Figure 1: A Tanka in Rajasthan

Catch every drop of water where it falls…

A rain water harvesting compendium

Compiled by Nitya Jacob & Sunetra Lala;
Edited by Sumita Thapar

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Foreword

Rain water harvesting systems (RWHs) are decentralized, cost-effective and serve different uses. These range from domestic consumption, agriculture, ground water recharge, soil and water conservation, drought proofing, flood control to augmenting water storage capacity of the country as a whole. RWHs are the main source of water in the drier parts of India, as also in areas where ground water is too contaminated to drink.

This publication is based on discussions in the Water Community of Solution Exchange over the past four years. These discussions have looked at rain water harvesting (RWH) as a safe means of supplementing other sources of water for drinking, for ground water recharge and for irrigation. The Water Community members have shared a wealth of experience on RWH that has been collated in this compendium. We have provided references to people and organizations working on RWH across India with each example, so that those interested in setting up systems can contact them for technical, financial and other assistance. All these references come from the consolidated replies circulated in the Community.

In the conclusions, we present arguments for and against RWH, taken from the discussions on the Community. Based on these, we have summarized policy recommendations for the government and other agencies wanting to take up RWH in a big way.

We have divided the examples by water use. You will find RWH models for drinking water in one place, followed by RWH for agriculture and then for other purposes. We have provided the contact information for the organization or individual for more information and help in implementing a RWH system. We have selected a few RWHs for detailed description. These are usually the 'base' systems on which others can be designed.

At the end of the publication you will find references from where we have taken these examples, again collated from the consolidated replies, for further reading and action.

We hope this publication will take the debate on rain water harvesting forward for India, given the importance of this method of harnessing nature's bounty.

We are grateful to UNICEF for their support, and the Department of Drinking Water Supply for their help in bringing out this publication.

Nitya Jacob, Resource Person & Sunetra Lala, Research Associate
Water Community,
Solution Exchange,
UNICEF,
73 Lodhi estate,
New Delhi 110003

Chapter 1: Introduction

India's water crisis has aggravated over the past few decades. Surface water is not enough to meet the needs of domestic, agricultural and industrial consumption. The existing river basins are either fully or over committed and ground water is over-exploited in 13 percent of the districts in India. The estimated per capita water storage capacity is just 200 cu m per year, which is inadequate to meet the daily requirements of India's population.

In addition to quantity, the quality of water is declining because of rapid urbanisation, industrialisation and modernization of agriculture. Studies conducted by the Central Ground Water Board (CGWB) in several parts of India reveal that groundwater is contaminated with fluoride, arsenic, nitrates and other salts, and is unfit for drinking without treatment. In coastal Kerala and Gujarat, and parts of Tamil Nadu, sea water ingress has turned well water brackish.

The source of all water is rain. Lakes, water bodies, rivers, ground water are secondary sources of water. Rain water has been collected and used down the ages for irrigation, human consumption and now, by industries. Rain water harvesting is the process of collecting and storing rain water for future use. Its role and significance are seeing a revival today owing to the enormous pressures on limited ground and surface water resources.

While RWH is a broad generic description in the rural context, as water collected mainly for agriculture purposes in dry land and tank-irrigated area, rooftop rain water harvesting has a clearer definition as water collected from rooftops chiefly for domestic consumption. It is estimated that about 70-80 percent of all rain that falls can be harvested.

India's rich tradition of rain water harvesting

Figure 2: Chand Ki Baoli, a stepwell in Rajasthan

India has a rich tradition of rain water harvesting. In ancient times, households and communities were self-sufficient in their water needs. Houses were designed to collect and store rain water; community tanks and systems of irrigation ensured the maximum use of rain. Water structures were community-owned and managed. All of this changed with the coming of piped water supply. With the government assuming ownership of water management, age-old traditions and practices of managing water by the community were abandoned.

The present water crisis has led to a revival in traditional methods of rain water harvesting across India. At the same time, since the 1990s, practitioners have developed new techniques to harvest rain water. Rain as the primary source of water is being rediscovered and harvested for multiple uses: Groundwater recharge, domestic use, drinking, irrigation.

In central and western India, the former rulers built an elaborate system of surface storage structures for each town or fort. These collected rain water from a set of catchments and were either stored and used in one place or channeled through the town or fort.

Step wells are India's most unique contribution to architecture. They are called vav or vavadi in Gujarat, and baolis or bavadis in Rajasthan and northern India. The step wells of Gujarat consist of a vertical shaft in the middle from which water is drawn. This shaft is surrounded by corridors, chambers and steps, which provide access to the well. They were profusely carved and served as a cool resting place in summer. Mata Bhavani's vav at Ahmedabad, built in the eleventh century, is one of the earliest step wells, while the Rani Vav (Queen's well) at Patan, built during the late eleventh century, is the grandest. The Dada Harir's vav at Ahmedabad, and the octagonal vav at Adalaj, are some of the finest examples of step wells.

In 1615, during the Mughal rule, Abdul Rahim Khan built a unique water supply system of the Burhanpur town (Madhya Pradesh). The system involved construction of long lines of underground tunnels with vertical airshafts to tap the underground water flow from the nearby Satpura hill ranges to the Tapi River lower down. The system is still functioning well and is adequate to meet the entire water requirements of the town.

The city of Hyderabad (Andhra Pradesh) has a glorious tradition of tanks built by its ruler Mohammad Quli Qutub Shah in the 16th Century. The first source of water supply to the town was the Hussain Sagar Lake built by Hussain Shah Wali in 1562. In the hills near Daulatabad, two reservoirs were built by the Hindu Kings, in ancient times to meet the water requirements of the city.

Many uses of rain water harvesting

Rain water is the purest form of water and therefore an excellent source of drinking water. It can be filtered or put in the sun in glass bottles to further disinfect it with UV rays. It does not require chlorination. Rain water does not have the arsenic and fluoride pollutants present in groundwater and hence, is good for drinking with minimal treatment in area where groundwater is contaminated.

Rain water harvesting also helps conserve groundwater, and can be taken up as a people's movement especially in regions where there is excessive groundwater exploitation for agricultural, domestic and industrial needs. Aquifer recharge also reduces the energy required to pump groundwater and therefore, impacts climate change. By extension, it has a role to play in food security and growing value-added crops.

Rain water harvesting is especially important in India, where most rain fall is concentrated in the four months of the monsoons, and the rest of the year is relatively dry. While some parts receive large amounts of rain over a few days, many parts of the country get scanty and irregular rainfall. In this context, rain water harvesting is important for storing water for communities in locally accessible structures.

In rural areas, most rain water harvesting structures serve more than one purpose while in urban areas, rooftop rain water harvesting is used primarily for domestic use and supplements the municipal water supply.

Decentralized social structures help sustainable development by binding people and water together. Rain water harvesting systems are sensitive to local ecological demands and community needs, for example, where the number of days with rainfall is short, the systems use rain water for recharging groundwater.

Figure 3: A talaab in Rajasthan for bathing and washing clothes

Rain water for drinking and domestic use

Given its intrinsic qualities, rain water is ideal for drinking with minimal treatment. It is especially useful where groundwater is contaminated, but also where other sources of water, such as from wells, hand pumps, the municipal corporation or panchayat sources, is irregular.

There are different ways to collect rain water for drinking and domestic use, depending on where RWH is being practiced. In cities, where there is a shortage of open spaces but abundance of concrete roof areas, roof top RWH is the preferred option. These collect and store water for domestic consumption – drinking, maintaining gardens flushing and other household purposes. Apartment complexes, housing societies and high-rise buildings have developed effective models to harvest rain water.

Roofs are easier to maintain, water from rooftops is easily channeled and fit for consumption as it does not contain bacteria and chemical impurities which may be present in run-off from other unpaved and paved areas. The rain water collected is filtered and treated to make it suitable for consumption for household needs such as cleaning, washing, bathing, watering plants, sanitation. This reduces dependence on piped water supply, used only for drinking and cooking. The excess harvested rain water is channeled into a recharge ditch or well.

In cities, people usually depend on the municipal supply for drinking and cooking, while the rain water is used for other purposes, reducing dependence on, and conserving, municipal water supply.

In rural areas of Rajasthan, ***tankas*** (a round concrete rain water harvesting and storage structure) are used for collecting and storing rain water. These are circular, dish-antenna shaped structures made of concrete. The catchment is either round or rectangular depending on the space available and the collected rain water is stored in an underground tank in the centre. A variation of the tanka is found in Gujarat where households channel water from rooftops to an underground tank for storage.

A very simple method is practiced in heavy rainfall areas of Kerala and Karnataka. During the three monsoon months, drinking water needs of each house are met by a simple saree-based rain water harvesting system. All the three parts of the system – Catchment, transport and filtration of rain – comprises of a single piece of cloth. This traditional method is used in Kuttanad (Aleppy district), Kerala, where the available water is heavily contaminated. Families using this system boil the water before drinking. They keep this water in storage vessels and use it for drinking needs for a week. There is hardly any hesitation to drink rain water in these areas.

In Nagapattinam, Tamil Nadu, which has a severe water problem, roof water harvesting structures have been installed in schools, temples, panchayat office, as well as 90 households. House types include tiled, thatched-roof and concrete. Results post-rains found that families which had installed the RWH structures had enough rain water for their own needs. They sold the surplus at Re 1 per pot. If the roof was thatched, a tin sheet was placed over it from where a pipe conveyed water into a plastic tank after filtration. The water was tested and found safe for drinking.

Ooranis are surface storage structures that also used in Tamil Nadu for collecting rain water from a catchment area as well as what falls directly on it. These are designed to keep the water free from bacterial contamination, and filtration methods remove suspended impurities. The details are given in Annexure 2.

Rain water for recharge

Groundwater is lifeline of India's water sector, accounting for half of all water consumed. It can be a sustainable source only if the recharge equals or exceeds the amount of water drawn and this usually depends on the level of exploitation of the watershed, amount of rainfall, and percolation efficiency. Rain water can be recharged into aquifers through natural or man-made structures like dug wells, borewells, recharge trenches and pits. The quality of water used for recharge is critical as it risks polluting ground aquifers. Buildings with rain water harvesting systems must ensure garden areas are free of chemicals such as insecticides and pesticides. In some cases, only water from the roof is used for recharge.

However, it is important to understand only excess water from the storage structure goes towards recharging aquifers. Against this background, rain water harvesting in one place actually affects the recharge potential of an aquifer elsewhere. This is discussed in detail in the chapter on recommendations.

Rain water for irrigation

Traditionally, most agriculture in India has been rainfed, dependent on the two monsoons. Farmers and rural communities have developed a whole host of rain water harvesting techniques in each geographical area to suit local climatic and cultural conditions. These are described in detail in the section on rain water harvesting for irrigation in the next chapter.

Water policy and legislation

In recent years, many states and cities have mandated rain water harvesting. This is partly as a result of the growing problem of providing an assured supply of water for all purposes, partly to raise awareness of the need for conserving water, and partly because of growing public awareness that the government cannot provide for all the water needs of everybody. All states use a combination of monetary and punitive measures to 'encourage' their citizens to set up rain water harvesting systems.

Himachal Pradesh

All commercial and institutional buildings, tourist and industrial complexes, hotels etc, existing or coming up and having a plinth area of more than 1000 square metres will have rain water storage facilities commensurate with the size of roof area. *No objection certificates,* required under different statutes, will not be issued to the owners of the buildings - unless they produce satisfactory proof of compliance of the new law. Toilet flush systems will have to be connected with the rainwater storage tank. It has been recommended that the buildings will have rain water storage facility commensurate with the size of roof in the open and set back area of the plot at the rate of 0.24 cft. Per sq m of the roof area.

Ahmedabad

In 2002, the Ahmedabad Urban Development Authority (AUDA) had made rainwater harvesting mandatory for all buildings covering an area of over 1,500 square metres. According to the rule, for a cover area of over 1,500 square metres, one percolation well is mandatory to ensure ground water recharge. For every additional 4,000 square metres cover area, another well needs to be built.

Bangalore

In order to conserve water and ensure ground water recharge, the Karnataka government in February 2009 announced that buildings, constructed in the city will have to compulsorily adopt rain water harvesting facility. Residential sites, which exceed an area of 2400 sq ft (40 x 60 ft), shall create rain harvesting facility according to the new law.

Port Blair

In 2007, Port Blair Municipal Council (PBMC) directed all the persons related to construction work to provide a proper spout or tank for the collection of rain water to be utilised for various domestic purposes other than drinking. As per the existing building by-laws 1999 the slab or roof of the building would have to be provided with a proper spout or gutter for collection of rain water, which would be beneficial for the residents of the municipal area during water crisis. The PBMC had advised all the owners of buildings in the Municipal area to comply with the provisions within four months failing which action would be taken against them by the Council.

Chennai

Rainwater harvesting has been made mandatory in three storied buildings (irrespective of the size of the rooftop area). All new water and sewer connections are provided only after the installation of rainwater harvesting systems.

Kerala

The Kerala Municipality Building Rules, 1999 was amended by a notification dated January 12, 2004 issued by the Government of Kerala to include rainwater harvesting structures in new construction. It also specifies the amount of storage and linkage with ground water recharge, and requires the occupier of the building to maintain the rain water harvesting structure.

New Delhi

Since June 2001, the Ministry of Urban affairs and Poverty Alleviation has made rainwater harvesting mandatory in all new buildings with a roof area of more than 100 sq m and in all plots with an area of more than 1000 sq m, that are being developed. Dual piping has to be installed to make use of the harvesting water.

The Central Ground Water Authority (CGWA) has made rainwater harvesting mandatory in all institutions and residential colonies in notified areas (South and southwest Delhi and adjoining areas like Faridabad, Gurgaon and Ghaziabad). This is also applicable to all the buildings in notified areas that have tubewells. The deadline for this was for March 31, 2002. The CGWA has also banned drilling of tubewells in notified areas in Delhi, where ground water levels have fallen substantially over the past several decades

Indore (Madhya Pradesh)

Rainwater harvesting has been made mandatory in all new buildings with an area of 250 sq m or more.

A rebate of 6 per cent on property tax has been offered as an incentive for implementing rainwater harvesting systems.

Kanpur (Uttar Pradesh)

Rainwater harvesting has been made mandatory in all new buildings with an area of 1000 sq m or more.

Hyderabad (Andhra Pradesh)

Rainwater harvesting has been made mandatory in all new buildings with an area of 300 sq m or more.

Tentative for enforcing this deadline was June 2001.

Tamil Nadu

Through an ordinance titled Tamil Nadu Municipal Laws ordinance, 2003, dated July 19, 2003, the government of Tamil Nadu has made rainwater harvesting mandatory for all the buildings, both public and private, in the state. The deadline to construct rainwater harvesting structures is August 31, 2003. The ordinance cautions, "Where the rain water harvesting structure is not provided as required, the Commissioner or any person authorised by him in this behalf may, after giving notice to the owner or occupier of the building, cause rain water harvesting structure to be provided in such building and recover the cost of such provision along with the incidental expense thereof in the same manner as property tax". It also warns the citizens on disconnection of water supply connection provided rainwater harvesting structures are not provided.

Haryana

Haryana Urban Development Authority (HUDA) has made rainwater harvesting mandatory in all new buildings irrespective of roof area.

In the notified areas in Gurgaon town and the adjoining industrial areas all the institutions and residential colonies have been asked to adopt water harvesting by the CGWA. This is also applicable to all the buildings in notified areas having a tubewell, deadline was for March 31, 2002.

The CGWA has also banned drilling of tubewells in notified areas.

Rajasthan

The state government has made rainwater harvesting mandatory for all public and establishments and all properties in plots covering more than 500 sq m in urban areas.

Mumbai

The state government has made rainwater harvesting mandatory for all buildings that are being constructed on plots that are more than 1,000 sq m in size.

The deadline set for this was October, 2002.

Gujarat

The state roads and buildings department has made rainwater harvesting mandatory for all government buildings in the state. The water will be harvested and directed to percolation wells, and from there will be also used to maintain gardens. All new buildings need to have rain water harvesting systems, else they will not be issued building-use permissions.

Chapter 2: Models for Rain Water Harvesting in urban areas

In this chapter, we will examine a few models, shared by members in their responses to queries on rain water harvesting, on rain water harvesting. We have divided the chapter by use of rain water in urban and rural areas.

RWH for Domestic Use and Recharge in Urban Areas

Several cities have included norms for rain water harvesting in municipal by-laws for new buildings and some even require existing buildings to be retro-fitted with these systems. Uptake has been slow however, due largely to a lack of information on RWH, who to approach for implementing a system and the costs. People filter the harvested water for drinking, or store it for other domestic uses. RWH systems in parks provide enough water to irrigate them through the dry months.

Basic Principles of Rain water harvesting for drinking

In actual field conditions, the size of the collector and storage system is dictated by the available roof area and the rainfall. While these factors are usually fixed, some modifications can be made in the type of roof covering to improve runoff. The water harvested from the available roof area, therefore, is more or less fixed and has to be judiciously used. The typical rooftop water harvesting system includes the following elements:

- Sloping roof, designed appropriately in the direction of storage and recharge. The roofing material should be non-toxic and the surface should be smooth, hard, dense and easy to clean. It should not release material or fibre into the water. Roof painting is not recommended since paint contains toxic substances.
- There should be no trees overhanging the roof and birds should not be allowed to nest on the roofs
- Gutters and/ or down pipes depending on site rainfall characteristics and roof characteristics. The gutter ends should be fitted with wire mesh to keep out leaves, insects and rodents
- A first rain separator to divert and dispose off the first 2.5 mm of rain.
- Filtering the water to remove solids and organic material
- Storage tank of appropriate size with a tight fitting cover that is light proof, a manhole cover and a flushing pipe at the base. There should be a reliable and sanitary water extraction device such as a tap or handpump that obviates the need to take water out by immersing vessels. The tank should be situated such that there is no chance of waste water entering it
- Recharging groundwater through open wells, bore wells and percolation pits. To convey excess water, a hygienic soak away channel should be built at water outlets and a screened overflow pipe should be provided.

The details of setting up a roof top rain water harvesting structure are discussed in annexure A in terms of the type of structure, quantity of water, and use of the water harvested.

Case studies

Apartment blocks in Badlapur, Mumbai

The average rainfall in Maharashtra state is 2,000 mm annually, mostly from June to September. In July 2005, rainfall reached 1,000 mm in one day, flooding almost the entire state. In Kulgaon-Badlapur, 60 km away from Mumbai, residents realized the rain's potential as a solution to their water needs. The Kulgaon-Badlapur Municipal Corporation decided to make a strong action plan for water management, including rain water harvesting.

The RWH system is being implemented for housing societies to enhance the groundwater table and to provide additional water for residents. Rain gutters and pipes were used to connect the roofs of 36 apartment buildings forming a system that captured and stored rain water. An electric pump is used to pump water back into the buildings' taps for everyday household use.

About 2,000 residents now get water 24 hours a day, 7 days a week from this RWH system. The additional water amounts to about 100 liters per person per day, more than enough to meet washing, toileting, and other domestic water needs. It has reduced the demand from the municipal system, which is used only for drinking and cooking. A water filtration plant treats water with alum and sodium hypochlorite, making it water clean enough for bathing. A big plus of the system was reduction in groundwater withdrawals.

Badlapur's rain water harvesting unit, which started in March 2007 directs the surplus water into an underground "absorption pit", and allows it to percolate through the soil to recharge the groundwater table. An over-ground storage tank with an electric pump draws water from the underground tank when needed. The pipeline has a header and lateral system with a float valve that operates on a hydro pneumatic system. This means that whenever the water level goes down for individual buildings, the storage tank's electric pump starts automatically.

The project cost Rs.17 lakh (about US$40,000) to build, of which the Mumbai Metropolitan Region Development Authority (MMRDA) provided Rs 10 lakh as a grant and another Rs 5 lakh as a loan. The local municipality raised the rest of the cost. Each household pays Rs 2-3 a day, enough to cover maintenance costs and ensure full loan payment within 2 years.

For more information on the project, you can contact Ram Patkar, President, Kulgaon-Badlapur Municipal Council Ram 0251 2691556; email: rampatkar@gmail.com.

Source: http://www.adb.org/Water/Actions/IND/Badlapur.asp

Asian Paints' High-rise Housing Society in Powai, Mumbai

To pilot the concept of total water management, corporate Asian Paints chose a high-rise co-operative housing society in Mumbai. An innovative and highly cost-effective RWH scheme was developed in 2002 taking into consideration the existing infrastructure of the building. The dome structure and terrace of the building were used as catchment areas. The dome is the highest part of the 27-floor building and stands above the overhead water supply tanks. This dome structure has been used to an advantage by making arrangements to collect rain water and connecting it directly to the overhead tanks that provide water for flushing and domestic use. Since this scheme delivers water directly from the dome to the overhead water supply tanks, there is no need to pump water. This gives a tremendous added benefit of saving electrical power along with water.

The rest of the terrace is used to collect rain water, and taken through the existing down pipes to the underground flush water tank. These have been extended using PVC water pipes to an underground flush water tank. The existing down spouts which were earlier just left on the ground to join the storm water drains are now extended using PVC water lines to the underground flush water tank.

For the Housing Society, the RWH has not only reduced fresh water intake from the Bombay Municipal Corporation, it has eliminated the requirement for water tankers during the monsoon. The cost-benefit analysis for saving water and electrical power showed that the investment was paid back in just one monsoon.

The company also set up a total water management centre to educate citizens on the concept of total water management, implement water conservation in buildings, showcase rainwater harvesting and provide free expertise.

For more information and assistance, please contact Jason / Rajdeep, Asian Paints Limited Tel: 56958547 / 8000 (B), Email: proffice@asianpaints.com

Vinod Chopra, independent consultant, New Delhi

Vinod Chopra has built a RWH structure that collects water from all the rooftop areas at one point, and drains it into a single 1.5 cu m unlined pit containing layers of gravel and sand to filter out mud. As the pit is 1.5 m deep, it never overflows, allowing water to percolate into the ground. In experiments over the past four years, it has been found that 1500 litres easily percolates through the pit even in peak monsoons. Using this RWH method an estimated 45,000 litres (150 sq m x 30 cm) is collected per year. This is assuming that 50 percent of the rainfall (30 cm of the 60 cm annual rainfall) can be collected.

The cost of installing the RWH system was about Rs. 15,000. The cost of enhancing groundwater below the house is about Rs 33.33 per kilolitre over a 10-year period. In contrast, the cost of water received from the municipality is Rs 6 per kl, making the system "an economically unviable option", according to the house owner. There is a discussion in the cost of water from RWHs and what municipalities provide in the next chapter.

For more information, please contact, Vinod Chopra vinodchopra@gmail.com <mailto:vinodchopra@gmail.com>

Rahul Banerjee, Aarohini Trust, Indore

The rain water collection system in … house was built in and is similar to the house in Delhi (above) but the recharge mechanism is different. Five recharge bores 30 cm each in diameter were drilled 5 m into the ground and filled with layers of gravel and sand.

This system has worked very well in recharging the water from the roof without overflowing. Annually, 40,000 litres of water is harvested using the same assumptions as above for the Delhi house. However, cost of recharge is much less. The cost of pipe has not been included as these pipes had to be installed to drain water from the roof regardless of whether the water is used for recharging groundwater. (If this is not done, the water flows onto the street from the rooftop which is against municipal rules.) The recharge bores cost Rs 1,000 each, thus giving a total cost of Rs 5,000. Over a ten-year period the cost of recharge is Rs 12.5 per kilolitre. The Indore municipality has just taken a decision to hike water rates to a commercially viable value of Rs. 16.67 per kilolitre from the present subsidized rate of Rs. 6.67 per kilolitre. Thus, recharge cost per kilolitre is competitive to the new commercial rate of the Indore Municipal Corporation.

Moreover, Mr Banerjee spent another Rs. 15,000 in constructing septic tanks and soak pits to treat and recharge all wastewater produced from the house into the aquifer, thus saving the municipality the cost of disposing off wastewater.

The RWH systems are well designed and have had no problem since they were constructed three years ago. "Thus, if actual costs are taken into account, recharging of storm and wastewater is a viable economic proposition and an environmentally sound mode of using scarce water," says Mr Banerjee.

For more information you can contact Rahul Bannerjee, email: aarohini@yahoo.com, Phone: 09926791773

M M Sharma, International Agricultural Research Institute, Hyderabad

The rooftop rain water harvesting system in the house, built along with the house in 1995, collects rain water in an underground tank with a capacity of about 100,000 litres. The house gets over 125,000 litres rain from the roof in a single monsoon. Since 2005, the neighbour's roof has also been connected to the underground tank taking the collection to 250,000 litres of water in a year. This water is used for drinking, cooking, bathing and washing clothes for the whole year. The used water goes to a soak pit to replenish the aquifers.

When the house in the Sainikpuri area of Secunderabad was constructed in 1995 the municipal water supply was not available in the colony. Since supply began in 2002, it has been grossly inadequate. All houses need to have their own dug wells or bore wells. Most dug wells (except those in low-lying areas) have dried up in the last 10 years with the receding water table. In 1995, the depth of the bore well was 170 feet. Since 2004, the new houses in the colony have 6-inch diameter bore wells (unlike 4 inch as earlier) and the depth is now 800-1100 feet.

In Mr Sharma's house, half the water supply of the house comes from rain water and the rest from municipal supply. The bore well is not used at all. The cost of RWH structure was almost 10 percent of the total construction cost of the house when it was built, given its size. It was designed to provide for household needs the year round, in conjunction with the municipal supply. Residents say costs have been recovered and now the system gives a net savings on electricity by avoiding use of the bore-well pump of two horsepower. The quality of water is also much better.

For more information, contact M M Sharma, email: murli.sharma@cgiar.org

Rain water harvesting by industries

Asian Paints first implemented a RWH scheme at its oldest manufacturing facility in Bhandup, Mumbai, in 2002. It was the first corporate house in Mumbai to install such a system. The system is designed to collect 70 kilolitres of rain water per day from rooftops during the monsoon. In the first phase of the implementation (2002-3), a catchment area of 2400 sq m collected 2,274 kilolitres. In the second phase (2003-4), a catchment area of 5400 sq m collected 6,845 kilolitres. The criterion for selection of rooftop was its size and distance from the rain water collection tank.

Water consumption from outside sources has been reduced by 60 percent. Owners say the scheme pays for itself within a three-four year period. The company has replicated the RWH system at four of its other paint plants and also across its housing colonies. The system has been emulated by a number of other companies including Godrej Industries Ltd, in its factory and housing colony in Vikhroli, Mumbai.

Godrej initiated its RWH project in May-June 2003 with two pilot projects in Mumbai. The roof of one of the Godrej Industry buildings measuring 240 sq m was taken as the catchment. Plastic pipes used as conduits carried the water to the 8,000 litre storage tank about 15 m on the opposite side of the building. The existing pipeline letting out rain water from the terrace was attached with a new pipe to discharge the rain water into the storage tank. The water in the tank is used for cooling purpose in the Godrej industry. A second terrace measuring 720 sq m was used to collect water and charge the existing bore well. The total cost of installing the two pilot rooftop RWH projects for the company was Rs 30,000.

Godrej has expanded its RWH initiative. In 2007-2008, 8,500 sq. m roof area was covered and 22,500 cu m of water was collected. This has resulted in reducing water consumption from the municipal supply. Recharging of two borewells has also been undertaken, which resulted in improved yield and quality. The Godrej Garden Enclave, a township of nine towers, has a dual system of water supply: Municipal supply for domestic use; recycled and harvested rain water for flushing, washing and gardening.

Chapter 3: Rain water harvesting in rural areas

Unlike in cities, where rooftop RWHs is the preferred method, villages have developed an array of systems. The reason is simple – India still primarily lives in her villages and people use local material suitable for RWH to build their systems. They tweak these depending on the rainfall, geography, soil and other conditions.

Unlike in cities too, rural RWH usually serve more than one purpose. It is common to see the same structure providing water for irrigation and watering animals, while a well on the site provides drinking water. Water standing in these surface structures also recharges the shallow and medium aquifers, benefitting people living several miles away as well.

Nearly all rural RWHs can be broadly classified into open and closed systems. In the open system, the basic unit of RWH in rural areas is a surface pond with a catchment area. This differs slightly in construction from place to place depending on the topography, local material available, water use and population. It is suitable for use in most areas save for the sandy desert or coastal regions because it is cheap to make and maintain even though the water collected needs filtration and basic disinfection to be potable. Surface ponds work better where is medium to light rainfall (600-800 mm of precipitation per annum) while rooftop systems are better for places where rainfall is scarce (less than 400 mm per annum) as they are more efficient at collection and storage of water. These systems have separate collectors for water depending on the use – drinking from a well dug nearby, washing in an enclosed compound to keep out animals, water animals in an overflow trough; the excess water drains into the ground.

In closed systems, RWH systems, a cemented catchment (roof or ground level) channels water into a tank. These are usually single-purpose systems given their cost and size.

However it is captured, rain water is better than groundwater for drinking as it contains no arsenic, fluoride, iron or pesticides which are difficult to remove even with hi-tech filters. Simple filtration and boiling makes rain water fit for consumption. Studies conducted by IIT Delhi show bacteria die after some time in a storage tank due to non-availability of nutrients.

Rooftop rain water harvesting is a sustainable solution to provide clean, potable water, especially in fluoride- and arsenic-affected areas in rural India. The prerequisite for this model is that the roof (or catchments) be made of steel sheets or some other non-porous material that will allow water to flow into a collection chamber. They must be cleaned before the rainy season.

The techniques and principles for rooftop RWH in rural areas are similar to those in urban areas. The main difference is the type of roofing in rural areas that is either tiled or thatched in many cases. Thatched roofs can be modified for harvesting by covering all of part of them with plastic sheets.

People collect rain water for drinking either directly or indirectly throughout India. One of the better rain water harvesting structures for drinking water suitable for rural and some urban areas are *tankas*, native to Rajasthan. Tankas combine the catchment and storage into one structure that is relatively easy to make and maintain. Rain falling on the catchment flows to the centre and enters the tank through small holes. These can be owned either by an individual or the community. Please refer to Annexure 3 for more details.

In Uttarakhand, people have made rain water harvesting tanks with capacities of 7,000 litres with ferrocement that collect rooftop runoff. In Kerala, there are schemes for recharging drinking water wells using rain water to augment the supply of drinking water in the summer.

Case studies

Rain water harvesting for drinking

Karnataka: Rain water harvesting flouride affected areas

In Karnataka, 5,400 habitations report high levels of fluoride in ground water, used for drinking. In June 2006, the state government launched **SACHETANA.** Under this, the NGO BIRD-K is facilitating construction of rain water harvesting systems in 64 villages across four talukas and four districts which have a high level of fluoride in groundwater. The total cost of the project is Rs 14.5 crore. The project's greatest success has been to overcome resistance to drinking rain water in this area where people were used to drinking water from wells. Recharge of aquifers is also being tried to dilute the levels of fluoride in ground water.

The project has been successful because of a partnership between the government, NGO and local people. The NGO oversees design and construction, and sanctions release of money to the builder of the RWHs only after it is satisfied. Part of the cost of each system is borne by the householders, while those below the poverty line pay a smaller amount.

Approximately 20 litres per family per day is required for drinking and cooking purposes. In a year this translates to 7,300 litres of water. A roof area of 30 sq m and a climatic zone with 300 mm of rain has 9,000 litres of rain water falling on the roof. Under the Sachetana project, household RWH systems are installed to collect rain water, filter in a good sand filter, and store in either an underground or over ground tank. Rain water can be stored for a year without getting spoilt.

The rooftop rain water harvesting tanks have capacities of 5,000-10,000 litres. This water is filtered and 20 litres per day of this fluoride-free water is provided to families for drinking and cooking. This has received an excellent response from the community which has found a notable improvement in health over three months of drinking rain water compared to groundwater high in flouride.

The tanks are situated underground with a robust filter. Some are located inside the house below the room floor or the kitchen floor and hence occupy no outside space. The water is regularly tested for potability using the H2S strip test. Maintenance issues are resolved with the community. The RWH system costs about Rs 12,000 per household. The household contributes about Rs 2,000. The family uses this water only for drinking and cooking purpose.

In Bagalkot district, NGO SKG Sangha has installed 16 rain water-based drinking systems at government schools. The systems have slow sand bed filters with activated carbon in the form of wood charcoal and a sealed storage tank in brick masonry with capacities of 1,500-3,000 litres. The savings in electricity charges to pump ground water will recover the cost of the units within two years and provide clean potable water to fluoride-affected areas.

Although the use of harvested water for drinking has increased in Karnataka, a great deal of interaction is needed to make it popular. Unlike in Rajasthan or Gujarat where rain water from rooftops have traditionally been used for drinking, this is new for Karnataka.

Gujarat: Community Rain Water Harvesting to Fight Salinity, Patan District

Figure 4: Well next to a pond in Katch, Gujarat

In the Saurashtra region of Kutchh, Gujarat, communities harvest enough water to last them six months even though rainfall is as low as 50-200 mm a year. Pravah, a state-level network of NGOs, individuals, institutes has demonstrated examples of decentralised programmes in drinking water by setting up for rooftop rain water harvesting structures.

Madhutara village, Santalpur block, in the dry Patan district of Gujarat has a high degree of salinity in ground water. Almost all villagers are suffering from fluorosis. In 2001, villagers started a community drive to solve the crisis with help from the Ahmedabad-based NGO, UTTHAN. They desilted a 3.05 km long canal through which they diverted rain water to a 300-year-old tank, lined with plastic sheets to keep the water from mixing with the saline groundwater.

About 82,000 cubic m of silt was extracted from the tank at a cost of Rs 42 lakh, of which the government gave 60 percent and the community contributed the rest as labour. They rebuilt a 12 km long bund to hold the diverted rain water. Adjacent to the tank, was a 45 m deep recharge well fitted with special plastic pipe to carry water from the tank. Water from the well is pumped into a storage tank near the well. A dead well nearby also has water now that is free from fluoride. This water is increasingly used by villagers for drinking.

Villagers say over-extraction of groundwater over the past 20 years had caused the increase of salinity in groundwater. While RWH initiatives have solved drinking water problems, providing flouride-free water for irrigation remains a concern.

Kerala: Rain water for backwashing in Kadalundi, Calicut district

In Kerala, there are over 250 open wells per square kilometer, the highest concentration in the world. The majority of these wells had become unusable due to high saline content and a low water table. The average life span of wells providing clean safe water is 5-6 years.

Since Kerala lies along the Arabian Sea, it is the first state in India to receive the monsoon rains that fall twice per year. The rainy season lasts nearly four months and is particularly abundant with an annual rainfall of 3,000 mm. These rains were never harvested which often led to flooding and run-off. As a result, the water table was depleted and many wells became unusable.

Backwashing provides a solution by regenerating shallow open wells by harvesting rain water from rooftops. It does not involve any additional storage structures compared to conventional rain water harvesting units. The first rains wash off the roof tops and channels; subsequent rain water is diverted into the well. The soft rain water mixes with the existing water; gradually the well adjusts with the new influx of water regenerating itself and the water table below.

In 2004, PLANET Kerala, a local NGO began working in a small village located in Kadalundi, Calicut district in north Kerala where there is a serious water shortage. Twenty households volunteered to be part of a pilot project to divert water back into their wells to replenish the water table and rejuvenate wells back into use. PLANET Kerala provided the expertise and the households bore the cost.

The cost of this infrastructure varied: Tiled roofs (Rs 1,000-1,300), flat terraced roofs (Rs 300-750), slope terraced roofs (Rs 200-1000), thatched roofs (Rs 1,000).

The practice has been proven effective in Kerala and has a huge potential for up scaling. Assuming a modest collection per household of 100,000 litres, with an average cost of Rs.1,000 and a life expectancy of 5 years, the cost of backwashing works out to Rs.3 per kl of harvested water. Even though the immediate benefits would be more apparent in regions with over 1500 mm per annum of rainfall, adoption of the practice in areas having lower rainfall also will have a positive effect.

Rooftop Rain Water Harvesting in Schools

Rooftop rain water harvesting is a viable source of drinking water for schools, as well as a means for recharging groundwater. School authorities, students and communities must be involved for school RWH programmes to work as they need constant maintenance and water quality monitoring.

In Madhya Pradesh, an agency helped a tribal girls' school implement a RWH project. In Delhi, the Government provided financial support for the construction of RWH systems through its school eco-club programme. Several city schools have built these systems and use the water for gardening.

In Uttarakhand and Himachal Pradesh, schoolchildren and teachers in 40 schools contributed to the creation of a rooftop RWH system. The size of the rain water storage tank is 30-40,000 litres. The system serves 400 schoolchildren and 20 teachers in each school. Most of the rain water is used to maintain the toilets.

In Chirawa, Rajasthan, a private school set up a rooftop RWH. Water from the large roof was channeled into two underground cement tanks; both open at the bottom so that the aquifers also got recharged. Their combined capacity is 40,000 litres, enough to supply the school's needs for a few months. The water is used for everything except drinking for which there is the municipal water supply.

In Jharkhand, an NGO involved schoolchildren and teachers in a groundwater recharging and rain water conservation programme. In Jhabua and Dhar, Madhya Pradesh, where rainfall was low and erratic and the fluoride had contaminated groundwater, the government launched an initiative to set up RWH systems for tribal schools and hostels.

In Karnataka, a programme called Suvarnajala was launched to set up RWHs in rural schools but it did not work out. The Karnataka State Council for Science and Technology set up RWH systems in more than 23,000 schools across the State. A simple system that involved running pipes from the school roofs to a concrete storage tank through a sand-bed filter was built in these schools. The average roof area was 147 sq m and the average number of students, 118. The tank storage capacity was fixed at around 6300 litres for each school. The project did not work because (1) The roofs did not have the requisite gradient or the flow to channel water to the pipes (2) the pipes were fixed improperly and came off (3) the plastic used in the pipes could not withstand the weathering caused by the sun (4) the filter beds were not located under the pipes so water flowed onto the ground (5) the tanks were substandard and cracked (6) taps from the tanks were stolen so the water poured out (7) nobody was put in charge of maintaining the systems.

Rain water harvesting for agriculture and recharge

Over the last two decades there has been a revival of minor irrigation systems that catch and store rain water, such as tanks and ponds. These serve the dual purpose of providing water for irrigation and recharging aquifers through natural percolation. In some cases, water is channeled into deep wells, jackets wells, and purpose-dug bore wells for recharging deeper aquifers.

High altitude regions: in Ladakh, the snow and ice melt slowly through the day and water is available in the streams only in the evening, when it is too late for irrigation. The water in the streams was hence led by channels to storage tanks called **zing** and used the next day. In the Spiti area of Himachal Pradesh, diversion channels called **kul** were used to bring the melting snows from glaciers to circular tanks, from where the water was distributed.

Ponds were the main source of drinking water in Jammu. Ponds in the Kandi region were dug beside rivers. During floods the river waters were diverted into them. In Himachal Pradesh a temporary headwall of boulders called **kuhl** was constructed across a ravine to divert the waters of natural flowing streams (khud) through a canal to the fields. About 20 ha could be irrigated by a community kuhl. The water would flow from field to field and surplus water would drain back to the khud. The kohli or water tender distributed and managed the water.

In the eastern Himalayas, systems made from bamboo called **shyngiar** (in Meghalaya) or **apatani** (in Arunachal Pradesh) are used. Farmers harvest both ground and surface water; they block streams with a low wall and channel the water to their fields.

Kuhls – gravity-based irrigation canals in the Kangra valley of Himachal Pradesh – were built by the kings for irrigation and water supply in ancient times. Presently, the future of these kuhls is threatened as hydel projects coming up in the area ignore community concerns to release water into these lifelines of the villages. This has reduced or stopped water supply into the Kuhls.

In hilly areas: Gravity-based irrigation systems are better suited to hilly areas. A combination of check dams, percolation tanks and field ponds are used. Small structures like brushwood dams or gabions slow the flow of water down hillside gullies and ensure more even distribution. Larger gabions can divert part of this into field ponds, provided the region has enough plains to make fields. On steeper slopes, contour bunding and terrace farming where steps 'carved' into the hillside check the runoff can provide water for irrigating at least one crop.

Contour bunding is a watershed management practice to build up soil moisture storage and arrest run-off through bunds connecting equal ground elevations. A contour trench is the reverse of the bund. Trenches are excavated at different contour levels to conserve the run off in trenches, facilitating percolation of stores water underground. In sloping/ hilly areas, these contours bunds/trenches can be inter-connected by masonry chutes to allow smooth flow of excess run-off water from the hill tops to the hill base wherein necessary ground structures could be constructed to contain water. Use of half-moon trenches is also useful in slope stabilization and also allowing percolation of rainfall into the ground.

Check dams reduce the velocity of rain water run-off allowing it to percolate into the soil and recharge aquifers. They raise soil moisture levels, enabling people to cultivate at least one crop and improve water availability in wells or hand pumps. In the villages of Ralegaon Sidhi and Hiware Bazaar in Maharashtra, the Arvari river basin area of Rajasthan and several other parts of India, people have built an elaborate network of check dams to arrest the flow of water, allowing it to percolate and recharge aquifers. Local materials such as mud and rocks are used to make the check dams while larger structures are built with concrete.

Brushwood dams are the simplest kind of dam, and comprise thin long sticks tied together with rope, placed across a gully between two rows of stakes planted in the ground. Large boulders are put on top of the stakes to hold them place and make up the rest of the dam. These are ideal for narrow gullies and hilly areas to arrest the rapid flow of water.

Gabions are 'bags' of rocks, 15-25 cm in size, bound together by heavy-duty galvanized wire or nylon nets. This is a kind of check dam being commonly constructed across small stream to conserve stream flows with practically no submergence beyond stream course. The boulders locally available are stored in a steel wire mesh and are tied up in the form of rectangular blocks. This is put up across the stream to make it as a small dam by anchoring it to the stream banks. The height of such structures is around 0.5 m and is normally used in the streams with width of about 10 to 15 m. The excess water overflows this structure storing some water to serve as source of recharge. The silt content of stream water in due course is deposited in the interstices of the boulders to make it more impermeable. These structures are common in Maharashtra, Madhya Pradesh, Andhra Pradesh, etc. Both are extremely useful in checking the silt load in streams, the bugbear of any water management system.

In the Gangetic plain, the rivers and their floodwaters are the main source of water. Ahar-pyne is a traditional floodwater harvesting system indigenous to south Bihar. Here the terrain has a marked slope, the soil is sandy, groundwater levels are low and rivers flood their banks only during the monsoon. The ahar is the catchment basin embanked on three sides, while the fourth side is the natural slope. Pynes or artificial channels start out from the river, and meander through fields to end up in an ahar.

Inundation canals were an efficient irrigation system in Bengal. Floodwaters rich in silt entered the inundation canals, and were carried to the fields. The canals were broad and shallow and long and continuous. Channels cut into their sides distributed water to the fields. They were closed once the floods ceased.

In arid regions: *Khadin* is a land-use system in Rajasthan in which run-off from a catchment is stored in fields at lower levels behind a bund. Fields immediately behind the bund typically remain submerged during the rainy season while those at higher levels within the khadin have assured moisture for a rainy season crop. A second crop is grown using the stored moisture in areas that are submerged during the rainy season. Farmers manage to eke out a crop during the rainy season even in drought years.

In the Alwar district, Rajasthan, people revived the traditional watershed technology ***Johads*** to restore the ecological balance of the region. These are usually crescent shaped earthen walls built across the slope of the land to catch and store rain water runoff. They usually store enough water to supply the community's needs between monsoons and the water is put to multiple use – watering animals, domestic use, agriculture and aquifer recharge. People use handpumps or wells situated downstream of the johad for drinking water.

The Bhil tribals of Jhabua district, Madhya Pradesh, have a unique water harvesting system which is suitable to hilly terrain. This consists of constructing a temporary diversion weir of earth and stones on a hilly stream at the beginning of the kharif season and diverting the water into a channel parallel to the stream, but at a shallower gradient. After a few kilometers, this channel is at a considerable height from the stream bed and can reach a farm situated on the bank of the stream to irrigate it. This system is called the ***pat*** system by the Bhils and is still being used because it is much cheaper than pump irrigation. The system is put in place and maintained with the involvement of the community. In village Bhitada on the banks of the Narmada, the *pat* is taken to fields over 4 km downstream from the place where the weir is constructed.

In Bundelkhand: In this region of central India, the former Rajput rulers built enormous artificial lakes to store water from seasonal rivers. Called ***talaabs***, these lakes were made by building a stone-and-adobe wall across a seasonal river. These held water for several seasons if the rainfall was good and supplied water for agriculture, drinking and watering animals. They were also often used for recreation by the local royalty. The talaabs were also helpful in regulating the climate in this part of India that experiences extremes of temperature.

In south India: In Tamil Nadu, Andhra Pradesh and Karnataka, there is a complex system of village tanks for collecting rain water. All three states have erratic rainfall and therefore, nearly every village has built its own tanks to maximize the collection of rain water. The tanks provide water for irrigation, animals, and recharge drinking water wells. Tamil Nadu has 39,000 tanks; Karnataka has 30,000 and Andhra Pradesh 75,000.

Approximately one-third of the irrigated area of Tamil Nadu is watered by crescent-shaped tanks called ***eris***. Earthen walls, sometimes lined with stones, make up two-thirds of the sides of an eri; one-third is open, facing the slope from where rain water flows in to fill it. The overflow of one eri fills the next and the next one's overflow fills the next. Eris act as flood-control systems. They prevent soil erosion and wastage of run-off during periods of heavy rainfall. They recharge the groundwater in surrounding areas.

In Kasaragod district, northern Malabar region of Kerala, people depend on groundwater, and on a special water harvesting structure called ***surangam*** – a horizontal well mostly excavated in hard laterite rock formations. A *surangam* is about 0.45-0.7 m wide and about 1.8-2 m high. The length varies from 3-300 m. Usually several subsidiary *surangams* are excavated inside the main one.

How to select a good pond site

A good pond site should possess the following traits:

1. It should be a narrow gorge with a fan shaped valley above: so that a small amount of earthwork gives a large capacity.
2. The capacity catchment area ratio should be such that the pond can fill up in about 2-3 months of rainfall. The capacity should not be too small to be choked up with sediments very soon.
3. The pond should be located where it could provide adequate drinking water security throughout the year.
4. Junction of two tributary, depressions and other sites of easily available fill material and favourable geology should be preferred.
5. The site should not have excessive seepage losses.
6. The catchment area should be put under conservation practices.

New techniques

In Nashik district of Maharashtra 200 farmers formed a cooperative to harness water from a distant source and irrigate their fields. They have developed their own system to tap and store rain water and use it during the dry months for agriculture.

In Hiware Bazar, a village in Ahmednagar district of Maharashtra, the bore blast technique was used to use explosive for splitting rocks on flatland. This allowed water from check dams located in the hills near the village to percolate into the aquifers. This has resulted in village well and handpumps having sweet water.

The government has used remote sensing and aerial photo-interpretation to assess India's ground water resources since 1974. Hydromorphological maps were prepared through aerial photo-interpretation on a 1:50,000 scale indicating the hydromorphic unit-wise ground water potential in quantitative terms. In 1978, geomorphological maps were prepared based on visual interpretation of Landsat-1 imagery on a 1:2,50,000 scale and geomorphic province-wise ground water potentials were evaluated taking into account the landform, lithology, drainage and lineament density and the ground water potentials indicated in qualitative terms.

In the year 1984, Ground water potential maps were prepared on a 1:2,50,000 scale based on visual interpretation of Landsat-MSS data where ground water potentials were evaluated by combining the geology, geomorphology, terrain conditions, depth of weathering, etc. In 1985, ground water potential maps were prepared on 1:50,000 scale using high resolution Landsat-TM date taking into account the lithology, landform and structural information. Ground water potential maps were also prepared by Department of Space for the states of Maharashtra, Karnataka and Rajasthan by adopting a common legend.

The Department of Space also prepared hydro-geomorphological maps on a 1:2,50,000 scale using Landsat-TM and IRS-1A/1B data for all districts. Subsequently, the National Remote Sensing Agency (NRSA) prepared 1:50,000 scale maps under the Integrated Mission for Sustainable Development.

The most details survey was conducted by the Rajiv Gandhi National Drinking Water Mission that engaged NRSA to prepare hydro-geomorphological or ground water prospect maps on 1:50,000 scale using IRS-1C/1D FCC satellite imagery.

The Arvari story - a river is revived

In the beginning of the 1980s the 45 km river Arvari in Alwar district, Rajasthan, was considered dead and the fields surrounding it were barren while just a century before, the river was considered as the main groundwater recharge stream for the villages on its banks. In the village of Bhaonta-Kolyala 30 wells were dry and only 30 percent of the 221 hectares of land were cultivable. The villagers used to grow one, rain-fed, crop. In 1986 the villagers through voluntary labour built a huge johad to catch the water from surrounding hill-slopes. Since 1986, 238 water harvesting structures, mostly *johads*, have been built in the 70 villages in the 503 sq km watershed. The effort was to catch and allow water to percolate and thus recharge the aquifer. They built check dams across each monsoon stream in the watershed, and treated the hill slopes to reduce run-off and soil erosion to recharge aquifers. Gradually, the Arvari River began to flow even after the monsoon period and since 1995, it has become perennial again

Today about 5 percent of the rain water is used for irrigation. This seemingly small percentage makes a huge difference, because the water is now available at critical stages of plant growth. Small-scale water harvesting systems operate in a similar way, giving the farmer a tool to supply water to the crop when it is most needed. Before the water harvesting structures were built, the water was lacking during those critical periods and thus resulting in poor yields or crop failure.

IMPACT: Using Rain water Harvesting Systems to prevent drought, Rajkot, Gujarat

As recently as 20 years ago Rajkot, Gujarat, faced a major water crisis. The groundwater table had receded to a depth of 250 metres. By 1985, villagers started to build check dams and tanks by using funds from the District Rural Development Authority. Now the town uses remote sensing technique and geographic information systems to locate subsurface dykes to store water. As a result it survived the drought of 2002 and agricultural production has gone up as well.

According to the sarpanch of Raj-Samadhiyala village, 20 km from Rajkot city, a decade ago, the village was declared a dry area and put under the arid zone development programme of the state government. The sarpanch who also heads the 11-member village development committee took on the task of creating a rain water harvesting programme for the village.

Indian Space and Research Organisation conducted a hydrogeological survey using satellite imagery to locate fissures in the topography with the maximum percolation of water. The villagers constructed 12 check dams between 1986 and 1988. Since 1998, they have also implemented 50 microwatershed projects. The results are phenomenal: Despite poor rainfall in the last two years, the village has plenty of water. The annual income of the village is Rs 2.5 crore and they earn Rs 50 lakh from the sale of vegetables alone. Adjoining villages like Aniyala, Aili Sajadiyala and Laklapur are taking a cue from Raj-Samadhiyala.

Other success stories come from Mandlikpur, Rajkot, Gujarat which built check dams and farm ponds in 1993 to recharge about 300 wells with monsoon rain water.

Through the drought in 2001, the village had drinking water and was able to cultivate crops in the monsoon.

Gandhigram, Kutchh, Gujarat is seeing reverse migration. Dams and nullahs are being used to harvest rain water.

In drought-affected Mahudi, Dahod Gujarat, four days of rain was sufficient to provide drinking water security.

CHAPTER 4: Conclusions and Recommendations

Rain water harvesting is an age-old approach to using the abundant rainfall over India. It declined in importance once the piped water systems, tubewells and handpumps came into vogue in urban and rural India, respectively. Assured of a water supply independent of the rainfall, people abandoned rain water harvesting structures and the social constructs that held them in place.

Over the past few years, practitioners and the Central and state governments have realized the need for RWH to supplement water supplied from surface and sub-surface sources through municipal and panchayat sources. Implicit in this is the realization that RWH is a good source of water for a variety of domestic and agricultural uses – drinking, washing, watering animals and cropping. It is relatively pure and abundant, free and can be used without much treatment. Rain water is also the preferred source of drinking water where ground and surface water sources are contaminated and depleted, as is happening in many parts of India.

RWH should not be viewed in isolation. It is part of a larger process of social engineering that puts back the community structures needed to hold it, soil and water conservation and balancing recharge with downstream flows. It affects the overall hydrological cycle as it reduces runoff, increases recharge and soil moisture. While RWH increases the water availability wherever it is implemented, it can affect those downstream if they live in areas that get lower rainfall and are dependent on surface and sub-surface water flows. Therefore, it is important to recognise RWH's place in integrated water resources management.

Several states have enacted bye-laws to encourage property developers, housing colonies and individuals to set up RWH systems. These have met with mixed success. The Central Government has schemes for creating assets in villages, and a large percentage of the expenditure goes on creating or renovating water structures in villages. Most of the work and disbursements takes place through panchayats, and therefore, the schemes work best where the panchayats are strong.

Despite the numerous positives of RWH, there is no national movement for it. Several reasons are advanced by RWH's proponents, most blaming the government for a lackadaisical attitude. However, the problems lie with both people for not taking up RWH despite government schemes and initiatives, and the government for not giving it the importance it is due.

Several examples in this document point to another issue: that of the cost of water obtained from RWHs as against what is supplied by the government. In many cities, the water supplied by municipalities (when indeed it comes) is either free or heavily subsidized. In no instance does the water tariff pay for even the cost of treating raw water, leave along the capital cost of providing the supply. RWHs however have a real cost, usually borne by the builder, with minimal government support; therefore, the cost of water obtained from RWHs is higher than what is supplied by the public utility, at least in the short term.

The solution is to take a long-term view, where RWHs will supply water for next to nothing, reliably and of consistent quality, once they are built, for decades. They tap a free resource, otherwise going waste, put control of water resources in the hands of communities and individuals, and are the only means of decentralizing water supply by making it available at the point of consumption. RWHs encourage water savings. On the other hand, public utilities' supplies are irregular and of variable quality. These systems have enormous start up costs, are centralized, not accountable to their customers and extremely wasteful; there is no sense of ownership and people waste water flowing into their homes through pipes.

The argument for RWH

The centralization of drinking water sources has resulted in systemic neglect of local sources such as groundwater, tanks, ponds, lakes, etc. Use of other water sources should be studied and if possible, incorporated in the planning process.

RWH as one of the alternate technologies for delivering drinking water needs to be exploited further. About 10 percent of rural habitations are small, remote or in water-scarce regions where conventional ways of supplying drinking water is difficult and expensive. Depletion of groundwater in the last few decades has led to scarcity of drinking water in parts of the country and quality of extracted groundwater is often poor. Therefore, developing alternate sources for drinking water become extremely important.

Community Participation

The best practices from across the country show that community leadership and collective action have been the cornerstone of a success story as mentioned above. **In Hiware Bazaar village, Maharashtra,** community action helped transform the village from water scarce to surplus. **In Alwar District, Rajasthan,** Rajendra Singh, Tarun Bharat Sangh revived a system of five streams that feeds the Yamuna. A combination of social and physical reconstruction involving the village community in reviving johads, contour bunding, soil conversation, preventing tree felling in the highlands, promoting tree plantation ensured adequate and safe drinking water for the village. A Water Parliament in the Arvari river basin with representatives from 72 villages encourages soil and water conservation, decides cropping patterns and the amount of water withdrawals. It also raises funds for maintaining water bodies that have been restored in each village. The river system has now become perennial as a result and groundwater levels have risen substantially. **Ralegaon Sidhi, Ahmednagar District,** under the leadership of Anna Saheb Hazare, became a water-surplus village from a water deficit one. This was achieved by soil conservation, afforestation in the catchments and deepening the village water tank that helped recharge the village wells. People were prevented from sinking borewells deeper than 200 feet, which not only provided adequate and safe drinking water, but also ensured there was enough for agriculture and dairying.

Environment magazine Down to Earth (May 2002), which tracked villages that have used RWH to fight drought, says RWH systems are ideal for India. It adds: "But it is also clear that RWH is not about building structures. It is about collective leadership. In all the villages we found some critical changes. Water security was possible. But only because villagers took critical decisions about how to ration and prioritise scarce drinking water, which crops they should grow and which not. It was not that water was abundant and forever, but that these societies had learnt to manage their water collectively."

The argument against RWH

One of the most important underlying values in RWH is that it is a benign technology without undesirable consequences. RWH initiatives are driven by the following assumption: 1) there is a huge amount of monsoon flow, which remains un-captured and eventually ends up in the natural sinks, especially seas and oceans; 2) local water needs are too small and as such exogenous water is not needed; 3) local water harvesting systems are always small and, therefore, cost-effective; 4) since the economic, social and environmental values of water are very high in water scarce regions, RWH is viable; 5) incremental structures lead to incremental benefits; and 6) being small with low water storage and diversion capacities, they do not pose negative consequences for downstream uses.

These ignore a few critical parameters that govern the potential of RWHs in meeting local water demand. a) the hydrological regime of the region/locality; b) the reliability of RWH, governed by the reliability of rainfall; c) the constraints imposed by local geological settings on recharge potential; and d) the aggregate demand for water from various sectors within the local area.

For runoff harvesting, rainfall has to exceed a threshold to generate runoff. The actual runoff rates depend on the correlation between rainfall and runoff in a given basin, and this relation weakens if there is a major change in rainfall intensity and pattern. In regions with lower annual rainfall, rainwater harvesting as a dependable source of water is likely to be low. Fewer rainy days also means longer dry spells and thus greater losses from evaporation for the same region. Higher intensity of rainfall can lead to high intensity in runoff, occurring in short durations, limiting the effective storage capacity of rainwater harvesting systems to almost equal their actual storage size. Some studies on infiltration show that the rate declines to a minimum value within 4-5 days of ponding. For artificial recharge, the storage potential of the aquifer is extremely important and is determined by the characteristics in geological formations, and the likely depth of the dewatered zone.

In any basin, the marginal benefits from new water harvesting structures will be smaller at higher degrees of development, while the marginal cost would be higher. This is because in highly developed basins, it will be harder to get socially and economically viable sites for building water impounding structures, increasing the economic and financial cost of harvesting every unit of water. Therefore, the cost and economic evaluation should move from watershed to basin level. It is also important to keep in mind that the negative social and environmental effects of over-appropriation of the basin's water resources may be borne by a community living in one part of the basin, while the benefits are accrued to a community living in another part.

Constraints in taking RWH to Scale

- Technology is not standardized and few within the building industry have the skills to build RWH systems for different purposes.

- The initial costs are high compared while municipal or panchayat water supply is much cheaper; this means the cost of harvested rain water will not be competitive and will be a disincentive for people to install the system.
- Financial incentives are opaque and not accompanied by a how-to. The government, responsible for the financial incentive, does not inform people where to go for the money and how to obtain it. There are conditions and complicated processes that discourage most people from setting up RWHs.
- The biggest concern in using rain water for groundwater recharge remains the quality of the water. Most filters only remove biological matter, sediment and silt load and there are no cheap techniques available for large-scale removal of fertilizer and pesticide residues in the water used for recharging. Hence, from the point of view of managing drinking water supplies, this is dangerous.
- All RWH systems need maintenance to ensure that rooftops are clean, the first-flush is not stored and there are no fertiliser and pesticide residue from gardens going into the run-off.
- Scaling up of RWH is best done when both individual and collective roof house units in a locality divert rain water to a collection system and then to a storage structure with due care to water quality. The excess should then be allowed to recharge groundwater.
- While setting up new structures for groundwater recharge, it is important to protect existing groundwater recharge zones. In urban areas, river beds, flood plains, lake beds, wetlands, old tanks including temple tanks, low lying areas, open spaces, playgrounds and parks are either being filled-in or built-on or being used as garbage dumps. Large scale paving of curbs and footpaths further prevent natural ground water seepage. It is important to identify such areas, protect and revive them.

Policy Recommendations for RWH

Problems notwithstanding, we have seen numerous states pass laws to mandate RWH. It is essential to view RWH as part of a larger strategy for water security, and one way that can provide quality water at the point of use at reasonable cost. That said, policy to promote RWH has to be community-led, as illustrated by numerous examples earlier, to be effective and owned by the people it is intended to benefit. The government as enabler has to provide suitable financial and technical incentives as one of the drivers. It has to work with civil society and the vast system of local governance as enablers.

A national policy for rain water harvesting should be based on the success stories of watershed development with the involvement of village communities in different parts of the country. The salient features that such a policy can incorporate are:

- Promotion of small water harvesting structures, and the concept of small is beautiful.

- Focus on community-driven initiatives so the ownership rests with the local people rather than distant government structures.

- Propagation of structures suitable for diverse geographic and climatic zones, that are robust yet simple enough for local people to build and maintain.

- Convergence of government schemes at the village and municipality levels to make funds and technical expertise available for RWH.

- Rooftop rain water harvesting should be mandatory to increase the amount of available rain water.

- A policy for reviving traditional water harvesting bodies in the villages should be made

- Regional knowledge hubs can be created to share information on local and traditional water management practices, such as those initiated by Tarun Bharat Sangh, Rajasthan; Anna Hazare, Maharashtra; and the N M Sadguru Water and Development Foundation in Gujarat.

- Waste water management should be a part of the policy to complement RWH.

- The policy should encourage region-specific plans based on agro-climatic conditions. In areas where monsoon rainfall is abundant, the aim should be to generate awareness and increase the use of RWH systems for household, agriculture and commercial purposes.

References and further reading

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http://www.rainwaterharvesting.org/ *Hosted by Centre for Science and Environment (CSE), New Delhi; Presents numerous initiatives across different agro-climatic regions of the country, with details of community based water management initiatives*

http://www.rainwaterharvesting.org/Urban/Latest-Designs.htm *Page has some of the latest designs provided by the Centre for Science and Environment as technical expertise to individuals and organizations interested in undertaking RWH*

http://www.rainwaterharvesting.org/rural/Raj-Samadhiyala.htm *Provides information on water recharging experiences, including Rajkot which was successful in surviving droughts due to its quality water management practices*

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http://www.rainwaterharvesting.org/policy/legislation.htm

http://indiaenvironmentportal.org.in
Tel: 91-11-26066854, 26059810, 29955410, 29955781, 29956394
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http://indiawaterportal.org/tt/rwh/case/indiatogether.html
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Asian Paints' RWH in Housing Society, Powai, Mumbai

Organizations working on rain water harvesting

Department of Drinking Water Supply http://ddws.nic.in

IRC International Water and Sanitation Centre. **http://www.irc.nl/**

Ministry of Urban Development and Poverty Alleviation http://urbanindia.nic.in

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United Nations International Children's Education Fund
http://www.unicef.org/india/wes.html

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Water Partners International, USA, http://www.water.org/watercredit/

Watershed Support Services and Activities Network (WASSAN), Hyderabad
www.wassan.org

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Tarun Bharat Sangh, Rajasthan
34/46 Kiran Path, Mansarover, Jaipur – 302020; Tel.: +91-141-2391092;
watermantbs@yahoo.com;

Pravah C-24 B, Second Floor, Kalkaji, New Delhi 110019; Tel: +91-11-26440619/26213918/26440619;
mail@pravah.org; http://www.pravah.org/

Rainwater Club 264, 6th Main, 6th Block, B.E.L Layout, Vidyaranyapura, Bangalore 560097; Tel.: 080-23641690/ 672790

Accelerated Rural Water Supply Programme, New Delhi
Ministry of Rural Development, Government of India, 9th Floor, Paryavarn Bhawan, CGO Complex, Lodhi Road, New Delhi 110003; Tel 91-11-24361043; Fax: 91-11-24364113; jstm@water.nic.in;
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Baif Institute for Rural Development - Karnataka (BIRD-K), Karnataka
P. B. No.3 Kamadhenu, Sharda nagar, Tiptur 572 202, Karnataka; Tel: 91-8134-250658; Fax: 91-8134-251337; birdktpr@gmail.com;
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Development Alternatives, Usha Srinivasan and Ridhima Sud usrinivasan@devalt.org, rsud@devalt.org B-32, Tara Crescent, Qutab Institutional Area, New Delhi – 110016;Tel: 91-11-685-1158, 696-7938; Fax: 91-11-686-6031

Action for Food Production (AFPRO), New Delhi
25/1-A Pankha Road, D-Block, Janakpuri, New Delhi 110058; Tel: +91-11-28525452/28522575/28525412; Fax: +91-11-28520343; afprodel@afpro.org; http://www.afpro.org/; Contact D. K. Manavalan; Executive Director; ed@afpro.org

Water and Sanitation Management Organisation (WASMO), Gujarat
3rd Floor, Jalsewa Bhavan, Sector 10-A, Gandhinagar 382010 Gujarat; Tel: +91-79-23247170/ 23247171/23237075; Fax: +91-79-23247485; wasmo@wasmo.org; http://www.wasmo.org/eng/default.shtm

People's Learning Centre for Water and Sanitation, UTTHAN, Gujarat C-1157, 1st Floor, Manu Raja Chamardiwala, Opp. SBS, Kaliyabhid - Bhavnagar 364002; Tel.: +91-278-2573061; plc_watsan@rediffmail.com; http://www.plcwatsanutthan.org/

Centre for Science and Environment, Green Schools Programme, Centre for Science and Environment (CSE), New Delhi
41, Tughlakabad Institutional Area, New Delhi - 110062; Tel: +91-11-29955124; Fax: +91-11- 29955879; cse@cseindia.org; http://www.cseindia.org/programme/eeu/html/index.asp;

International Rainwater Harvesting Alliance (IRHA)
Maison Internationale de l'Environnement II, Chemin de Balexert 7-9, 1219 Genève, Switzerland; Tel: 41227974157; Fax: 41227974159; secretariat@irha-h2o.org; http://www.irha-h2o.org/

Annexure A: Details of urban rooftop rain water harvesting system

The nature of the catchment determines the quality of rain water collected. While 70 percent of water over tiled surface of a terrace can be used, only 10 percent over grassy areas can be used – the rest percolates into the ground.

Generally, run-off from paved surfaces only is used for drinking and domestic use as it is free of bacterial contamination. Mesh filters are provided at the mouth of the drain pipe to prevent leaves and debris. A ‘first-flush’ device ensures the run-off from the first spell of rain – which carries pollutants from air and from catchment surface – is flushed away and not collected in the storage system.

It is important to ensure water used for recharge is free of pollutants so that it does not damage groundwater. Run-off from grassy areas can be contaminated with pesticides and therefore, in rural areas, runoff from threshing floors can be collected and stored in an underground tank. The catchment areas of other surface RWH and storage systems must be clear of encroachments or sources of pollution. Storage systems must not be polluted by industrial or domestic waste.

The size of the catchment area and tank should be enough to supply sufficient water for the users during the dry period; usually in most parts of India, the tank should be large enough to provide water to a family of 5 for up to 6 months. Assuming a full tank at the beginning of the dry season (and knowing the average length of the dry season and the average water use), the volume of the tank can be calculated by the following formula:

$V = (t \times n \times q) + et$

Where,

V = Volume of tank (litres)
t = Length of the dry season (days)
n = Number of people using the tank
q = Consumption per capita per day (litres)
et = Evaporation loss during the dry period

Since evaporation from a closed storage tank is negligible, the evaporation loss (et) can be ignored (=zero)

If, for example, 40 lpd (q) is agreed upon and a dry period of 180 days (t), a storage volume of 36 m^3 would be required for a family of 5 members (n). [V = 180 (t) × 5 (n) × 40 (q) = 36,000 litres or 36 m^3]. The required catchment area (i.e. the area of the roof) can be determined by dividing the volume of the tank by the accumulated average rainfall volume (in litres) per unit area (in m^2) over the preceding wet months and multiplying this with the runoff coefficient, which can be set at 0.8 for galvanized iron or tiled roofs.

Experience shows that with the water storage tanks next to their houses, people use between 20-40 litres of water per person per day (lpd). However, this may rise in time as people relax their water use habits because of easy access. This contrasts with a maximum of l0 lpd consumption levels under similar environments with people fetching water from distant sources. Together with the community/ family, a decision must be taken on how the water will be used or what affordable service level can be provided. Rooftop water harvesting systems can provide good quality potable water if the design features outlined below are taken into account.

To calculate the water available, and then design the system, you must first get the rainfall data in the region for at least the preceding decade. Take the lowest figure (R, in mm) as that is the most reliable – the amount of rain will certainly exceed that in any given year. Given the roof area is A and a runoff coefficient (amount of runoff as percent of total rainfall) of 0.8, the amount of water available in a season is 11.2 m^3 or 11,200 litres. If the family uses 10 litres per capita per day (lpcd) this water will last them lover 7 months. The tank size will be 3.2m (diameter) X 1.6 m (height), though it usually is better to make two smaller tanks. The cost of the tank depends on the material and the place the structure is being built; the options are PVC, concrete and steel tanks.

Annexure B: Surface drinking water system based on ooranis, Tamil Nadu

In rural Tamil Nadu, ooranis have provided drinking water and are now seeing a revival of sorts. Ooranis offer a simple rural solution to storing rain water exclusively for drinking and can be set up anywhere given their similarity to other commonly used rain water storage structures across India.

Ooranis are made by raising earthen walls around an area that can be square, rectangular or circular. The main components of an Oorani harvesting structure are the pond with well dressed slopes, hard and impervious bottom, a channel leading run-off water from a specified catchment, a filtering unit, a draw well attached to a hand pump to collect drinking water. Ooranis are normally fenced on all the sides. There are basically seven technical design units for an Oorani system, these are:

1. Catchment area
2. Inlet (combined grit chamber with baffle wall)
3. Oorani (storage chamber)
4. Emergency or recharge well
5. Horizontal roughing filter system
6. Draw or storage well
7. Vertical upflow fine sand filter system

The catchment area is the extent of land surface that would add to the surface runoff/ ground water recharge in a sub-basin with respect to a particular stream or source. In combination with hydrological data the surface runoff can be simulated to find out about the runoff potential of the catchment. The supply channel allows the controlled drainage of sheet flow runoff from the catchment and supplies the water towards the oorani. It has to be designed and constructed for most economical condition (trapezoidal or rectangular) by taking the maximum intensity of rainfall during a year. The suitable size and gradient of the channel depends on the volume of runoff from the catchment.

As inlet arrangement, silt trap and stilling basin has to be designed as per the velocity of flow in the channel, soil type and particle size. Grit chambers are required to remove gravel, sand and mineral particles from the raw-water and to protect following units from silting and abrasion. The amount of raw-water very much depends on the size of catchments and the rainfall intensity. While the first is site specific, the rainfall intensity can be evaluated from available data.

The runoff obtained from the catchment for 365 days should meet the total annual water requirement of the people or the total required storage capacity of the Oorani. The Oorani system has the capacity to store water in two different ways. Around 75 % of the storage capacity seeps into the ground to recharge the ground water. This water can be made accessible by providing a recharge or emergency well in the middle of the storage tank. During dry season after the surface water dried out it can be used for drinking water supply. The surface storage of the Oorani will provide water for about 10 month of a year. This requires the exact calculation of the volume of water to be stored. The basic storage equation to be followed is:

$Q = D + R + E$

For, Q- Volume in m3

D-Demand in m3
R-Recharge in m3
E-Evaporation in m3

After defining the volume of the storage the shape has to be chosen. Round ooranis save as much as 20 percent in construction costs compared to the other shapes. The recommended depth should be 5 m as it has been proven that the evaporation loss can be reduced significantly. To stabilize the sidewalls of the storage and to reduce the infiltration capacity of the oorani it is recommended to provide a stone pavement, built in several steps in a slope of 1:1.5. At the bottom of the revetment a foot wall should be built for stabilizing the slope.

The problem with water from ooranis is the high level of turbidity. The traditional system provided water without filtration. Turbidity was removed by using gypsum or seeds which flocculated the floating impurities. With technical developments in rural areas new pollutants like artificial fertilizers, pesticides and aromatic hydrocarbons have entered the supply chain of ooranis, requiring more sophisticated treatment. Therefore the design of filter system becomes crucial for the development of the new ooranis.

Advanced treatment systems incorporate a filter system for removal of one of the following contaminants:

1. Residual organic and inorganic colloidal and suspended solids
2. Dissolved organic constituents
3. Dissolved inorganic constituents
4. Biological constituents

Depth filtration systems are the only ones competitive and suitable for ooranis. This involves removal of particulate matter by passing the water through a filter bed made up of a granular and compressible medium. The options are a slow sand filter, rapid porous and compressible medium filter, intermittent porous medium filter and recirculating porous medium filter. The slow sand filter has proven to be the most appropriate for use.

Annexure C: Tankas as an efficient means to provide rain water

The tank is completely covered and has a manhole through which people may enter to clean it. Water is pulled out by buckets through the same manhole, though larger tankas may have a hand pump. Tankas are designed to hold water for 7-8 months, the size depending on the number of users. Household tankas have capacities of around 21,000 litres while community tankas can hold around 200,000 litres. The tanks are always made of concrete, as it the catchment. Before the rains, the family or community cleans the catchment so dirt and debris do not enter the tanka. The water is usually clean enough to drink without any treatment.

Because of the constraints of availability of large open areas around the tanka and the unit cost of treatment, a circular strip of land of 12 m width around the tanka is usually treated, the slope of which is kept as 3 percent i.e., a fall of 3 cm in a length of 1 m.

This provides bulk of the water to fill the tanka. A tanka of about 21 cu m capacity for an individual household should preferably be built in front of the house in an open area of about 10 m x 10 m size. Since the rainwater from this area will be collected in the tanka, human beings and animals should not venture into the area during the monsoon to prevent pollution of water.

For a community tanka of about 200 cu m capacity, the size of the open area should be at least 30 m × 30 m. In both the cases the land surface should be firm and sandy with a slope of about 3 percent.

A tanka of 21 cu m capacity is usually adequate to meet the minimum drinking water requirements of a family of 6 persons for one year, assuming a person gets 10 litres of water per day. Community tankas, however, have only a supplemental role since these can only partially meet the requirements depending upon the size of the community and the availability of land for constructing the tankas. Viewed in this light, the water requirement of the community is not necessarily a governing criterion for design of a tanka scheme. Instead, conservation of available water and its proper distribution and use are of crucial importance.

Some part of the rainwater is lost due to evaporation and seepage into the ground. This loss varies with the amount of rainfall. For low rainfall the losses are high and for high rainfall these are low. For a 21 cu m capacity tanka, you require an area with a diameter of 3.9 m and a tank that is 3.5 m deep. The wall is cement, 150 mm thick with plaster and the cover is a stone or RCC slab. The apron around the tanka is usually 1 m wide and 100 mm thick. The tank of the tanka is 100 cm X 25 cm. there are three inlets in the tank at the apron level, each 6X3 cm with iron bars and expanded metal. There is an opening at the top to draw water which is 1X1 m.