RAINWATER HARVESTING IN URBAN AREAS

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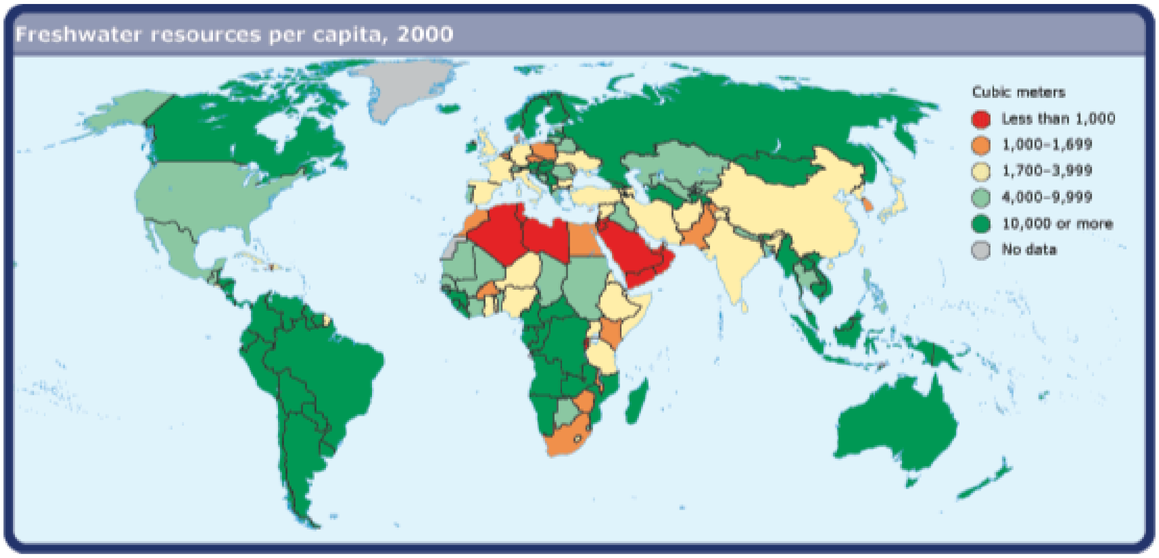
"After thousands of years of human development in which water has been a plentiful resource in most areas, amounting virtually to a free good, the situation is now abruptly changing to the point where, particularly in the more arid regions of the world water scarcity has become the single biggest threat to food security, human health and natural ecosystems" – David Seckler, David Molden and Randolph Barker



Introduction:

Rainwater harvesting is defined as the process of collecting and storing rain for later productive use.

Rainwater harvesting is a mini-scale water resources project that collects, stores rainwater by structural measures and regulates and makes use of it for domestic and production use (Chinese Code of Practice for rainwater collection, storage and utilization)

The term water harvesting refers to collection and storage of natural precipitation and also other activities aimed at harvesting surface and groundwater, prevention of losses through evaporation and seepage and all other hydrological studies and engineering interventions, aimed at conservation and efficient utilization of the limited water endowment of a physiographic unit, such as a watershed.(Rajiv Gandhi drinking water mission Government of India as quoted by R.N.Athavale)

Water harvesting is also defined as the process of collecting and storing water from an area that has been treated to increase precipitation runoff. (Frazier 1983)

Suffice to say that there is a connotation of small scale and immediate to the whole process which differentiates it from large water retaining structures such as dams and reservoirs.

Characteristics of water demand in urban areas:

Urban areas are typically characterized by concentrated demand because of high population densities and the sheer number of people. Especially in the developing world the growing population adds to a growing demand typically unmet.

In addition the major problem is of skewed distribution with the relatively well off accessing more water and the economically disadvantaged having to do with very little.

Urban demand for water:

Typical urban demand for water is characterized at least in the Indian context as

Domestic – for household use and consumption

Non-domestic – for commercial and service sector demand as well as that for schools parks, hospitals etc

Industrial – for minor and major industries and factories
Recreational use – for boating, fishing, water sports
Ecological use – As a place for preserving and fostering bio-diversity.
Environmental use – To moderate the micro climate and to absorb storm run-off as a detention basin.
Agricultural use – For parks, gardens and for urban agriculture.

In the fast growing cities Industrial demand shows spectacular growth and is the fastest rising demand in the Indian context.

Traditional Sources of urban water supply:

Much of the supply comes from rivers or lakes and the constant quest of engineers is to seek these 'perennial' sources. Then comes the putting up of reservoirs for storage, treatment plants, pumping stations, supply lines, storage reservoirs and distribution pipes.

Underground aquifers too are another source from open wells or deep bore wells water is pumped up and distributed.

Of interest is the growing 'Ecological footprint' for water. As local sources dry out, become polluted or are simply insufficient the city marches farther and farther for its water. The city of Bangalore, India used to meet its requirement from lakes and tanks within the city's boundary till 1896, then it moved to a source 25 kilometres away. Proving insufficient the next source was identified as a reservoir 35 kilometres away in 1936. This too proved insufficient and the current source is a river 95 kilo-metres away and about half a kilometer below the city's elevation. The city of Chennai (population 7 million) India has as one of its water source a lake about 235 kilo-metres away. The chase for a source is on and the sustainability a big question mark.

Why rainwater harvesting in urban areas?

Given this quest for water it is but logical to look at rain, the primary source of almost all water , as **one** of the city's water source. Urban areas are confronted with many issues pertaining to water

- Lack of full water from traditional sources and therefore rainwater as a supplementary source
- Urban flooding therefore rainwater harvesting as a flood mitigation measure
- Depletion of groundwater aquifers and therefore rainwater harvesting as a method of artificial recharge
- Disappearance of lakes and natural hydrological courses therefore rainwater harvesting as a method of restoring these water bodies

International experience with rainwater harvesting in urban areas:

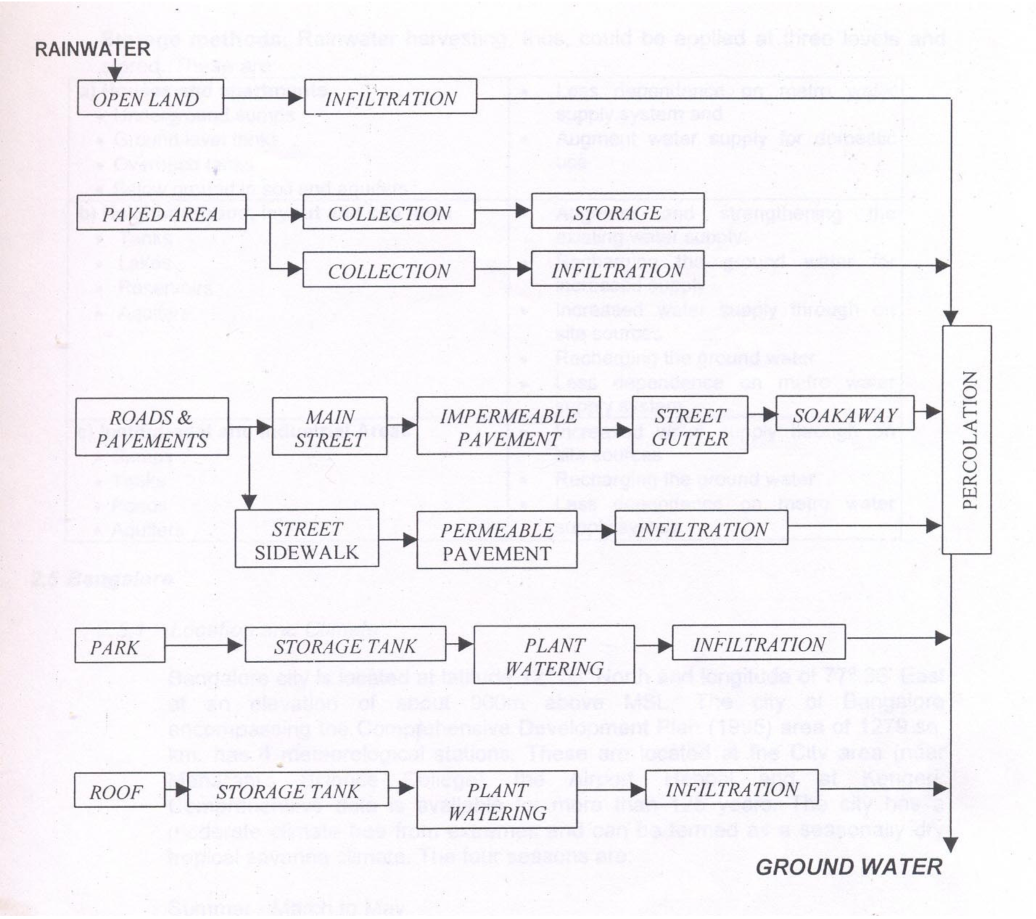
The international experience with rainwater harvesting in urban area is on the learning curve but growing at a rapid pace. Singapore, the island nation in the Indian ocean, is a case in point. Appan and Seng (2001) report ' about 48% of the land area of Singapore is being utilized as water catchment. The water abstracted is not sufficient for the increasing demands in a rapidly growing industrial society. Consequently, about 60 % of the water is impoted. Hence ways and means are being looked into to harness more water from the rest of the land area in which 86% of the urban population live in high rise buildings. The potential catchments being looked into are the high rise buildings wherein the water collected on the roofs is of a high order."

Che Wu, Wang Huizhen, Li Junqi, Liu Hong, Meng Guanghui report that " Beijing is faced with dual pressure brought on by the shortage of water resources and water environment pollution. To cope with this situation, it is important to study the quality of the average annual runoff of about 200 million cubic metres in the urban area".

Bangalore in South India developed a master plan for rainwater harvesting for its entire Comprehensive Development Plan area of 1279 square kilometers. The report suggested that upto 25% of the city's requirement by 2011 cold be met through rainwater harvesting and in the optimistic scenario that 592.90 million litres per day equivalent could be harvested in the city.

Chennai again in South India has made rainwater harvesting compulsory for all buildings in the city both old and new and claims that 98% buildings have complied with the requirement which seeks to wither store rainwater or to recharge it to the underground aquifer.

Systems of rainwater harvesting:



Criticism of rainwater harvesting in urban area:

Criticism is best articulated as the lack of dependency and unreliability of rain and rainwater, its supplemental role as opposed to a full replacement role, problems of quality especially chemical and microbiological contamination, the hazards of vector breeding, the uneconomical aspects of rainwater harvesting and bad cost benefit ratios.

Understanding urban rainfall:

Getting the right data is crucial to understanding the potential of rainwater harvesting and its sensitivity across the years. The mean is usually used for design purpose. However for flooding the maximum is a good unit and for sensitivity to reliability the minimum is a good design. An example is given for Bangalore, India.

MONTHLY RAINFALL(mm) DATA OF GKVK (GANDHI KRISHI VIGYAN KENDRA-UNIVERSITY OF AGRICULTURAL SCIENCES, BANGALORE) OBSERVATORY FOR THE PERIOD 1972 TO 2003.

IYEAR	JAN.	FEB.	MAR.	APR.	MAY	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.	ANNUAL
1972	0	0	0	14.2	88.2	56.9	32.5	99	195.4	232.9	39.6	53	811.7
1973	0	0	0	18.7	50.1	61	100.1	205.2	226.7	210.7	40	17.9	930.4
1974	0	0	0	4.2	134.2	12	138.2	105.5	180	172.6	7.1	0	753.8
1975	0	26	4	10	154.6	89	191.7	165.9	133.9	134.1	179	105	1098.7
1976	0	0	0	65.2	43.5	*10.5*	55.5	180	117.5	66	154.5	1	693.7
1977	0	0.5	37.5	64.6	93	97.9	110.6	74.4	120.5	242	852	0	926.2
1978	0	22	0	47.6	137.7	53.2	240.8	128.3	235.7	165.8	44.2	11.1	. 1086.4
1979	0	69.5	0	152	39.8	129.6	123.8	113.9	455.1	123	98.5	0	1168.4
1980	0	0	15.6	55	1263	37.7	110.4	61.6	106	106.5	32.9	0	652
1981	1.4	0	35.7	68.5	150.9	16.3'	35.8	114	211.9	155.4	28.8	6.3	825
1982	0	0	0	1.6	229.7	156.6	73.3	62.9	270.8	77.7	29.3	0	901.9
1983	0	0	0	7	102.6	168.6	77.2	163.1	162.1	69.6	0	42.4	792.6
1984	0	48.5	70.1	17.5	442	119.4	217.1	64.6	231.9	168.8	8.5	6.4	997
1985	16.6	0	2.6	38.4	75.8	38.1	87.5	51	214.8	603	75	6.1	666.8
1986	8.1	6.5	0	1.2	51.4	153	74.1	70	333.6	28	59.6	132	798.7
1987	0	0	89.2	21.6	53.8	80.8	45	124.4	158.5	123.1	100.2	29.4	826
1988	0	0.8	7.6	75.8	163.4	7.7	272	167.7	388.1	123.9	18.9	59.8	1285.7
1989	0	0	11.2	1.5	522	9.3	154.4	48.2	283	193.4	22.6	0	775.8
1990	1.4	0	5.8	2.6	116.8	48	32.2	79.7	92.6	111.9	32.2	4.8	528
1991	1	0	3.6	88	89.6	212.9	21.1	1522	66.9	540.9	152.2	0	1328.4
1992	6	0	0	10	167.7	]67.6	135.8	98.6	194.2	107.6	70.8	0	958.3
1993	0	0	5.8	0.4	127.6	145.2	58.5	150.6	328.1	273.4	21.6	65.4	1176.6
1994	2	39.8	0	31.4	93.7	30.8	92.3	94.8	lI5.3	, 212.1	21	3.2	736.4
1995	2.8	0	26.6	6.3	802	36.4	86.6	189.4	75.9	126.4	26.6	0	657
1996	0	0	0	75.5	66.8	230.6	26.7	164	211	84	2	26	886
1997	2.2	0	53.2	71	94.8	53	30.4	67.8	294.9	316.8	193.8	18.8	1196.7
1998	0	0	0.8	78.2	49.6	32	132.2	352.2	245.7	241.7	37.5	14.7	1184.6
1999	0	7.8	0	53.8	154.3	95.2	49.4	205.8	238.7	196.8	712	18.2	1091.2
2000	0	133.2	0	64.8	89.6	104.8	973	312.4	239.8	' 168.4	5.8	16.2	1232.3
2001	0	0	3.8	243	5	18.8	136	78.1	347.6	121.8	32.6	13.8	1000.5
2002	0	0	0	1.8	133.6	150.5	44	31.8	43.8	167.8	52.2	2.8	628.3
2003	0	0	11.8	104	3.2	30.2	90.4	107.6	65.8	231.9	4.8	0	649.7
MEAN	13	11.1	12	42.5	95.7	82.9	99.2	127.6	205.8	167.4	54.6	13.8	913.9
'MAX.	16.6	133.2	89.2	243	229.7	230.6	272	352.2	455.1	540.9	193.8	65.4	1328.4
MIN.	0	0	0	0.4	3.2	7.7	21.1	31.8	43.8	28	0	0	528
SD.	3.3	27.3	21.8	47.6	50.5	62.4	62.5	71.2	983	94.4	51.3	17.8	215.5
CV%	253	246	181	112	53	75	63	56	48	56	94	129	24

Scale of rainwater harvesting in urban area:

The best unit is the individual house followed by apartments, neighbourhoods, institutions, industries and common areas such as parks, roads,playgrounds etc.

Domestic rooftop rain water harvesting:

Rainwater Harvesting –Definition: Since all source of water is ultimately rain all water supply systems are in effect rainwater-harvesting systems. A definition for this term would in effect necessarily have to take into consideration the difference in catchments. While previously catchments were typically far off from the urban area served, now the city itself is seen as a catchment for its water requirement. Rooftops, paved areas and unpaved areas and the entire city itself is therefore to be managed as a water provision area. As the Centre for Science and Environment, Delhi puts it '**Catch water where it falls**' would be a good definition of rainwater harvesting.

A further elaboration of the definition of rainwater harvesting would be:

A process of collecting and storing rainwater runoff from
rooftops – roof water harvesting,
from the ground –runoff harvesting and
from channel flow – flood water harvesting. (Gould and Nissen-Petersen).

The process of Rainwater harvesting would encompass catching rainwater, directing it to an appropriate location, filtering it if required and storing it for use. Storage could be in tanks, sumps, ponds or lakes. Wherever appropriate and conditions permitting recharge of ground water would also qualify as storage. Harvested water could be used immediately as a first choice thus saving city level supplies or ground water for a future date or a decision could be to store it for later use say during water shortage days.

Fig 1. A Typical rainwater harvesting system with filter and sump for a residence

Scale of Operations:

From a small rooftop to large areas such as that of institutions and industries, rainwater harvesting can work well. Neighborhoods and finally the city itself should be the ultimate scale of operation for rainwater harvesting. Singapore for example plans to manage and harvest almost all rainwater incident on the city-state. Germany is a pioneer and adopts rainwater harvesting on a large scale to supplement its water requirements and prevent overload of its sewage treatment units. One primary step would be to keep the catchments un-polluted, a difficult but manageable task but on which increasing attention will need to be focused in the future.

Typical structure:

Designing a rooftop rainwater harvesting system would mean taking the following steps. Sloping the roof appropriately preferably towards the direction of storage and recharge. Designing gutters and/or down-pipes depending on site rainfall characteristics and roof characteristics. Putting in place a first rain separator to divert and manage the first 2.5 mm of rain. Filtering the water to remove solids and organic material. Storing the filtered water in appropriate devices and recharging the ground water through open wells, bore wells or percolation pits.

Cost of water:

In the India context urban water is heavily subsidized. As the water connections are usually to households who are in the higher income group in effect subsidies travel to the rich. The poor generally make to do with public stand posts and public hand pumps. The true cost of water is when we release it back to nature in the same quality situation as which it was appropriated. If not in the same condition it should be released back to nature within the carrying capacity of the soil or water system and geographical area to which used water is released. This rarely happens.

The true cost of water is when it accommodates the following:

Capital cost
Operations and maintenance cost
Opportunity Cost
Economic externality
Environmental externality

While this is rarely done at the city level, it is possible for individual houses, apartments, institution buildings and industries to be proactive and accommodate this process. While this may add to short term cost in the long term it ensures sustainability.

Strategies:

A water audit statement would need to be prepared for each consuming unit where water is used. This would include identifying such parameters as

Water demand. Stratified to all classes of requirements such as potable water, water for process, de-mineralized water, landscaping/garden water, water for toilet flushing etc.

Sources and quantum of supply need to be identified next. City level supply, from open wells bore well supply, private tankers etc.

Supply of water from rainfall can then be calculated using various areas of the buildings including:

- Rooftop area.
- Paved area.
- Unpaved area.

Determination of incident rainfall is calculated by obtaining average rainfall data for 30 years. Month wise data averages increase accuracy. By using a factor of loss total monthly supply is determined on each of the surfaces. Then a decision is made whether to store the water or to recharge the water so collected from rainfall. The process of rainwater usually works best as a combination of storage and recharge.

Some rules of thumb provide interesting information on rainwater harvesting potential. In Bangalore for example with an average rainfall of 970 mm over the last 10 years, a 100 square metre roof area of any building would have 97,000 litres of rainwater incident on it in a year and of which 87,000 litres would be harvestable. For a family of 5 this harvested rain could provide nearly 50 litres of water per person per day.

Similarly on an acre of land 39 lakh litres of rainwater is incident. It is for the designer to put in place strategies to ensure maximum benefit from this free gift of nature.

Checklist for rainwater harvesting:

Here is a 20-point programme

1. **Determine catchment area and stratify to**
   -rooftops;
   -paved areas;
   -unpaved areas
2. **Segregate to harvestable and non-harvestable areas (some area may be contaminated or prone to contamination in all 3 sectors and would therefore have to be excluded from**

harvesting). Look towards improving catchment runoff quality through appropriate treatment.

3. **Collect rainfall data from nearest rain measuring station, preferably monthly data, for 30 years. Do a probability analysis and provide for a 95% probable rain as a worst-case scenario. Working on averages may be misleading.**
4. **Calculate rainfall endowment and rainfall harvestable for all 3 catchments i.e. rooftops, paved areas and unpaved areas.**
5. **Determine surface water flows based on contours and identify points for storage or recharge based on contours.**
6. **Do a hydro-geological survey to determine ground water extant, quality and ideal recharge areas (this is especially necessary in hard rock areas).**
7. **Design storage and recharge systems based on maximum or optimum intensity of rainfall (typically 50 mm per hour for Bangalore).**
8. **Provide filters, silt traps, grease traps and appropriate locations.**
9. **Device a catchment management strategy to prevent and avoid point and non-point sources of pollution (is a solid waste management plan in place and is it being properly taken care of?)**
10. **Identify your water consumption for various demands and work towards optimising and reducing demand. Identify quality requirements and ideal source of supply for each demand. For example treated grey water may provide all your landscape water demand requirement and rainwater may need to be used for flushing or process purpose only.**
11. **If landscape water requirement is your top demand can appropriate planting strategies be adopted to reduce water consumption? Examine.**

12. If you are recharging ground water how much are you improving quality of ground water and quantity of ground water? Do an estimate.

13. Always be very, very sure of the quality of groundwater you send into the ground. Contamination of groundwater is generally irreversible or very difficult to treat once contaminated.

14. While storing rainwater sumps are the most effective but costly mode, lined ponds are the cheapest but factor in evaporation losses, which are very high. Deeper pond makes better storage and lesser losses. Evaporation prevention strategies are important.

15. Look for defunct storage systems. Sometimes empty sumps and unused septic tanks or construction sumps may be available for storage. Since storage is the largest cost for rainwater harvesting optimising makes sense.

16. Work out a cost benefit analysis based on present and future costs of water. Remember future water is likely to be scarce and costly. Think sustainability. Can you be largely dependent on harvested rainwater alone?

17. Remember to factor in rainwater harvesting into your EMS 14000 strategies. You may earn a lot of brownie points.

18. Examine whether separate storage and lines for potable water and non-potable water makes economic sense. Build it into future designs.

19. Remember rainwater harvesting minimises storm runoff and soil erosion in many sites. The positive externalities should also be factored in.

20. Rainwater harvesting is practised in over 65 countries and is the future of sustainable water management strategies.

If begun in a phased manner will enable a 'zero runoff strategy' the ultimate goal for rainwater harvesting.

Design Examples:

Bangalore is a city located at 920 metres above sea level. A peculiar characteristic of the surface water flow for the city is that no water flows **in** into the city but all rainwater flows **out** in broadly 3 different valleys. A city of over 270 lakes and tanks in 1972 is now down to 80 or under. Ground water levels too show both a decline in unconfined water levels in places as well as the effects of pollution with nitrates reported as a threat in many ground water sources.

Water supply to the city is managed by the Bangalore Water Supply and Sewerage Board. Two major sources are the River Arkavathy and the River Cauvery. The latter is now the predominant source but is located 95 kilometers away and about 500 metres below the city necessitating huge pumping costs and energy usage. As infrastructure for the peripheral area is limited and system loss of water is high there is a large section of the population dependant on ground water through bore wells. One estimate puts the number of bore-wells in the city as close to 1 lakh. Situated on the edge of the Deccan Plateau and on granite rock access to ground water is not uniform and easy. However houses in the periphery are dependent entirely on groundwater.

Rainwater harvesting systems from rooftops work on the following conventions. Generally roofs are flat and accessible. This means the roofs can be cleaned easily. Rainfall intensity is less than 50 mm per hour. It is a convention to build sumps for water storage and the size is usually 5000 to 6000 litres, this is because water required for construction is usually bought from private tankers and stored in these sumps.

Rainfall:

Average rainfall over the last 10 years is around 970 millimetres with about 59 rainy days spread from April to November. Rainfall is a relatively well-distributed and typically bi-modal with peak in April-May and September-October. This makes Bangalore relatively better for rainwater harvesting because of the spread.

Case Study: 1

Residence of Pradeep and Pushpa. Located 17 kilo-metres North of the city in a suburb called Vidyaranyapura adjacent to the University of Agricultural Sciences campus –GKVK- the city water lines have not yet reached the colony. Water supply is through common bore -wells being maintained by the Association. The plot area for the site is 288 square metres and the roof area of the house is 121 square metres.

By appropriately sloping roofs, locating down-pipes and providing filters at each down-pipe clear water is guided to a sump of capacity 8000 litres. Overflow from the sump is led to a storm water drain.

For the remaining plot area ground slopes are worked and water collected in a small water body. Overflow from the water body will also recharge the ground water through percolation pits.

Every year it is estimated that 1,15,700 litres of rainwater will be harvested and 32,400 litres of water will be recharged.

It is estimated that an additional cost of about Rs 4000/- has been incurred mainly in the filters towards rainwater harvesting.

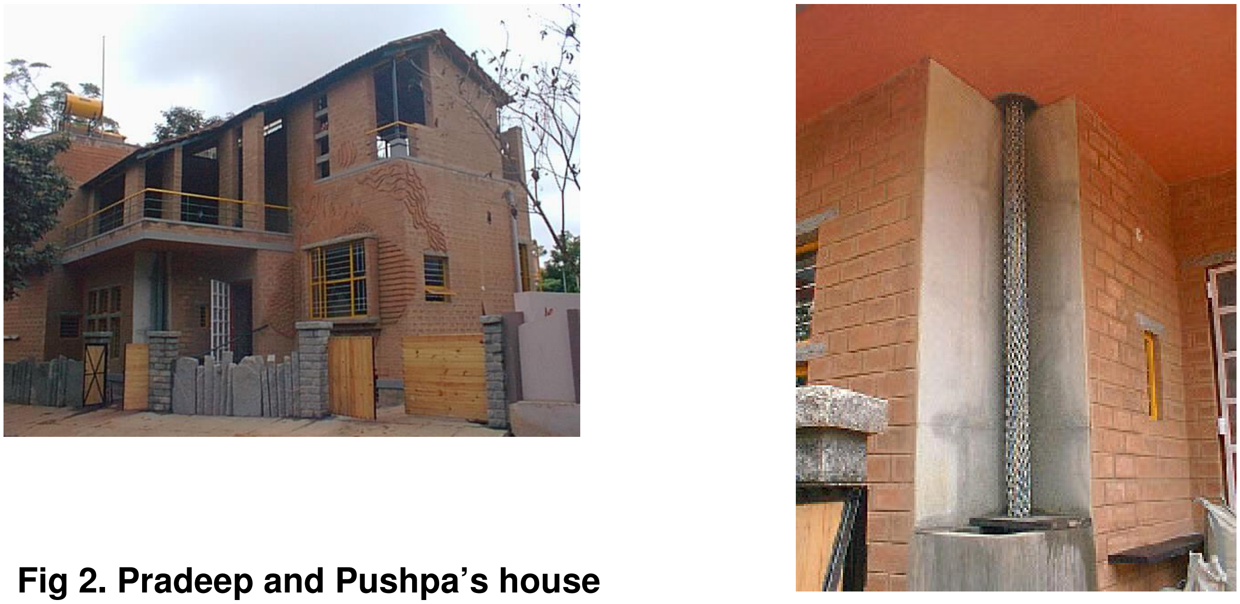


Fig 2. Pradeep and Pushpa's house
with chain link as down-water guide and rainwater harvesting in ferro-cement tank.

Case study: 2

Residence of Prithvi and Purshottam. Located in Sahakara Nagar about 13 km north of the city centre. City water lines are connected to the house. The twins have an open well in the plot, which is about 6 metres deep. Water levels in the dry season are at about 5 metres below the ground and in the monsoon it comes up to about 1 metre below the ground.

The flat roof of about 60 square metres was gently sloped to a single point for the down water pipe, which would come down close to the sump location. A first rain separator was provided to segregate the first 2.5 mm of rainwater. A drum filter designed by the owner was installed on the down pipe. After filtration the water is led into a sump of capacity 6000 litres. Overflow from the sump is led to the open well to recharge the unconfined aquifer. If by chance the well water reaches to the top, provision is made for leading it out to a storm water drain outside.

Every year close to 54,000 litres will be harvested and about 40,000 litres recharged.

An additional cost of about Rs 2,500/- towards filter and pipeline to open well has been incurred towards rainwater harvesting.

Zero rainwater runoff house. Rainwater harvesting in sump and excess water recharged to an open well.

Case study:3

Chemical Engineering Dept., Indian Inst. Of Science. A roof area of about 511 sq mt was tapped and water redirected by altering and linking the down pipes appropriately to an existing sump of capacity 30,000 litres. A first rain separator and a filter was introduced. At an expenditure of Rs 11,000/- it is estimated that a savings of Rs 22,650/- per year is being generated by harvesting 377 kilo-litres every year at Rs 60/- a kilo-litre

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Case study: 4

Industrial unit of ESCORTS-MAHLE-GOETZE. Located in Yelahanka a northern satellite town of Bangalore the industrial unit has a site area of 20 Hectares.

Rainwater incident on the site was calculated to be 185 million litres of which it was estimated that 62 million litres could be harvested. A rooftop harvesting system for 1280 square metres of roof area has been put in place, which collects 1.05 million litres every year. The rooftop harvesting has now been extended further to collect approximately 2.50 million litres of water and finally designing has been done to harvest the entire 62 million litres harvestable. A payback period of about 4 years is expected.

A cost of Rs 2.50 lakhs was incurred towards the pilot project including storage sump, pump and pipeline.

Case study: 5

A neighbourhood colony of about 4 square kilometres has put in place a decentralised water management system incorporating rainwater harvesting more by serendipity than by design. Two small tanks Narasipura 1 and Narasipura 2 collect rainwater and act as percolation tanks to recharge the aquifer. About 15 bore-wells on an average sunk 80 metres deep, and then supply water to the colony of about 3000 houses. Sewage discharged from each house is collected and treated both physically and biologically through an artificial wetland system and led into Narasipura 2. The loop of water supply and sewage treatment is completed within a small geographical area, in an ecologically appropriate manner and economically.

Fig 4 NARASIPURA-1rainwater harvesting for groundwater recharge

Fig 5 NARASIPURA-2 (With Domestic Effluent Treatment Plant)

Case study: 6

In a study commissioned by the Government of Karnataka named **'A Conceptual Framework for Rainwater Harvesting for Bangalore'** it was pointed out that nearly 3000 million litres per day of rainwater is incident on the city of Bangalore with an area of 1279 square kilometres. This in comparison to approximately 1500 million litres per day, which will be, pumped in after the completion of two augmentation projects under implementation. The study points out that at-least 20% of the cities water requirement can be met through rainwater harvesting provided a strategy is put in place to persuade owners to go in for rooftop rainwater harvesting and also surface storage structures like lakes and ponds are maintained well. Recharge structures to augment aquifers and their utilisation in a sustainable manner would benefit the city immensely.

Costs: Typical investment costs for rooftop rainwater harvesting systems are in the range of Rs 4000/- to Rs 6000/- if made as an adjunct to a new construction and has the potential to generate up-to 80 kilo-litres a year. Assuming 20 year life period for structures costs per kilo-litre work out to less than Rs 4 /- a kilo-litre making it extremely cost competitive to alternative sources. City supplies themselves have a production cost of Rs 15/- a kilo-litre.

A completely new structure exclusively for rainwater harvesting would have a cost involvement as follows.

Storage at Rs 2.50 a litre	6000 x 2.50 =	15,000/-
Pipes to lead rainwater to storage tank		1,500/-
Pump to place water into an overhead tank		2,500/-
Pipeline for pump		2,000/-
Labour		2,000/-
	For a total of Rs	23,000/-

This investment would yield about 70 Kl of water every year for 20 years i.e about 1400 kl of water. The cost of harvested rainwater would be about Rs 16.50 a kilo-litre. The current production cost of water for the BWSSB is reported as Rs 15 /- a kilo-litre and the marginal cost of production is reported as Rs 45/- a kilo-litre. When compared to marginal costs of production rainwater harvesting is definitely cost-effective.

Conclusions:

The onus is on architects, engineers and planners to start to integrate rainwater-harvesting systems in building designs, landscapes and neighbourhoods. Right from small houses to the city itself rainwater harvesting can be adopted provided inter institutional coordination and professional involvement is generated. In a high water demand scenario it will be rainwater harvesting and water recycling which will not only provide for a sustainable water supply scenario but also will mitigate urban flooding to an extent.

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RAINWATER HARVESTING IN URBAN AREAS –INDUSTRIES

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INTRODUCTION:

The paper seeks to address the issue of rainwater harvesting for houses, apartments, industries and institutions especially in an urban context. It does not specifically exclude peri-urban and semi-rural area as land use restrictions in many cities push industries to peripheries and fringes. **The main focus is however industries**.

Water demand all over the country and internationally is rising rapidly. Though agriculture continues to be the single largest sectoral consumer of water worldwide, industrial demand for water is also escalating sometimes at a much faster pace than any other demand. Traditional and Centralized piped water supply systems are finding it difficult to cope with meeting such exploding demand. Ground water is also depleting especially in India and China in many cities including Bangalore, Hyderabad, Beijing, Chennai and Delhi.. Unconfined ground water or open well water is getting contaminated due to bad management practice with catchments, storm water, sewage and industrial effluent.

Industrial water price:

Typically in a cross-subsidized scenario for water tariff, industrial water supply is priced the highest. In Bangalore for example industrial water tariff is Rs 60 a kilo-litre (1US $ = Rs 47/-) with a sewage cess of 10%

thus making it effectively Rs 66/- a kilo-litre. Every kilo-litre of rainwater harvested will replace piped water and save the industry Rs 66 /- a kilo-litre. In the context of the rainfall in Bangalore , one acre of land receives as its rain endowment on an average 36 lakh litres to 39 lakh litres. This is 3600 kilo-litres to 3900 kilo-litres. In money terms it is Rs 2,37,600/- to Rs 2,57,400/- of water falling as an endowment free, for now. It therefore makes more and more environmental and economic sense for industries to reject current paradigms of treating rainwater as a waste but instead to see it as a valuable natural resource and seek ways to harvest it and put it to productive use. In the long run it will be rainwater harvesting and grey water recycling which will provide sustainable water supply to industries and cities.

DEFINITION:

Rainwater harvesting is the process of collecting and storing rainwater for future use. **Storing** rainwater is possible in sumps, tanks or lined ponds. **Recharging** of aquifers is also a form of rainwater harvesting and filtered rainwater can be used to charge aquifers to improve quantity and quality. Recharging is done through percolation pits, dispersion trenches; open wells or bore wells and is dependant on aquifer and hydro-geological characteristics.

OBJECTIVES:

Rainwater harvesting has primarily three major objectives

1. To provide supplementary water requirements
2. To mitigate urban flooding
3. To increase soil moisture and ground water levels

PROCESS:

Industries typically have large roof area and large site area and therefore can harvest large quantities of rainwater. The first step is to establish the catchment area for rainwater harvesting. A catchment for a point is nothing but the area from which rainwater falling will pass through that given point. Two clear catchment areas emerge for industries and institutions

-rooftops
-land area (other than rooftops)

The land area is further subdivided to **paved** area and **un-paved** area. The slope characteristics, soil characteristics and hydrogeology, apart from rainfall amount, pattern and intensity play a great part in **quantity** of rainwater runoff and collection.

Total Rainwater incident on a site in a year would therefore be equal to Yearly rainfall (mm) x Site Area (Hectares) cubic metres or kilolitres.

Rainwater Harvesting for an industry to a Rain Barrel

In Delhi which receives an annual average rainfall of 613 mm for example, in a 1 Hectare area the average rainwater incident would be

613 x 1 = 613 cubic metres or kilolitres

That is to say 6.13 lakh litres of water needs to be managed in a year of average rainfall over a site of 1 Hectare.

Not all the rainwater incident on a site can be harvested. Losses due to evaporation and percolation occur. Storage systems too cannot be designed for the entire water incident and will overflow. A rough rule of thumb would say that between 50% to 70% of the rainwater incident could be harvested provided paved surfaces are large enough.

Of these 6.13 lakh litres the water quantum that can be harvested could possibly be (assuming 5000 sq. mt of roof area, 2000 sq.mt of paved area and 3000 sq.mt. of unpaved area in the 1 Ha or 10,000 sq mt of total area)

5000 x 0.613 x 0.80 +
2000 x 0.613 x 0.60 +
3000 x 0.613 x 0.20
= 3555.40 cu mt **or**
.355 million litres

This represents 58% of the rainfall incident on the site.
Note that 0.80, 0.60 and 0.20 represent coefficients of collection.

PARAMETERS:

A brief listing of the parameters to be considered for rainwater harvesting in houses, apartments, industries and institutions is listed below.

I. RAINFALL

Total rainfall (mm)

Rainfall pattern (No. of days and when)

Intensity of rainfall (mm/hour)

Average rainfall for 35 years

95% probable rainfall

II. CATCHMENT

- Collection surface
  - Roof area
  - Land area
    - Paved area
    - Unpaved area
      - Slope characteristics (contours)
      - Surface characteristics
      - Soil characteristics

III.Drainage system

- Down water pipes
- Storm water drains/pipes

IV. Storage system

- Availability of space
- Method of storage

V.Coefficients of collection – for various surfaces and slopes

VI.Evaporation losses

For the year

During various months

VII. Percolation losses

VIII.Water use

De-mineralized water

Soft water

Potable water

Irrigation water

Non-potable water

IX.Hydro-geological characteristics

Open wells location and quality of water

Bore wells -failed

Bore wells – depth, quantity and quality of water

Soil profile – up-to 150 feet

X.Infiltration and percolation characteristics

Infiltration rate of soil

Percolation rate – at various depths

WATER DEMAND:

Typical methodology for rainwater harvesting is to work backwards from demand. Total demand, with seasonal fluctuations, should be broadly established. A water audit is helpful and by metering from various sources of supply a good database on water consumption can be created.

The next step would be to stratify demand in terms of quality. How much of the water is needed for potable purpose? How much for flushing toilets and for gardening? How much for cooling towers? How much for processing? Any demand for special quality requirements like no TDS?

In terms of the water pollution and control act, Pollution control Boards monitor water effluent from industries. Legislatively, it is insisted in many states, that gray water be treated and recirculated. This gray water many a time meets substantially landscaping and gardening requirements and thus takes away from overall water demand.

With additional demand control strategies like identifying and eliminating leakages in pipelines and storage reservoirs, using water efficient devices like low quantity flushes, sensitizing workforce on conserving water etc substantial reduction in water consumption can be achieved.

CASE STUDIES:

An industry on the periphery of Bangalore, India had a land extant of 1 Hectare. Its water demand was 8000 litres per day for 300 working days. The management decided to go in for rainwater harvesting primarily because of its environmental concerns and also because of other reasons

- of the 2 bore wells supplying water 1 was almost packing up raising concerns about the sustainability of ground water
- storm water runoff could not be led out of the compound area because the neighbour was objecting to its release into his land
- the company was aiming for ISO 14000 Certification and rainwater harvesting would get it brownie points

A quick examination of the site, the contours and existing water storage systems indicated that the company could harvest 28 lakh litres of water as against its yearly demand of 24 lakh litre. A combination of storage in a 32,000 litres sump and recharge of the failing bore well was suggested. The recharge mechanism was suggested after carrying out percolation tests. For an investment of about Rs 0.25 million about 56 million litres of water would be generated over 20 years. Giving a cost of Rs 4.50 per kilolitre. This as compared to city supplies of Rs 66 a kilo-litre.

The systems suggested for harvesting included

Separation of gray water and rainwater

Silt traps for reducing sedimentation in water

Filters and storage in a 32,000 litre sump

A small water treatment unit to treat 8000 litres of water every day to potable standards. This would in most situations mean a rapid sand filter and an online chlorinator.

PRECAUTIONS and SUGGESTIONS:

Industrial areas are prone to chemical **pollution** and therefore recharge of groundwater from rainwater harvesting should be carefully examined. The surface runoff from catchments should be tested and only after the quality of the runoff is assured should it be used for any purpose. **Especially recharging of groundwater should be avoided if there is any possibility of contamination**. It is always better to store rainwater in lined ponds and put it back into the non-potable water consumption cycle of the industry.

It is always better to **phase** out projects and investments. A small rooftop harvesting system can be first set up. Quantity and quality of water observed and slowly the system can be scaled up to perhaps make the area a ‘ zero discharge’ zone in so far as rainwater is concerned.

It is always better to take special precautions and to segregate water for potable use including hand wash and face wash areas. Special care should be taken to treat this water very well and keep it segregated and free from contamination and accidental mix up.

Non-point sources of pollution need special attention.

DOMESTIC RAINWATER HARVESTING

A brief explanation is attempted here since domestic rainwater harvesting is now widely propagated. In the Bangalore context a 100 square metre roof area would receive about 97,000 litres of water spread over 60 rainy days.

For apartments, individual houses, institutions and industries the first step could be a RAIN BARREL. Depending on the performance of the Rain Barrel the project could be scaled up to cover the entire plot or site to ensure maximum utilization of rainwater.

RAINWATER HARVESTING – THE RAIN BARREL WAY

- **Rainwater harvesting is collecting and storing rain.**
- **One simple way to start harvesting rainwater is by getting a RAIN BARREL.**
- **A RAIN BARREL is a HDPE drum placed on a platform 18 inches high to collect rainwater.**
- **Check the quality of rainwater in a lab and determine its use.**
- **People use it for DRINKING too, sometimes it is that good.**

- A 500-litre Rain Barrel placed for 50 square meter roof areas can collect nearly 23,500 litres of water in a year. This assumes a usage of 500 litres of water per day from the Rain Barrel.
- Similarly a 1000 litre Rain Barrel can generate nearly 36,000 litres of water in a year.
- A SPACE of 4 feet x 4 feet is required for a Rain Barrel

- A RAIN BARREL has a rain bye-pass system and a FILTER to filter the rainwater.
- Installing a 500 litre Rain Barrel should COST about Rs 2645/.
- The COST for a 1000 litre Rain Barrel should be Rs 3895/-
- The water from the rain barrel can be used to RECHARGE open wells or bore-wells easily using a hosepipe and a Zero-B type filter.
- Overflows from Rain Barrels can also be used for RECHARGING the ground.
- Rainwater harvesting through Rain Barrels generates water for productive use and prevents wastage.
- Rain Barrels reduce urban FLOODing and reduces pressure on city level supplies.
- Rain Barrels can be installed in individual houses, apartments, institutions and industries.

- Rain Barrels also can be installed in phases depending on money availability.
- A clean terrace helps

Year	No of days with rainfall	Amount of rainfall (mm)	Volume of rainfall on 50sq m roof	Volume of rain collected in a 500lt tank	Overflow for recharge
1992	77	870.3	43515	22695	20820
1993	82	1176.2	58830	23725	35105
1994	95	731.5	36575	21395	15180
1995	81	657.5	32865	20750	12115
1996	96	887	44350	25235	19115
1997	93	1196	59810	23425	36385
1998	84	1135	57515	23425	34090
1999	82	1004.3	50215	24395	25870
2000	96	1092.2	54610	26625	27985
2001	87	1116.4	55820	24955	30865
AVERAGE	87	986	54432	23662	25753

Conclusion:

Rainwater harvesting is an important new technique to confront the increasing shortage of water and to manage the precious water judiciously. However a systematic and structure procedural approach is required to ensure that the maximum benefits are drawn from this technique. Great care is also required to ensure that negative externalities are not generated by the adoption of this technique such as pollution of groundwater or flooding damage to structures, or weakening of foundations etcetera.

The development of a Code of Procedure by organizations like the Bureau of Indian Standards will facilitate a systematic approach.

ANNEXURE 1

1.00	***PHE Services***		
1.10	***Scope of work*** External and internal water supply		
	External and internal drainage		
	Rainwater,its collection and disposal		
	Stormwater,its collection and disposal		
	Swimming pool water requirements		
	Landscape water requirements		
1.20	***Design Calculations***		
	Type of building:	**Corporate**	
1.21	**Water Requirement of all Blocks:**		
	Population details for all Blocks:		
	Expected population in CFC Block	100	persons
	Expected population in Process Block(in 3 shifts)	860	persons
	Expected floating population	50	persons
	Maintenace staff	25	persons
	Total population for all Blocks---(A)	**1035**	**persons**
1.22	**Water consumption requirement for all Blocks:**		
	For all Blocks:		
	As per National Building Code(NBC) the water consumption for offices is taken as	45	lpcd
	Total population of process block in 3 shifts	2580	persons
	Taking 33.3% diversity on total population of process block,		
	Total population of process block in 3 shifts	1720	persons
	For Process Block (1720 persons+25 persons for maintenance)	78525	lits.
	For CFC Blocks (100 persons+50persons floating population)	6750	lits.
	For cafeteria needs (2000persons @ 5 lits. per day)	10000	lits.
	Total quantity of treated water required	**95275**	**lits.**
	Additional quantity of raw water required to produce the required quantity of treated water for residential block population	1.15 x quantity of treated water required	
	Therefore quantity of raw water required to produce required quantity of treated water for total population	109566.25	lpcd
	Total raw water requirement for all Blocks,in lits.(say)---(B)	**109600.00**	**lits.**
1.23	**Water consumption requirement for car wash:**		
	Since no car wash is expected to happen this requirement is not taken into account		
	Total water requirement for car wash in lits.---(C)	**0.00**	**lits.**
1.24	**Water consumption requirement for landscaping:**		
	Total area available for landscaping	12500	m^2
	Assuming 7lits. of water will be required per m^2,		
	Total quantity of water required for landscaping---(D)	**87500.00**	**lts.**

1.25	**Water available from STP and its use:**		
	Total quantity of water required for landscaping as per clause 1.24	87,500.00	lts.
	Water available from STP (90% of domestic water)	98,640.00	m^3
	Surplus quantity of water available ---(E)	**11140.00**	**lts.**
1.26	**Water consumption requirement for mirror pool:**		
	Total area available for the mirror pool	920.00	m^2
	Total depth of mirror pool	0.6	m
	Quantity of water required for pool	552.00	m^3
	Flow through filter at 8 hour operation	69.00	$m^{3/}$hr.
	Backwash water required @ 5%	3.45	m^3
	Evaporation losses @ 12 lits./m^2	11040.00	lits.
	Evaporation losses @ 12 lits./m^2	11.04	m^3
	Total qty. of water required for backwash and for evaporation losses	14.49	m^3
	Total quantity of water for mirror pool requirements---(F)	**14490.00**	**lts.**
1.27	**Water consumption requirement for firefighting:**		
	As per NBC the capacity of u/g raw water sump for business buildings upto 15m in height shall be	93,000.00	lits.
	Therefore,		
	Total water requirement for firefighting in lits.---(G)	**93,000.00**	**lits.**
1.28	**Summary:**		
	Total water requirement for all Blocks---(B)	109600.00	lits.
	Total water requirement for car wash in lits.---(C)	0.00	lits.
	Total quantity of water required for landscaping---(D)	87500.00	lts.
	Total quantity of water for swimming pool requirements---(E)	14490.00	lts.
	Total water requirement for firefighting in lits.---(F)	93000.00	lts.
	Total raw water required,in lits. shall be (say)	***124,100.00***	***lts.***
1.30	**Recommended storage capacities:**		
a)	Raw Water Sump:		
	For Domestic use		
	Total raw water requirement as per clause 1.28	124100.00	lits.
	No. of days assumed for water storage requirement,	1.5	day
	Total qty. of water required	186150.00	lits.
	Hence,recommended net raw water sump capacity	***186,150.00***	***lits.***
b)	Treated Water Sump:		
	For Domestic use		
	Total treated water requirement as per clause 1.22	95275.00	lits.
	No. of days assumed for water storage requirement,	1.5	day
	Total qty. of water required	142912.50	lits.
	Hence,recommended net treated water sump capacity		***lits.***

		142,950.00	
c)	Firefighting Sump:		
	Total water requirement as per clause 1.27 for firefighting	93,000.00	lits.
	Hence,recommended net fire water sump capacity	***93,000.00***	***lits.***
	Overhead Water Tanks:		
a)	Overhead Water Tank for Process Block:		
	Total water demand in Process Block	78525	lits.
	No. of days assumed for treated water storage requirementin OHT,	0.5	day
	Recommended net overhead water tank capacity in Process Block	***39,300.00***	***lits.***
b)	Overhead Water Tank in CFC Block:		
	Total water demand in CFC Block	6750	lits.
	No. of days assumed for treated water storage requirementin OHT,	0.5	day
	Hence,recommended net overhead water tank capacity in CFC Block	***3,400.00***	***lits.***
c)	Overhead Water Tank in Cafeteria Block:		
	Total water demand in Cafetria Block	10000	lits.
	No. of days assumed for treated water storage requirementin OHT,	0.5	day
	Hence,recommended net overhead water tank capacity in Cafeteria Block	***5,000.00***	***lits.***
d)	Overhead Fire Water Tank in Process,CFC and Cafeteria Blocks:		
	As per NBC the capacity of OHT shall be	2500	lits.
	Hence,recommended net overhead fire water tank capacity in Process,CFC and Cafeteria Blocks shall be	***2,500.00***	***lits.***

1.40	***Design Brief Abstract***		
	Recommendations:		
	Recommended raw water sump capacity for all Blocks , (net)	186,150.00	lits.
	Recommended treated water sump capacity for all Blocks , (net)	142,950.00	lits.
	Recommended net fire water sump capacity	93,000.00	lits.
	Recommended overhead water tank capacity in Process Block,(net)	39,300.00	lits.
	Recommended overhead water tank capacity in CFC Block,(net)	3,400.00	lits.
	Recommended overhead water tank capacity in Cafeteria Block,(net)	5,000.00	lits.
	Recommended net overhead fire water tank capacity in Process,CFC and Cafeteria Blocks shall be	2,500.00	lits.
	Assumed water distribution system	Gravity system	

	Exclusions:
	Any work not specifically covered in the preceding pages
	Special Comments:
1	All capacities mentioned above are "nett" ,add 0.3m to the depth of the tank for freeboard depth.
2	Water treatment has been considered,hence provision for treated water sump has to be made by the Architect.
3	It has been assumed that the air conditioning system likely to be adopted for the project will not have any water requirements.Hence,no water requirement for airconditioning system has been taken into account.
4	Architect to convert above recommended storage capacities to sizes as appropriate.Pump room to be located in such a way so as to enable positive suction(as discussed and explained in design meeting)