlements. They actively took part in the planning, designing, choosing the location, construction, and management of the community rainwater harvesting systems in their neighbourhoods. In schools, temples and mosques, other stakeholders were as well involved - children, parents, teachers, priests, etc. Concerned agencies were contacted for necessary approvals, oversight, idea championing, etc. The diversity of locations and social mix of communities in the project helped achieve two things; one, establish a more engaged and deeper social process and a stronger community structure; and two, construct and validate the idea of resilience, enhancing its potential for replicability and scale. Because the process invested in people, robust multi-stakeholder community structures were formed, laying the foundation for a resilient community maintaining and using its harvesting structures and water.

LOCAL RESOURCES
In constructing the RWH systems, traditional well making techniques were used in building the underground storage tanks - reviving this dying skill. Use of natural material and resources ensured a very low ecological footprint. Researching and locating traditional well-makers and local artisans did delay construction for the first tank, and project deliverables to the dissatisfaction and impatience of the donors. The construction, however, went much faster in the subsequent builds. Communities played an active role in construction - locating and measuring sites, identifying local contractors for digging and negotiating rates, watching over the safety of children, trucking away the dugout soil, explaining the idea to curious neighbourhood settlements, arranging food and feasts and conserving water and preventing pipe leakages.

BENEFITS
The full range of interventions in Agra have directly benefitted over 11000 low-income households (about 60824 population) in 24 low-income settlements of Agra with economic, ecological, health and social impacts. Access to good quality drinking water has meant reported monthly savings per household on buying low-quality water from private tankers (Rs. 150 pm), and medical expenses for gastrointestinal treatments (Rs. 150 pm or an aggregated Rs. 9,150 pm for all households).

The city is potentially saving approx. Rs. 3.5 crores on energy from reduced groundwater pumping requirements and making tanker supplies. The next system being built by the city shall have a harvesting capacity of 1.6 lakh litres. As more households and communities start to harvest, the city shall eventually see a de-stressing of the load on the public health system as well.

The Ambedkar Nagar school in Tedi Bagia, Agra’s RWH systems are harvesting sufficient water for 320 children for 250 school days. Owing to fewer episodes of diarrhoea among children, school enrolment and attendance is beginning to improve, especially among girls. Each school saves Rs. 15000 per month to buy water and over Rs. 4000 annually on cooking fuel that now lasts longer. Last year’s scanty rainfall had little impact on the school.

PARTNERSHIPS
The project was a partnership between ANN, the communities and CURE. It was financed by Arghyam and Frank Water. Two other donor agencies - USAID and Cities Alliance, funded CURE’s ground efforts, creating the platform that supported the current intervention.
Planning and designing of rain water harvesting structures starts with mobilising communities to conserve water.
**A. SITE SELECTION**

Site selection is the first step in planning for rainwater harvesting. However, initially, it is essential to mobilise the community for conserving water before moving towards rainwater harvesting. Transact walks and community mapping exercises on site selection are a good way to initiate the dialogue with the community and learning about the neighbourhood.

Following steps should be followed while mobilising communities for site selection for the rainwater harvesting:

- Building awareness: Community events and Focus Group Discussions (FGD) showcasing the advantages and benefits of using rain water should be organised for developing a strengthened community for water. Establishing belief on rainwater quality through water tests and demonstration models on rainwater harvesting are useful tools that help communities understand rain water harvesting. Simple exercises with children and youth on collecting rain water and quality testing, can help reassure communities that rain water is beneficial and fit for use. Exhibitions on rainwater harvesting systems; their durability and safety can help establish its benefits.

- Understanding the need and context: Community meetings should be aimed at understanding the need and willingness for rainwater harvesting. This can be followed by developing historic timelines on water sources, their uses, existing water and sanitation infrastructure and mapping all available resources. Relevant information building and rain water harvesting bylaws of the respective areas can be accessed from government sources. A preliminary understanding of soil quality and catchment area should also be done with the help of community maps.

It is essential to mobilise the community for conserving water before moving towards rainwater harvesting.
essment of preferences for combined or segregated RWH systems should also be made.

- Conceptual plan and location: A rough sketch of the rainwater harvesting system indicating the best suitable location can be made on site and issues with respect to accessibility, capacity and construction can be discussed with the community.

- Operation and maintenance: A Communities must be engaged in the process of planning and building the system so that they are well versed with the new infrastructure and are able to maintain it independently or with the help of local authorities.

### Table 2: Things to Remember: Planning and Site Selection

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>History</td>
<td>It's important to check if the site has any heritage, historical or social significance, or is there any conservation or other city bylaws that may prevent building the rainwater harvesting tanks. It is also important to note if the community deems it a sacred religious place that should not be disturbed. FGDs should include senior citizens, religious leaders, school teachers/anganwadi workers and local body officials who are aware of the social composition, history and population of the area.</td>
</tr>
<tr>
<td>Population density</td>
<td>It helps in calculating present and projected water demand and determines the tank size.</td>
</tr>
<tr>
<td>Social Composition</td>
<td>It can provide indication to whether communities are willing to have a shared system.</td>
</tr>
<tr>
<td>Catchment</td>
<td>The site should have a reasonable catchment area from where rain can be harvested.</td>
</tr>
<tr>
<td>Groundwater depth</td>
<td>Level of ground water table must be checked. For low water tables, underground systems may be built, whereas for high water tables, tanks may have to be on the surface.</td>
</tr>
<tr>
<td>Soil structure</td>
<td>Different soils have their own distinct infiltration rate and percolation time. Soils with longer percolation time are better for harvesting, while those more permeable are more suited for recharging. Local knowledge and local means of measuring and assessing soil and rainfall volume, time and quantity exist in most regions and must be explored during community discussions. They can provide valuable insights for identifying the most suitable sites.</td>
</tr>
<tr>
<td>Rainfall Pattern</td>
<td>This helps determine the size of the rainwater-harvesting tank. Small domestic harvesting tank may be sufficient for areas with low rainfall spread over a long period whereas a larger tank with groundwater recharge may be more effective in areas with seasonal and heavy rainfall.</td>
</tr>
<tr>
<td>Trunk Infrastructure</td>
<td>Location of water, sewerage, electricity lines, etc. around the site should be assessed to ensure that these are not damaged during construction. Community mapping exercises can help in developing infrastructure and resources can be useful tool in gaining information as well as building awareness.</td>
</tr>
<tr>
<td>Accessibility</td>
<td>Site chosen should be accessible to users. It should also be feasible to bring in construction trucks and machines.</td>
</tr>
</tbody>
</table>
The following checklist may be used for the final selection:

Once a rough sketch has been developed for the rainwater harvesting site, it is time to choose options of the rainwater harvesting system which could be:

- Shared system for arresting roof run off and/or surface run off
- One or more tanks for arresting roof run off and/or surface run off

- Harvesting only
- Harvesting and recharging

This selection must be done based on the availability of space, population, estimated costs and social preferences in the community. It may be useful to create a simple chart indicating the various options with their pros and cons. The chart may indicate important factors that can bring down costs and requirements of O&M for each option.
B. MEASURING THE SITE

A typical site for rooftop rainwater harvesting will comprise a building with a roof area, open space (where the RWH tank can be located) and other natural and infrastructure features. Once a site is identified, it must be measured using measuring devices and tapes to provide exact site measurements for calculations of catchment area and rainwater tank design and volume.

- Measure the ground space for proposed site of RWH tank, building rooftops and catchments. Indicate accurately, other site features - sewer lines, manholes, drains, electricity poles, water lines, hand pumps or bore wells both functional and non-operational, trees, shrubs, boundary walls, etc.

- **The catchment area** is the area of the roof that will be used for harvesting rainwater. The size of the catchment area or roof will determine how much rainwater can be harvested. Fig. 7 shows the roof measurement technique.

- In order to assess a slope of the roof, pour water on the roof and observe its flow. Also, discuss with the community. They would know the roofs’ outlet points or points where the water may collect on the roof.

---

### Table 4: Indicative Parameters for Selection of Rainwater Harvesting System Options for Individuals/Cluster of Households

<table>
<thead>
<tr>
<th>System</th>
<th>Space Availability</th>
<th>Estimated Costs</th>
<th>Social Preferences / O&amp;M</th>
<th>Rainfall</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shared system</td>
<td>Requires a large catchment area and storage, preferable on common / govt. land</td>
<td>Costs can be reduced through community contributions in cash or kind</td>
<td>Are most effective where community organisation is strong and backed by local body support</td>
<td></td>
</tr>
<tr>
<td>Individual tanks</td>
<td>Requires less space and can be done on individual plots</td>
<td>Costs may be high for an individual</td>
<td>Are more effective where individuals prefer to take responsibility for smaller tanks</td>
<td></td>
</tr>
<tr>
<td>Harvesting only</td>
<td>Requires less space and can be done at a community/ individual level</td>
<td>Costs can be reduced through community contributions in cash or kind</td>
<td>Requires less O&amp;M</td>
<td></td>
</tr>
<tr>
<td>Harvesting and recharging</td>
<td>Can be spread across a large piece of land or a neighbourhood</td>
<td>Costs can be reduced through community contributions in cash or kind</td>
<td>Are most effective where community organisation is strong and backed by local body support</td>
<td></td>
</tr>
</tbody>
</table>
C. DECIDING RWH TANK CAPACITY

The rainwater harvesting tank capacity is primarily dependent on catchment volume and community’s water demand. The following table provides a break up of these factors that play an important role in calculating the volume of the tank.

An analysis of community water demand and catchment volume/RWH potential is necessary to finalize tank capacity. Most times, water demand may be quite large than catchment volume, then additional catchments are connected to the harvesting system.

The next section will explain the basic calculations for Catchment Volume and Community Water Demand. While these calculations are important, it is equally important to gather information from communities on these parameters. For example, through a trends analysis, communities can help determine the annual average rainfall. Communities will be able to share information on the amount of rainfall, incidences of flooding in the recent past, existing infrastructure networks, etc.

Similarly, communities are well informed about their water needs and the calculations for water demand should be informed with their inputs.

As a thumb rule, 80% of the catchment volume is considered to be the rainwater harvesting potential. The catchment volume is calculated by multiplying the average annual rainfall, catchment areas and run off coefficient. The run off coefficient is the unit that indicates how easily water can run off a particular surface. Hard roof material does not absorb the rain or pollute the run off. Thus, tiles, metal sheets and most plastics are suitable, while grass and palm-leaf roofs are not suitable.
Calculating Catchment Volume and Community Water Demand

Catchment volume can be calculated using the following formula:

Rainwater/Catchment Volume (in cubic meters) = a X b X c

Where:

- **Catchment Area of surface/roof sqm (a)** = Calculated catchment area from measured drawing
- **Total Annual Average Rainfall1 in mm (b)** = Average annual rainfall for 5 years (If maximum Rainfall > Average Rainfall, considering average annual rainfall as base) add the difference to the average annual rainfall
- **Run off Coefficient (c)** = 0.7 (As stated in table-3)

Rainwater Volume = 100 X 0.7 X 0.728 = 23 Total cubic meters (23,000 litres)

Of the total rainwater that falls on the catchment, about 80% can be collected.

Rainwater Harvesting Potential = 80% of Total Rainwater Volume = 80% of 23,000 litres

Rainwater Volume in the above case would therefore be 18,400 litres

---

1 The precipitation/rainfall over one year in a particular place or region is called its average annual rainfall. It’s expressed in mm.
It is important to know the roof coefficient to calculate runoffs. Use the table below to calculate roof coefficient.

**Community Water Demand:** RWH tank capacity should be planned with respect to "community water demand". Rainfall occurs every year with slight variation in seasons. Therefore, water demand for community systems should be calculated for a whole year considering the amount of rainfall that occurs every year. Water demand for such systems is calculated using the formula:

\[
\text{Water Demand for Community Systems} = \text{Total population} \times \text{Per capita daily drinking/cooling water demand} \times \text{No. of days in a year}.
\]

For instance, the water demand for a community of 10 households with an average household size of five people and an average domestic consumption of 10 lpcd will be:

\[
\text{Annual Water Demand for Community Systems} = 10 \text{ HH's} \times 5 \text{ (HH size)} \times 10 \text{ L (per capita water demand)} \times 365 \text{ days} = 1,82,500 \text{ L}
\]

An RWH Tank refills during rainy season in 90 days. Water demand in 90 days of same households is 45,000 L.

\[
10 \text{HH's} \times 5 \text{ (HH size)} \times 10 \text{ L (per capita water demand)} \times 90 \text{ (days)} \text{ is deducted from annual water demand i.e. } 1,82,500 \text{ L} - 45,000 \text{ L} = 1,37,500 \text{ L}.
\]

Community system of 10 HH's of 5 HH size requires 1,30,000 L water.

**ANNUAL HOUSEHOLD WATER DEMAND FOR A FAMILY**

CPHEEO norm for per capita consumption of water is 135 lpcd for cities with piped water supply and existing sewerage system.

**Annual requirement of a family of 5 for drinking and cooking**

<table>
<thead>
<tr>
<th>No. of family member</th>
<th>Per capita water consumption for drinking and cooking</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>10 L</td>
</tr>
</tbody>
</table>

No. of days in a year = 365

\[
\text{Water demand of HH} = \text{Total no. of family members} \times \text{Per capita water consumption} \times \text{total no. of days} = 5 \times 10 \times 365 \text{ L} = 18250 \text{ L (following the formula)}
\]

Considering that a tank can fill up in 90 days, an RWH tank capacity for a household can be 10000 L.
D. PREPARING A CONCEPTUAL PLAN

Based on the calculations and based on the tank capacity, a conceptual plan has to be developed. A conceptual plan or sketch plan has proposed location of RWH structures, numbers of tanks with sizes, types (above/below ground, circular/linear), depth, downpipes, the direction of water flow, roof slope, catchment area, land use and vacant areas.

E. DEVELOPING THE SITE PLAN

A Site Plan is a detailed scaled drawing of the conceptual plan using site measurements. Site Plan must be developed in compliance with the city building by-laws and rules. This will require the assistance of an architect/engineer/contractor or any qualified person with a basic understanding of measured drawings. A measured site plan on the site will help ensure that the location and size of the RWH tank fits well into the site and is not obstructing any existing features. It will also guide the construction team on appropriate placement of the tank. The drawing will also detail out other specifications such as pipe connections and sizes, slopes.
Sikarvar temple in Kolhai, Tajganj, Agra sits in the middle of the temple complex. Five trees, each with a circular platform, surround it. Fourteen residential buildings and open plots line its boundary wall on the outside. On their own, these residential roofs are too small to harvest a lot of water. However, if these roof surfaces are combined, there could be plenty of water for people’s use. The complex also has large open spaces for building the tanks and recharge areas. Based on catchment area calculations, two underground, circular tanks of 15 feet diameters were proposed, to be built diagonally across in the two corners of the temple compound. The tanks were to have a two-foot setback from the boundary wall as well as from other ground features - trees, pipelines, sewer systems, etc. The setback ensured the tanks would also be at a reasonable distance from the residential buildings, to avoid seepages into house foundations from rainwater or contamination from sewage/drainage water.

Soil analysis suggested that each tank could be 15 feet deep with capacity to store 75000L in each tank. Tree plantation and greening in the compound will improve ground recharge capacity and capture surface runoffs.
THINGS TO REMEMBER

Gutters: Gutters carry water from roof to downspout. Tin roofing and sloping roofs need gutters to collect and channelize water towards the downspout. They prevent water seepage in walls, increase catchment volume and divert water.

Downspout: A fixed vertical pipe that carries the rainwater from the roof to the ground/drain pipe. They are located along building walls. Downspouts should have mesh/jalis to restrict dust, leaves, debris accumulation and clogging. 3 and 4 inches PVC pipes are used for downspouts in RWH system.

A first flush device is one that takes the first shower from the roof and diverts it away from tank. The first shower needs to be flushed-off to avoid contaminating storage/rechargeable water by the probable contaminants of the atmosphere and the catchment roof. It also helps in cleaning in silt and other material deposited on roof during dry seasons. The provision of first flush device is made at outlet of each drainpipe or in downspout.
**THINGS TO REMEMBER**

Collection Chamber is a manhole to arrest water from the downspout and direct it to silt trap through cemented drains or 4-inch PVC pipes. They are also built to collect water from overflow pipes of more than one tank and then diverting it to recharge. Ideally, they should be located at drain interceptions to divert water wherever the drain or pipe size changes.

![Figure 10: Concept of Silt Trap](image1)

Silt Trap prevents water-borne soil from entering the RWH tank. It slows down the run off from surface or roof and allows run off to accumulate that enables settlement of sediment (silt) and pollutants attached to the sediment are trapped and not discharged into RWH tank. The best sites to install silt trap at interception of run off pathways. A larger silt trap is more effective for trapping sediment. However, it also depends on the soil type, run off volume and the amount of sediments to be removed. The ideal size of silt trap for RWH tank of maximum capacity 1,00,000 L is 0.45m X 0.45m X 1m. Large silt traps should have size of 0.6m X 0.6m X 1.15m.

![Figure 11: Location of chamber and circular drain](image2)

Circular Drains are of 15 feet diameter or more to allow free flow of water to the tank. Circular drains are 0.115m wide and 0.56m deep. They have inlet chamber to allow water passage into the tank. Size of inlet chamber is 0.3m X 0.3m x 0.56m. Jali is installed at silt traps and inlet chambers at tank entrance to restrict entry of waste, debris and silt into tank.

![Figure 12: Overflow Drain Construction from Tank to Recharge boring](image3)

Provision for overflow from tanks is made to cater to higher rainfall intensity or larger catchment area than the tank capacity. Best use of overflow drain is to recharge the additional amount of water unable to harvest. This additional water through overflow of PVC pipe or drain from tank should be directed to green areas, outside the complex/site to recharge the groundwater by a suitable mechanism.
F. RAIN WATER HARVESTING OPTIONS FOR COMMUNITIES

Rainwater can be harvested from the ground surface and from the roof. Rooftop harvesting is much easier to manage. Rooftop rain water has two options - harvesting and recharging. Harvested rain water stored in tanks is made available in Individual Households, community spaces, a cluster of households; public buildings, private spaces, religious and recreational areas as well. Harvesting and recharging options in built ups and open spaces based on their catchments and use of existing buildings/ already built space are classified below:

RWH tanks are usually built underground but surface tanks can be made depending on soil type and water table. Surface tanks are preferred in areas with low groundwater table; underground tanks are suitable in areas with a high groundwater table. They are designed for 30-50 years. They can be levelled to ground level or extended to a certain height for using it as a sitting space. They are linear/circular in shape based on the area available on site and made up of local materials for strength. Maximal depth of tank should be kept up to 15-20 feet for linear/circular tanks for manual excavation. Circular tanks have less capacity than linear tanks however they have certain advantages and a comparison is presented on page 36.

Figure 13: Rainwater Harvesting Options Based on Catchment area and Community Needs

RWH tanks are usually built underground but surface tanks can be made depending on soil type and water table.
i. Rainwater Harvesting in Homes

RWH systems in homes can be small or large depending on roof/catchment area, space, and affordability. Individual homes can install an RWH system to capture rainwater or a cluster of households can build a common RWH system. RWH systems in homes can be - Retrofit System, Shared RWH system, Cluster RWH System. They can be built out of stone or bricks.

- Retrofit Systems in Homes

Retrofit systems are specifically designed for Individual Households with a small catchment area where it is difficult to build a permanent structure due to space and cost constraints. They are mobile and detachable, have a low capacity, to be used in small catchments only. This system comprises a filter, a downpipe and a storage container. RWH Filter can be prepared at home. There are two types of filter used in retrofit systems.

Charcoal Water Filter:

A simple charcoal filter is prepared in a drum, an earthen pot or a bucket of 30L - 40L capacity. The filter is made up of gravel, sand, brickbat and charcoal, all of which are easily available. In case a large charcoal filter can be made, sand should be added to it. The top layer is filled with zero aggregate (Ratio of Zero Aggregate: Coal: Sand: Brick Bat is 1:1:3:2.5) to sift any waste. The second layer is made of charcoal to filter the large suspended particles. The third layer comprises sand, to remove turbidity and suspended particles and the fourth layer is made of brickbat– at the base to support the sand above and allow free flow of filtered water from the outlet.

- Sand Filters:

Sand filters have commonly available sand as filter media. Sand filters are easy and inexpensive to construct. These filters are used for the treatment of water to effectively remove turbidity (suspended particles like silt and clay), colour and microorganisms.

<table>
<thead>
<tr>
<th>Circular Tanks</th>
<th>Linear Tanks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Can withstand outward directed force of the water stored within</td>
<td>Can store large volume of rainwater</td>
</tr>
<tr>
<td>Are much easier to keep clean</td>
<td>Requires maintenance of the length-breadth ratio</td>
</tr>
<tr>
<td>Requires less building material than its box-shaped equivalent and is consequently more economical to build</td>
<td>Have dead corners that are harder to clean. Corners also harbour microbes</td>
</tr>
<tr>
<td>A circular tank has better strength than linear tank because pressure gets distributed on tank wall that balance the load. A tank may have one or more than one silt trap depending upon requirement</td>
<td></td>
</tr>
<tr>
<td>Tanks having diameter more than 15 ft need circular drain to allow free flow of water and reduce water logging at silt trap</td>
<td></td>
</tr>
</tbody>
</table>
Figure 14: Preparing a Charcoal Filter

1. Placing clean brickbats at the bottom of the bucket filter
2. Adding a second layer of charcoal to the filter
3. Cleaning the gravel to be placed in the filter
4. Placing the gravel in the filter
5. The ready filter

Figure 15: Sand Filter in Retrofit Structures

Source: rainwaterharvesting.org, CSE
• Installing a Retrofit RWH System at Home

The downpipe from the roof is connected to filter, then to the in-house water storage tank of variable capacity (depending upon space and affordability) that may be above or below the ground. The filter must be at least 1.5 ft below the downpipe to ensure the retention time and preventing excessive water accumulation on roofs.

Storage

Roof catchment area determines the volume of water produced but storage depends upon space and affordability. Fig. 18 and 19 show the placement of filter and container outside and inside the house, respectively. Water from downpipe goes to filter for purification; filtered water from filter outlet is stored in a drum.

Cost

The cost of the system varies. A cheap container/drum of 200L may cost about Rs.600. Homemade filter using in-house material does not cost much. One retrofit system costs around Rs. 1500. The storage container is placed in the front or back porch, depending on availability of space and positioning of the downpipe. These are small, mobile systems and can be dismantled in non-rainy days.

• Permanent System in Homes

Households with adequate space can build an underground tank of larger capacity using brick or stone. A permanent RWH system comprises a downpipe, silt trap and tank. If RWH tank cannot arrest all water from the catchments, then water from tank can be diverted to recharge the ground systems at homes.

Storage

Stone/brick RWH System store 5,000L - 10,000L water. Tanks should be wide enough to draw water and should be up to 7 ft deep to avoid manual deep excavation. They can be linear or circular.
• **Shared RWH System in Households**

Shared RWH systems are built for small numbers of households sharing an open space. All households using rainwater would be responsible for its operation and maintenance. Roof outlets are connected through a horizontal pipe leading up to a downpipe. The downpipe is leading to silt trap and storage tank; the capacity of which is based on catchment volume, ground space available and costs. It collects rainwater from many roofs in a single or a set of connected tanks depending on space. The tank(s) could be built at some common place like a park, playground, courtyard, etc.

Fig. 23 shows one shared tank between 4-5 households or small catchment area. It is built for few households sharing an open space and willing to harvest. Where household number exceeds from five or having a large catchment area, then system of tanks should be proposed for that group of households.

Fig. 24 shows two connected tanks capturing water from roofs of neighbouring households (catchment area in yellow). The first tank between the households has a low capacity whose overflow is directed to the larger tank capacity to collect ample water.

**II. RAINWATER HARVESTING IN GOVERNMENT COMPLEXES, SCHOOLS AND PANCHAYATS**

The existing institutional buildings - schools, colleges, public buildings often have ample space for building RWH systems. They have large catchment volume which can be used for harvesting, recharging and landscaping. Tank or set of tanks built to capture the large volume. Owner/RWA/Societies/Trust is responsible for maintenance and cleaning. Local community may also manage this system and provide water to a large number of people.
III. RAINWATER HARVESTING IN RELIGIOUS COMPLEXES

RWH systems are useful in religious buildings - temples, mosques and churches - that are visited by many. Rainwater in these buildings can be made available to all who come here. These complexes have large catchments and hence, bigger storage tanks can be planned. In case of excess water, it can be diverted into dysfunctional submersibles/boring or recharged into the ground through percolation pits, specially designed infiltration wells, etc.

IV. RAINWATER HARVESTING IN OPEN SPACES AND PLAYGROUNDS

Rainwater harvesting systems can be built in recreational areas such as parks, playgrounds, large open spaces, etc. Here one can capture the surface catchments. Playgrounds naturally recharge water into the ground by growing plants and trees (Fig.26). Those trees, shrubs, and plants should be planted that soak up less water, improve soil and support recharging. Excess water can be diverted to appropriately install recharging system.

Table 7: Cost Estimation in Retrofit Systems (Agra, 2016-2017)

<table>
<thead>
<tr>
<th>Type of System</th>
<th>PVC pipe</th>
<th>Fittings</th>
<th>Filter Container (Rs.)</th>
<th>Filter Media (Rs.)</th>
<th>Storage Tank (Rs.)</th>
<th>Total Cost (Rs.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Retrofit Systems</td>
<td>1000 (5ft)</td>
<td>1 elbow, Angle, drain cover, tank nipple Rs 300 (approx.)</td>
<td>600 - 800</td>
<td>900 (can also use an old storage tank or container to reduce cost)</td>
<td>1900 (without cost of tank)</td>
<td></td>
</tr>
</tbody>
</table>

Note: Costs can be reduced substantially if material is bought in bulk or materials such as the storage tank and filter container are repurposed.
V. RECHARGING

Large catchments produce a heavy volume of water that is to be harvested and recharged to ground. Many large catchments have little space on the ground, which makes harvesting difficult; in such cases, recharging is the better way. Many medium and high-rise buildings have large volumes of roof runoff and less space on the ground for storing the rainwater. They are also densely populated and need many storage tanks to cater to heavy demand. This could prove expensive. Therefore, for such areas, recharging is preferred.

Following the mandates for compulsory recharging in buildings of an area more than 300sqm, relevant recharging methods should be used as recommended by the Central Ground Water Board, Ministry of Water Resources as shown in Fig.27.

While preparing the recharge plan it is important to check the following:

- Hydrology and Lithology of the area
- The trend of groundwater depletion in past few years and groundwater depletion rate
- Groundwater quality and spread of water-borne diseases
- Listing & marking hotspots in the city (pre-monsoon and post-monsoon)
- Water table levels and aquifers
- Groundwater resource and groundwater development
- Scope for recharging should be analyzed in already built structures
- Suitable recharging techniques to be adopted for the area

VI. PRESERVING PONDS, POKHARS AND WELLS

They are natural water reservoirs and are linked to underground water resources/
Figure 21: One Shared Tank between many Households

Figure 22: Concept of more than one Shared Tank between Households
Figure 23: Concept of RRWH from roof catchments in a compound

Figure 24: Concept of RWH System from Surface Catchments in a Compound
• Reclaiming as much pond as possible by gradually pushing back the encroachments.
• De-silting the living ones and redeveloping their recharge slopes.
• Softening the hard edges where the catchments have been built over by landscaping and greening.
• Constructing reed beds, micro DEWATs and wetlands to clean the wastewater flowing into these water bodies from the surface drains and toilets.
• Recharging through dysfunctional boring and hand pumps.
• Catching the city’s surface run off through storm water drains and making them permeable or planning for recharge at regular intervals.
• Adopting softscape instead of hardscape and create awareness for planting more trees.

Medium and high-rise buildings have large volumes of roof runoff and less space on the ground for storing the rainwater. In such cases, recharging is a better option.
Source: Ground Water Stress –City Agra, (An Overview of Urban Aquifers and Ground Water Crises), July 2017, Ground Water Department, Uttar Pradesh.
CONSTRUCTION

Construction techniques for rain water harvesting to should benefit from local and traditional methods shared by the community.
Along with mobilisation, understanding local construction technique, local material, its cost, availability, transportation, and local skilled labour is imperative. An RWH Tank has three parts – base, wall and the top cover.

**A. CIRCULAR TANK CONSTRUCTION**

The nine steps of construction of a circular tank are

**Step 1: Lining out the tank**

Respective offsets distances should be marked from buildings, trees, wall, etc. to locate the central point of the tank using lime (chuna) demarcation by taking radius as distance from the centre of the tank.

**Step 2: Excavation**

Excavation can be done manually or mechanically, however, manual excavation is preferred as it does not disturb the lower layers of soil maintaining its compaction levels and causes no damage to surroundings. It is best suitable in inaccessible areas. Manual excavation can be done up to 20 ft. However, it requires skilled labour and is costlier. Mechanical excavation can be done in open areas with few building structures with adequate offset distance. It takes less time and is cheaper. A mini JCB/ excavator can reach up to a depth of 12 ft.

**Step 3: Soil Removal**

Deep excavation produces large no. of trolleys of soil which can be used to level the site/ another site. It can also be sold or put to other uses such as making earthen pots, etc.

**Step 4: Preparation of base**

Soil compaction is must after excavation to make strong base which can withstand wall weight. The base is prepared through ramming the brick blast and adding a layer of cement, sand and aggregate in the respec-
Step 8: Make Slope Corrections

Slopes that do not naturally slope to the side from where rainwater shall drain to the tank will need to be appropriately sloped. Sloping roofs such as in hilly or areas with high intensity rainfalls will need a collection system at the end of the roof slopes. In roofs that slope in several directions, more than one collection drain may need to be built.

Step 9: Piping & Fittings

Guttering through pipes should be installed along the length of the wall from roof catchment to the underground drain for carrying water. This includes connecting pipelines from roof and silt trap or drain.

Figure 28: Base Preparation Through Brickbat and Concrete Cement

Step 5: Preparation of Walls

Wall construction, the wall can be made in brick or localstones in a circular formation. Cement mortar ratio 1:6 should be compulsorily maintained for wall and 1:4 for tank lining. A230mm thickstone/brick wall is constructed in circular manner, finished with an 18mm thick plaster on base and wall.

Step 6: Preparing Tank Top

Top Cover, made up of I-girder along the diameter of the tank and stone slabs place over I-girder of 4 inches and length-breadth as per tank dimension should be used. Railway girders can also be used to hold the load and Stone slabs (with respect to tank dimensions) followed by cement plaster of 18mm.Manhole, an opening for drawing water and cleaning the tank should be provided. Tank is completed after cement plaster on the top of tank.

Step 7: Catchment Preparation

Many catchments do not have sloping towards gutter. Levelling and improvising roof slope is mandatory in every RWH structure. It may need cleaning, plastering parapet wall construction, etc.
MATERIAL REQUIREMENT AND COST ESTIMATION

An indicative list of materials and their estimated costs is provided in this section. The materials for construction of the RWH tanks can vary from region to region and the use of local construction material is ideal.

Charcoal Filters for Retrofitted Systems

Charcoal filter is best suitable for retrofit RWH systems. Material requirement for retrofit system is described in Table 8 below.

Figure 31: Fittings in RWH System

Permanent Household Rain Water Harvesting Systems

Permanent Household RWH Systems are composed of filter container or silt trap for large tanks. These systems have 5,000L to 10,000L capacity. Material requirement and cost estimate for these systems are described below:

Large RWH Systems

RWH tanks in Shared Systems, at Institutional Areas, Community Places, Religious Places and Recreational Areas should preferably be built from local materials, as these will support local environment and will be cost effective. Locally available material has long term durability, such as, – Khandha (stone), fly ash bricks, Patiya (stone slab), Morang (sand), aggregate, katchigiti (brick blast), cement should be used. Tank wall is made up of local stone “khanda”. That is covered by stone slabs “patiya” set on heavy-duty I girders. No steel should be used in the rest of the frame. girder, PVC pipe, T & Elbow are used for guttering and fittings. Material quantity estimate for different tank size, guttering and fittings (inclusive of linear/circular tanks) is detailed with their cost in Table 9.
Table 8: Material Requirement for Retrofit Systems

<table>
<thead>
<tr>
<th>Type of System</th>
<th>Description</th>
<th>Materials Required</th>
</tr>
</thead>
<tbody>
<tr>
<td>Retrofit Systems</td>
<td>Composed of 40L filter and 200L drum</td>
<td>PVC pipe</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4&quot; pipe for guttering and 2&quot; pipe for fittings</td>
</tr>
<tr>
<td>Quantity</td>
<td>As per need</td>
<td>As per need</td>
</tr>
</tbody>
</table>

Table 9: Material Requirement and Costing of 5,000L - 10,000L RWH Tanks

<table>
<thead>
<tr>
<th>Storage Tank Capacity</th>
<th>Tank Construction Material</th>
<th>Guttering &amp; Fittings</th>
<th>Silt Trap &amp; Filter</th>
<th>Top Cover</th>
</tr>
</thead>
<tbody>
<tr>
<td>5,000L - 10,000L</td>
<td>Description: Tank is made of: Stone/Brick, Cement, Fine Sand, Coarse Sand, Brick Bat, Coarse Aggregate</td>
<td>PVC pipe</td>
<td>Fittings</td>
<td>Filter Container</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4&quot; and 2&quot; PVC pipes (used or new) for gutters</td>
<td>Elbow, Tank, Nipple, Angle, Gutter Jaali or drain cover</td>
<td>Not Required</td>
</tr>
<tr>
<td>Quantity</td>
<td>1000</td>
<td>15</td>
<td>25</td>
<td>80</td>
</tr>
</tbody>
</table>

Cost (Rs) | 20,000 - 40,000 |

**THINGS TO REMEMBER**

- In built-up neighbourhoods, use manual excavation to avoid vibrations and damage to nearby buildings/wall structures.
- Construction must happen timely.
- Do not delay construction of the wall after excavation. If left open for too long, its sides may collapse.
- Compact the soil immediately after the excavation.
• Cement plastering should be done carefully to prevent leakages.
• Stone masonry work should be done for constructing walls of the tank. Stone has two advantages over brick masonry: 1) it provides better insulation; 2) it is cheaper than brick masonry.

Table 10: Material Requirement and Costing of Tanks of Varying Capacities

<table>
<thead>
<tr>
<th>Storage Tank Capacity</th>
<th>Material Required</th>
<th>Quantity</th>
<th>Cost (Rs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5,000L - 10,000L</td>
<td>Description Tank is made of: Stone/Brick, Cement, Fine Sand, Coarse Sand, Brick Bat, Coarse Aggregate</td>
<td>1800 25 60 150 30 30 30</td>
<td>80,000 approx (Inclusive of excavation, labour, material and transportation)</td>
</tr>
<tr>
<td>30,000L</td>
<td>Description Tank is made of: Stone/Brick, Cement, Fine Sand, Coarse Sand, Brick Bat, Coarse Aggregate</td>
<td>3000 35 100 200 50 50 50</td>
<td>1 lakh approx (Inclusive of excavation, labour, material and transportation)</td>
</tr>
<tr>
<td>40,000L</td>
<td>Description Tank is made of: Stone/Brick, Cement, Fine Sand, Coarse Sand, Brick Bat, Coarse Aggregate</td>
<td>4000 45 130 250 60 60 60</td>
<td>1.5 lakh approx (Inclusive of excavation, labour, material and transportation)</td>
</tr>
<tr>
<td>50,000L</td>
<td>Description Tank is made of: Stone/Brick, Cement, Fine Sand, Coarse Sand, Brick Bat, Coarse Aggregate</td>
<td>5000 55 170 350 100 70 70</td>
<td>2 lakh approx (Inclusive of excavation, labour, material and transportation)</td>
</tr>
<tr>
<td>75,000L</td>
<td>Description Tank is made of: Stone/Brick, Cement, Fine Sand, Coarse Sand, Brick Bat, Coarse Aggregate</td>
<td>7000 85 220 450 130 100 100</td>
<td>3 lakh approx (Inclusive of excavation, labour, material and transportation)</td>
</tr>
<tr>
<td>115,000L</td>
<td>Description Tank is made of: Stone/Brick, Cement, Fine Sand, Coarse Sand, Brick Bat, Coarse Aggregate</td>
<td>11000 125 300 700 160 150 150</td>
<td>5 lakh approx (Inclusive of excavation, labour, material and transportation)</td>
</tr>
</tbody>
</table>
5 MAINTENANCE AND SUSTAINABILITY
Rain Water Harvesting systems are designed for drinking purpose. Therefore, its maintenance is essential. A clean and well maintained RWH system will ensure that the water is potable. A community-based system integrates traditional know-how on-site identification, construction systems and maintenance for the long-term sustainability of the system. Community places, schools, playgrounds, private areas all can have RWH systems. However, each place requires different set of strengthened community/ groups/ champions/ individuals/ stakeholders who take responsibility for using and maintaining RWH System. The community groups should be organised at the beginning of the process and their role in the maintenance of RWH system must be discussed with them. It also ensures that communities are involved from the beginning of the process and are not alien to the technology and systems. The final plans and drawings should be shared with the community that includes location and other social factors affecting RWH system. Operation and Maintenance groups should be formulated and trained to ensure the long-term usage/sustainability of the system. These groups do the following:

- Oversee and ensure regular tank cleaning
- Collect money or resources for maintenance of the RWH system
- Prepare a plan for equitable distribution of water
- Spread awareness on the RRWH System concept and mobilise more households to adopt the system
- Contribute to the construction of the RWH system and its components

**Individuals** must take responsibility for cleaning the roof catchments; must not allow waste dumping into the tank; must not allow anyone to mix other water sources into rainwater tank. These systems should be cleaned before rain.

On an average the cost of cleaning the RWH systems is approximately Rs.1000 per annum. The use of good quality material (cement and bricks) and engaging skilled labour will also ensure long term sustainability of the system. A poorly built system will always lead to higher maintenance and repair costs.

Stakeholders/ Community Groups/ Individuals/ Champions responsible for operation and maintenance must ensure following:

**Daily / Regularly**

1. Rainwater must not be mixed with other water sources, which will contaminate it and make it unfit for use.
2. Area around tank and manhole should be cleaned daily to restrict entry of waste during manhole opening.
3. In case of large RWH tanks in open spaces, vehicles should not be permitted to park on tank top as this may lead to contamination of water.
4. Provide system for drawing the water to make it easy to collect and use. To make this eco-friendly, use non-motorized system. This will also avoid water wastage.

**Seasonally**

1. Tanks and roofs should be cleaned before rains.
2. First rain must be flushed away and not harvested because it has certain impurities.
3. Alum should be added periodically to disinfect the water.

**Annually**

1. Filters in retrofitted systems should be replaced after two seasonal rains.
2. Wastewater should not flow into the tank.
3. If tank water is contaminated, then it should be flushed out before the rains to capture fresh and clean rainwater.
CASE STUDIES ON RAIN WATER HARVESTING
AGRA

1 Pre-Middle School, Tedi Bagiya 60
2 Ambedkar Bagichi Panchayati, Basai Khurd, Tajganj 64
3 Madan Mohan Temple, Kolhai Tajganj 65
4 Billochpura Mosque, Tajganj 66
5 Retrofit RWH Systems in Agra 67
6 Recharging System at Nagla Teen, Taj Ganj 71

DELHI

1 G-Block Basti Vikas Kendra (BVK) Savda Ghevra J. J. Colony 75
2 Rain Water Harvesting & Water Resiliency at B-Block Seemapuri and D-Block Dilshad Garden 77
Centre for Urban and Regional Excellence (CURE) in partnership with other organizations – FRANK WATER and ARGHYAM has developed seven Community Rooftop Rain Water Harvesting Systems in six different locations in Agra.

- Three RWH Structure in Tedi Bagiya (Pre-Middle School Ambedkar Nagar Tedhi Bagia, Government School Kalindi Vihar Tedi Bagiya)

- Four RWH Structures in Tajganj (Ambedkar Bagichi Panchayati Basai Khurd Tajganj, Madan Mohan Temple Dalhai Tajganj, Mosque at Billochpura Tajganj, Government School Nagla Teen Tajganj). Five of these structures are described below:
Pre-Middle School, Tedi Bagiya

Tedi Bagiya area is not networked to the city’s piped water service. People extract groundwater for all uses either by immersing bore wells or buying groundwater. The submersible pump/bore-well in the school in the neighbourhood had stopped working. The school depended majorly on one hand pump for all water needs of drinking, cooking mid-day meals and flushing toilets. Since the school complex comprised an open ground and 3 single-story buildings comprising classrooms, a kitchen and toilets, there was enough rooftop area for harvesting rainwater.

The Rainwater Harvesting system at Tedi Bagiya School comprises 2 underground tanks with a capacity of 80,000 litres and 35,000 litres. The tanks are connected to the rooftops through a system of pipes and drains. The overflow of the tanks is channelized to a common groundwater recharge pit. An opening is provided extracting water and for cleaning the tank.

Rainwater is now used by 320 children, teachers and school staff members. They use it in mid-day meal and drinking. It reduces Gastric issues of teachers and school staff members. Parents reviewed that it is fit for drinking. School is...
saving Rs. 1200 per month from purchasing tanker water for their use.

The Manhole of the tank is closed for safety and the top slab of the tank is painted so that no vehicles park on top of the tank. They also use water from the tanks for plantation and greening of the school compound.

Ambedkar Bagichi is a triangular shape community space in Basai Khurd, Tajganj. There is a huge open space with four blocks of Community Hall, School, Temple and Toilet at the periphery. They mostly use it for marriages and festivals. To supplement water, women and children queue up at the community water tank filled by Agra Municipality tankers.

The initial proposal from CURE was to build two tanks – one for the rooftop water from Community Hall and School and the second one collecting all the surface catchment. The first tank's construction is complete and is used by the community members. However, the second tank proposed for channelizing the surface water has yet not started. People feel that the open space is not so clean to be used for water collection. Old people of the area who sit there spit paan-masala all over the space, making the compound filthy. Also, during marriages or other events, food is
Figure 3: Tank construction process in Pre-Middle School, Tedi Bagiya

Marking of the tank location

Digging the tank

Construction under progress

Connecting pipeline from the roof to silt trap

Preparing the tank top

Completion of the tank

Preparing the base and initializing construction
prepared and served to people. There is a possibility that the waste would also end up in the tank. Therefore, for now, the second tank has been put on hold.

80 Households living in the vicinity are using tank water for drinking whenever there is a shortfall of water in the year. They are also managing the system.

Figure 4: Tank Water and Locking Manhole for Student’s Security

Figure 5: Water Dispensing System Supplying Tank Water
Ambedkar Baghichi is a triangular shape community space in Basai Khurd, Tajganj. There is a huge open space with four blocks of Community Hall, School, Temple and Toilet at the periphery. They mostly use it for marriages and festivals. To supplement water, women and children queue up at the community water tank filled by Agra Municipality tankers.

The initial proposal from CURE was to build two tanks – one for the rooftop water from Community Hall and School and the second one collecting all the surface catchment. The first tank’s construction is complete and is used by the community members. However, the second tank proposed for channelizing the surface water has yet not started. People feel that the open space is not so clean to be used for water collection. Old people of the area who sit there spit paan-masala all over the space, making the compound filthy. Also, during marriages or other events, food is prepared and served to people. There is a possibility that the waste would also end up in the tank. Therefore, for now, the second tank has been put on hold.

80 Households living in the vicinity are using tank water for drinking whenever there is a shortfall of water in the year. They are also managing the system.
Ambedkar Bagichi is a triangular shape community space in Basai Khurd, Tajganj. There is a huge open space with four blocks of Community Hall, School, Temple and Toilet at the periphery. They mostly use it for marriages and festivals. To supplement water, women and children queue up at the community water tank filled by Agra Municipality tankers.

The initial proposal from CURE was to build two tanks – one for the rooftop water from Community Hall and School and the second one collecting all the surface catchment. The first tank’s construction is complete and is used by the community members. However, the second tank proposed for channelizing the surface water has yet not started. People feel that the open space is not so clean to be used for water collection. Old people of the area who sit there spit paan-masala all over the space, making the compound filthy. Also, during marriages or other events, food is prepared and served to people. There is a possibility that the waste would also end up in the tank. Therefore, for now, the second tank has been put on hold.

80 Households living in the vicinity are using tank water for drinking whenever there is a shortfall of water in the year. They are also managing the system.
Billochpura Mosque, Tajganj

This is a mosque complex situated in Billochpura, Tajganj. The complex has a huge foreground before the mosque, which is well connected to the street. There is a Gular tree on the right, with a platform (chabootra) underneath. It serves as a playing/informal sitting area for the residents of the area. There are shops to the left, facing the street, which are owned by the mosque and are rented out. Adjacent to it is a water tank which is connected to bore well and serves as a community stand-post. There is a graveyard attached to this mosque at the rear side and the community is majorly Muslim.

Minor amendment in the design took place while carrying out the work on the ground. The tank, chambers, drains and silt trap were constructed and covered to avoid contamination of water. The chabootra has been restored. The community took the initiative to clean up the terrace, tanks, drains and chambers and prepare the system to arrest the next rainfall.
5 Retrofit RWH Systems in Agra

Agra has retrofit rainwater harvesting systems in 54 households: 19 in Ambedkar Nagar, 9 in Islam Nagar, 3 in Sati Nagar, 4 in Jagjeevan Nagar, 1 in Bhagwati Bagh, 1 in Kalindi Vihar, 9 in Ambedkar Bahichi, 8 in Nagla Teen. We show location of these structures in maps below:
Figure 14: HRWH Systems at Islam Nagar, Tedhi Baghia, Agra
Figure 15: HRWH Systems at Jagjeevan Nagar, Tedi Bagiya, Agra

Figure 16: HRWH System at Sati Nagar, Tedi Bagiya, Agra
Figure 17: HRWH Systems at Bhagwati Bagh, Tedi Bagiya, Agra

Figure 18: HRWH Systems at Kalindi Vihar, Tedi Bagiya, Agra
The people of Nagla Teen depend on government provided stand posts, submersible and bottled water for fulfilling their water needs. The water from submersible and stand posts are used for washing and bathing purposes. Bottled water is used for drinking purposes by the people of Nagla Teen. The water extracted from submersible pump and bore-well however is saline, has high TDS levels and cannot be consumed without filtration. Further, the high rate of ground

Figure 1 RWH construction process at Primary School, Nagla Teen

BACKGROUND

The people of Nagla Teen depend on government provided stand posts, submersible and bottled water for fulfilling their water needs. The water from submersible and stand posts are used for washing and bathing purposes. Bottled water is used for drinking purposes by the people of Nagla Teen. The water extracted from submersible pump and bore-well however is saline, has high TDS levels and cannot be consumed without filtration. Further, the high rate of ground
water extraction has led to defunct bore wells and depleting ground water table. The current level of water stands at 200ft.

CURE for the past few years has been actively involved with the community to help make Nagla Teen water resilient. Two years ago, CURE helped install a rainwater harvesting tank in a Primary school in Nagla Teen which has a capacity of 76000L, built with local materials. Community members oversaw the tank construction, provided living space for masons and laborers in the school and community center and for storage of materials.

Since the construction of tank two years ago, the fresh water harvested is being used by the school children. Their health has improved, reflected in the better school attendance. The school was also able to save the money, that was earlier spent on buying drinking water. Since then, 5 SHG’s have been formed and after several meetings, the residents of Nagla Teen have taken an active part and initiative in the process of making Nagla Teen water resilient.

Five Self Help Groups overseeing their area and RWH tanks. Regular monthly meetings are conducted where issues on water and sanitation are raised and discussed upon. The SHG’s collect 100 rupees per member every month which is then given as loan to community members as and when required.

ADOPTION OF RECHARGING SYSTEM

During community rallies with CURE team, ward councilors, local leaders, groups and
exposure visits to RWH tanks; three SHG’s (Narayan Hari, Bheema Bai and Sandhya) have expressed their interest in water conservation. The work is to be taken up in three phases with respect to the three communities. Currently, the work undertaken is under the area covered by SHG-Narayan Hari.

CURE in partnership with USAID is supporting 14 households to conserve rainwater through recharge pits. The idea is to catch every drop of water that is likely to fall on their roof and put it into the ground. The recharging pit is connected to the rooftops through a system of pipes and drains. A few other points have also been identified for recharging. The aim is to build the entire area of Nagla Teen as water resilient in terms of groundwater recharging or harvesting. The community shares the view and understands that fresh water is a limited resource and the more we conserve, the better their future will be, the better chance their children will have at surviving.

An estimated 4,05,000L per year from the 14 households’ roof is expected to be collected and recharged in three separate pits through a system of pipes, filtration chambers and channels. The depth at which the pipe is placed for recharging is 120ft.

Majority of the households do not have a separate pipe for drainage of rainwater, therefore pipes have been installed in these houses creating a separate pipeline for discharge of rainwater. This pipe is further connected to a filter chamber before connection to the main pipeline which then discharges into the pit. The depth at which is the pipe is inserted is 120ft.

A few households of Nagla Teen have no source of income. Being short of money and resources, they unlike others cannot afford bottled water and consume the government supplied poor quality water for drinking. The work on water conservation, brings hope for a better and secure future for such families and the entire community.

The community today wants to be involved in the process, save water and is ready to provide support to the team and help in water conservation.
G-Block Basti Vikas Kendra (BVK) Savda Ghevra J. J. Colony

CURE observed that the water level of Savda Ghevra is depleting continuously. It went down from 40 meters to 60 meters within 3 years. Quality of groundwater is also poor. Water testing report shows that the TDS, Nitrate, sulphate and total hardness level is much beyond the permissible limit. Because of lack of water supply system, community is drawing more and more water from the ground, which is depleting the groundwater level. Due to lack of sewer line system, community constructs normal holding tank, and seepage from these tanks pollute the groundwater. It is hence necessary to action to conserve the groundwater and stop its contamination and or depletion.

Every block in Savda Ghevra J.J. Colony has at least one community hall or Basti Vikas Kendra. G Block Basti Vikas Kendra (BVK) already has a rainwater recharge system installed in it when the BVK was constructed. CURE conducted an on-site inspection and found that there is a lot of plastic waste dumped in the last chamber which restricts the percolation of water into the ground.

The plastic waste needs to be removed and the top layer of soil loosened to enable better recharge of ground water. Calculations suggest that the G-Block BVK has a catchment area to capture around 85,000 litres of water with substantial rainfall as-
assuming the average annual rainfall to be 715 mm. Rainwater is the purest form of water that can be harvested, provided the catchment area is clean and free from dust and impurities. With every year’s net rainfall, more than 1,00,000 litres of water is being recharged onto the ground. CURE proposes to harvest some water before it is being sent to recharge the groundwater. This would be a demonstration in Savda Ghevra. The water which is harvested would be used by households for drinking purposes.

Rainwater is usually harvested in underground tanks to utilize the maximum space and not obstruct the ground space.

In the BVK, there is an existing rainwater recharge system, a septic tank and a collection chamber for the kitchen waste. There is not enough space left to construct an underground tank without contamination. So, CURE proposes to place Sintex tanks of 2000 litres each and connect them to form a series of tanks. Approximately, 10,000 litres can be collected. CURE is propagating the idea of installing taps and using this water for drinking purposes. This would considerably decrease diseases caused due to contaminated water, thereby increasing the quality of life for the people. The total cost of the same is estimated to be Rs. 1,00,000.
Rain Water Harvesting at B-Block Seemapuri and D-Block Dilshad Garden

The two Primary School in Shahdra Zone were the worst schools under EDMC. Poor infrastructural facilities and hygiene, waste dumping in school premises, bad lighting and the poor quality of education, led to a reduction in enrolment. School operates in three-four shifts; and many students belong to the poorest sections of society including rag pickers. Many students come from 5 km.

As there was no open space available in the neighbourhood, it was decided that an RWH system will be built within the school premises. Through stakeholder and resource mapping with parents and teachers, it was found that school has one storage tank for storing water from Jal Board Supply. Municipal water supply was intermittent, frequent failure of the motor in summers forced them to purchase water from the tanker or outside. The
approach to the school was from a narrow lane and flooding was common during rains. The schools installed submersible for using groundwater for drinking and cooking to supply 3100 school staff, teachers and children in B-Block Seemapuri School and 1000 school staff, teachers and children in D-Block Dilshad Garden School.

School has large roof area and ground surface, therefore, the concept of conserving water through harvesting from the roof, recharging to ground, treating liquid waste from DEWATS was developed. It was planned to harvest half of the roof catchment volume of 24,000 L in the tank in B-Block Seemapuri School and 10,000 L in D-Block Dilshad Garden School by connecting roofs to present storage tanks shown in figure 28 below. Though tank is not fully utilised and subsequent connections will be made in future.

Overflow from the tank was made to recharge pit. The recharging pits are capturing water in B-Block School and 10,000L water in D-Block Dilshad Garden from roof run off and surface run off.

At present, the harvested water in both schools is used for plantation.