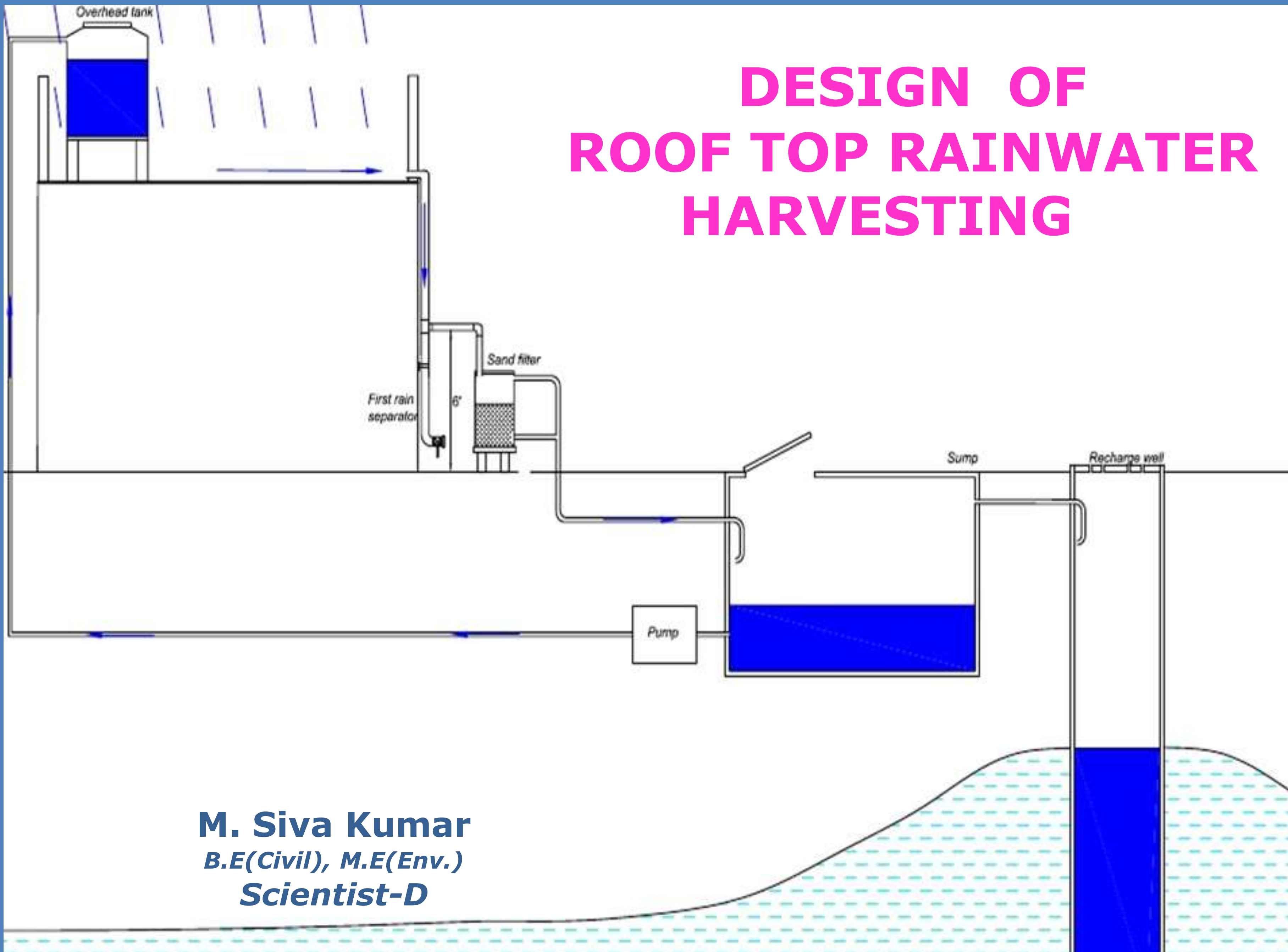
DESIGN OF
ROOF TOP RAINWATER HARVESTING



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Design Components of RTRWH system

The system mainly consists of :

- Rooftop run-off
- Storage tank
- Recharge structure
- Filter (sedimentation/ filtration)
- Gutter
- Rainwater pipes
- First flush

Roof top run-off estimation

To calculate maximum amount of rainfall that can be harvested from the rooftop, following details are required: -

Area of roof - (A)
Average annual rainfall - (R)
Runoff coefficient - (C)

Quantity of maximum annual rainwater harvesting = A x R x C.

Run-off co-efficient of Roof Types

Type	Runoff coefficient	Notes
GI sheets	> 0.9	Excellent quality water. Surface is smooth and high temperatures help to sterilise bacteria
Tile (glazed)	0.6 – 0.9	Good quality water from glazed tiles. Unglazed can harbour mould Contamination can exist in tile joins
Asbestos Sheets	0.8 – 0.9	New sheets give good quality water Slightly porous so reduced runoff coefficient and older roofs harbour moulds and even moss
Organic (Thatch)	0.2	Poor quality water (>200 FC/100ml) Little first flush effect; High turbidity due to dissolved organic material which does not settle

Source: http://www.eng.warwick.ac.uk/dtu/rwh/components2.html

Storage tank capacity

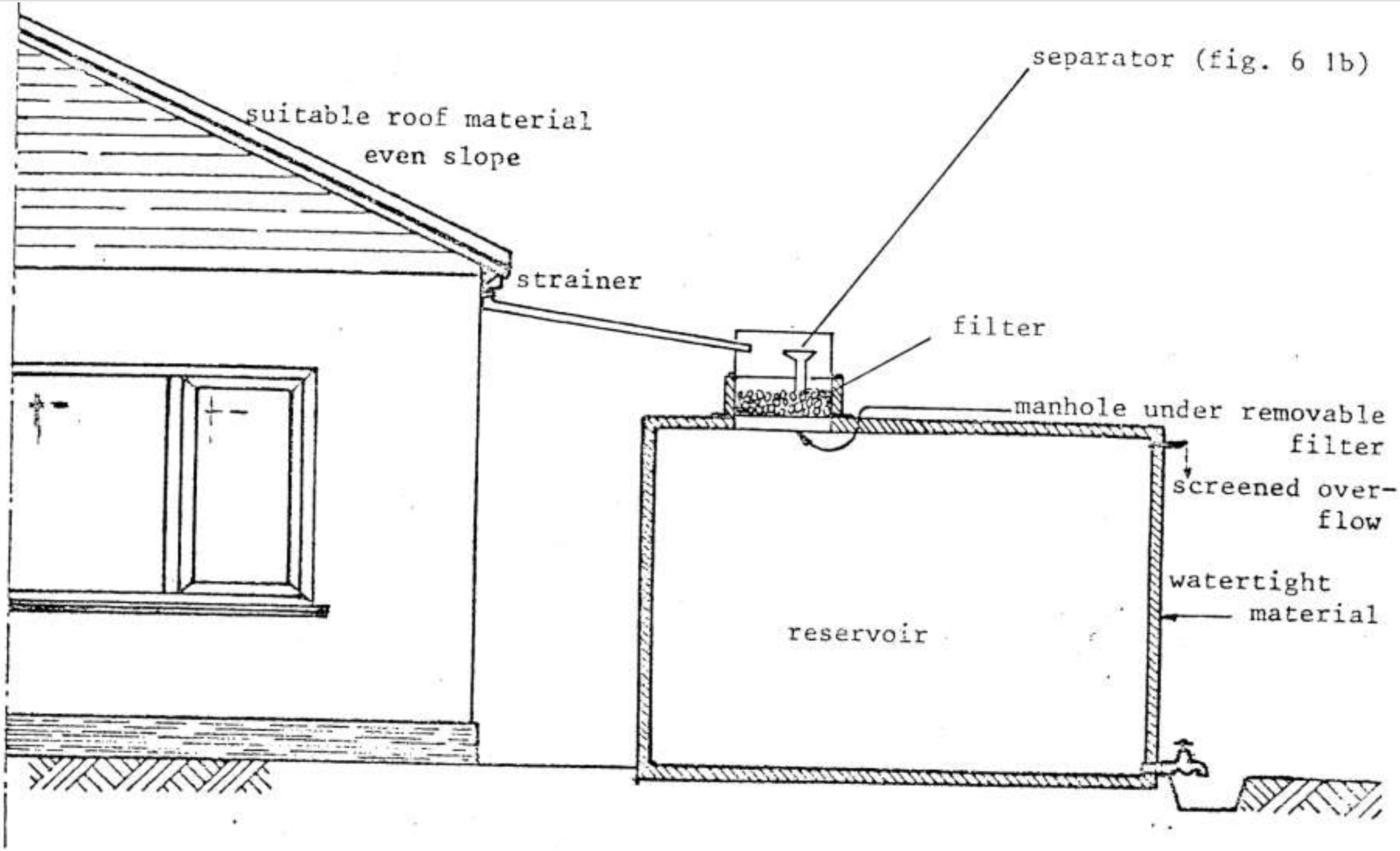
Based on rainfall and water demand pattern

- A better estimate of storage requirement can be made using the mass curve technique based on rainfall and water demand pattern.

- Cumulative rainfall runoff and cumulative water demand in year is calculated and plotted on the same curve.

- The sum of the maximum differences, on the either side, between the rainfall curve and water demand curve gives the size of the storage required

Roof catchment system with filter and storage tank



Storage tank & first flush

Storage capacity

Calculate the size of the storage tank required for a school with 65 students and 5 staff, assuming average water consumption of 5 litres/day.

Roof area = 200 m^2.

Assume runoff coefficient of 0.9.

The rainfall pattern in the area is given in the table below

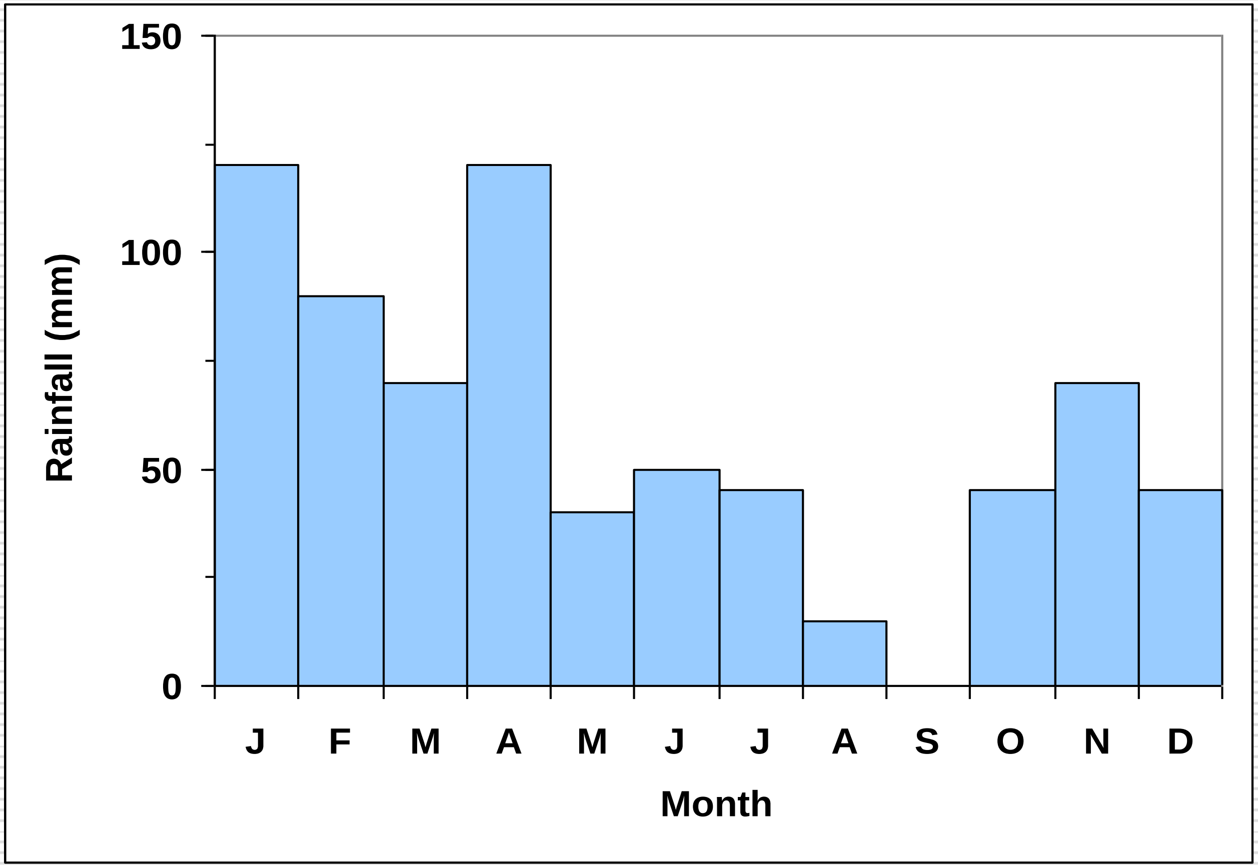
Average daily demand = 70 x 5 = 350 litres

Yearly demand = 350 * 365 = 127750 litres = 127.75 m^3 Average monthly demand = 127.75/12 ~ 10.65 m^3

Storage capacity calculations

(a) Rainfall pattern - 1

Month	Rainfall mm
Jan	120
Feb	90
Mar	70
Apr	120
May	40
June	50
July	45
Aug	15
Sep	
Oct	45
Nov	70
Dec	45



Calculation of required storage capacity (1)

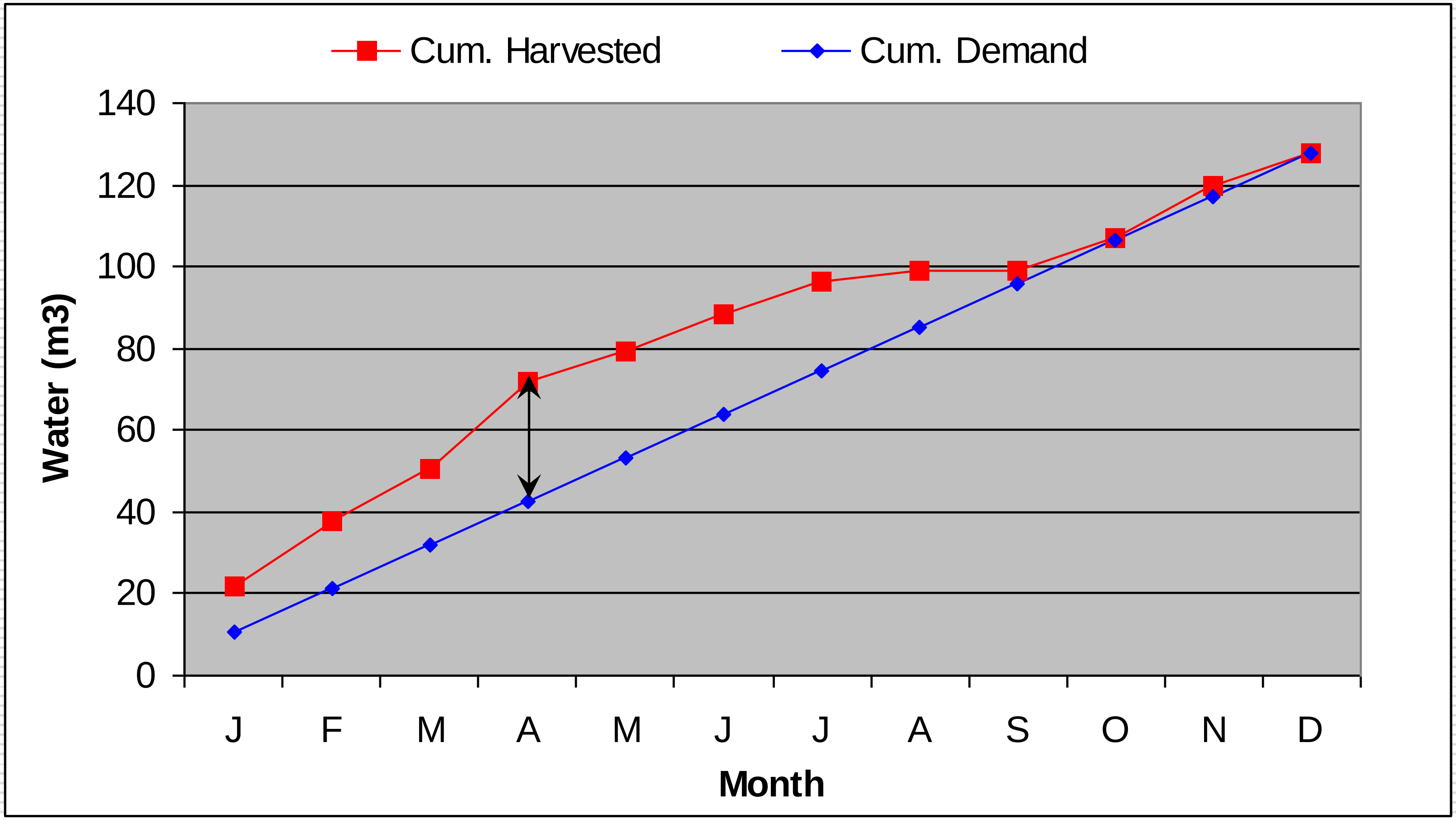
Month	Rainfall mm	Rainfall harvested m^3	Water Demand m^3	Cum. Rainfall harvested CH m^3	Cum. Water Demand CD m^3	Difference CH - CD m^3
J	120	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
F	90	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
M	70	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
A	120	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
M	40	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
J	50	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
J	45	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
A	15	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
S		[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
O	45	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
N	70	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
D	45	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]

Calculation of required storage capacity (1)

Month	Rainfall mm	Rainfall harvested m^3	Water Demand m^3	Cum. Rainfall harvested CH m^3	Cum. Water Demand CD m^3	Difference CH - CD m^3
J	120	21.6	10.65	21.6	10.65	10.95
F	90	16.2	10.65	37.8	21.3	16.5
M	70	12.6	10.65	50.4	31.95	18.45
A	120	21.6	10.65	72	42.6	**29.4**
M	40	7.2	10.65	79.2	53.25	25.95
J	50	9	10.65	88.2	63.9	24.3
J	45	8.1	10.65	96.3	74.55	21.75
A	15	2.7	10.65	99	85.2	13.8
S		0	10.65	99	95.85	3.15
O	45	8.1	10.65	107.1	106.5	0.6
N	70	12.6	10.65	119.7	117.15	2.55
D	45	8.1	10.65	127.8	127.8	0

Required storage capacity = 29.4 m^3 say 30 m^3

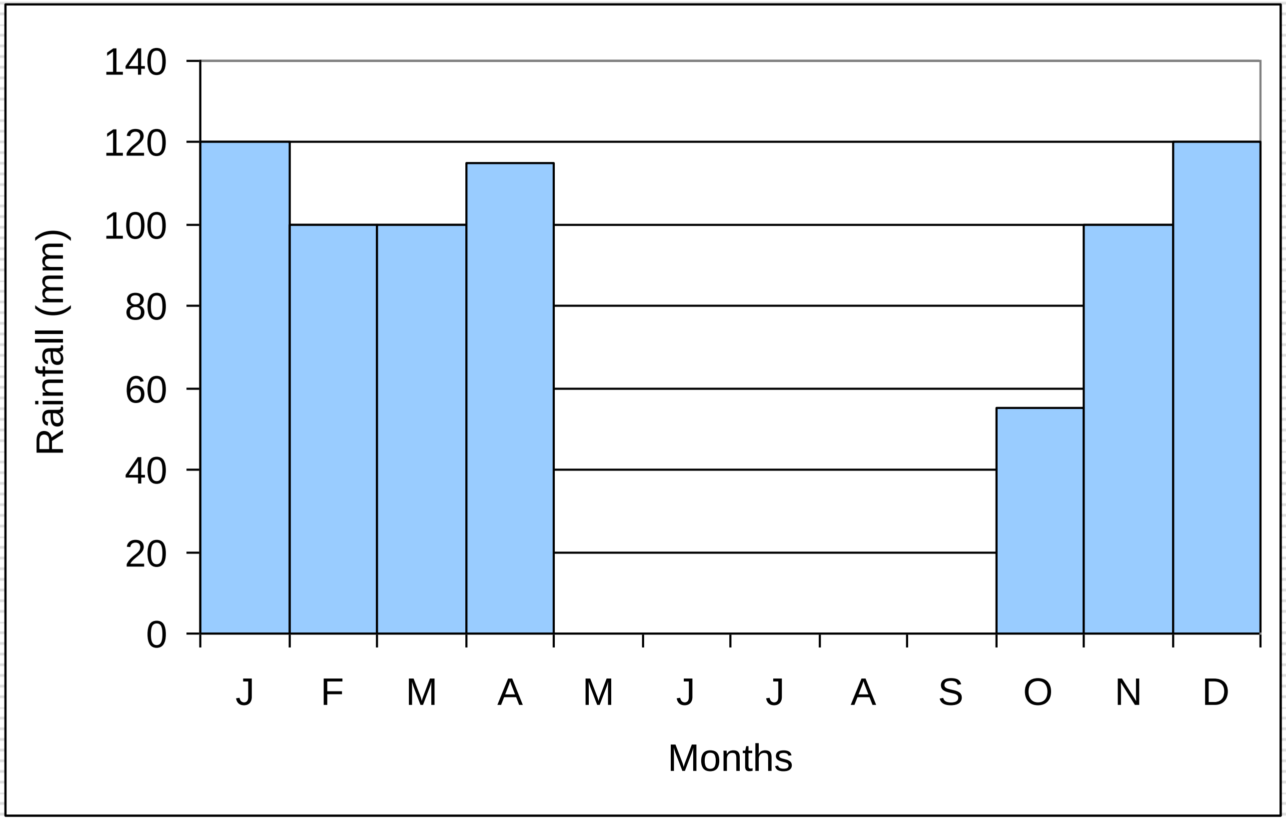
Mass curve for calculation of required storage capacity



Storage capacity calculations

(b) Rainfall pattern - 2

Month	Rainfall mm
Jan	120
Feb	100
Mar	100
Apr	115
May	
June	
July	
Aug	
Sep	
Oct	55
Nov	100
Dec	120



Calculation of required storage capacity

Month	Rainfall mm	Rainfall harvested m^3	Water Demand m^3	Cum. Rainfall harvested CH m^3	Cum. Water Demand CD m^3	Difference CH - CD m^3
J	120	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
F	100	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
M	100	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
A	115	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
M		[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
J		[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
J		[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
A		[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
S	0	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
O	55	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
N	100	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
D	120	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]

Settlement tank

The capacity of the settlement tank should be enough to retain the runoff of peak rainfall intensity period.

Following data are required to calculate capacity of tank

Area of roof top - A

Peak rainfall in 15 min. - Pr

Runoff coefficient - C

Capacity Q = A x Pr x C.

Settlement tank

The capacity of tank is designed to retain runoff from at least 15 minutes rainfall of peak intensity. (For example, the peak hourly rainfall is 100 mm (based on 25 year frequency) and 15 minutes peak rainfall is 25 mm.

For an area of 100 sq. m.,
volume of desilting/ settling tank required

= 100 x 0.025 x 0.85

= 2.125 cu. m. (2,125 litres)

Void ratio

Soil type	Coefficient of uniformity, c_u	Range of void ratio, $e_{min} \div e_{max}$
Fine and silty sand	≤ 2	0.55÷0.80
	(2;4)	0.50÷0.85
	≥ 4	0.40÷0.85
Medium and coarse sand	≤ 2	0.55÷0.80
	(2;4)	0.50÷0.80
	≥ 4	0.40÷0.80
Gravel and sand-gravel mix	≤ 2	0.55÷0.70
	(2;4)	0.50÷0.70
	≥ 4	0.40÷0.70

Void ratio of different types of soil

Recharge tank/ filtration chamber/ recharge trench

Water holding capacity of recharge pit/tank/ filtration chamber/ recharge trench is less then its gross volume because it is filled with porous material.

factor for void ratio has to be applied in the calculation

Following data required for the capacity: -

Area of roof top - A

Peak rainfall in 15 min - Pr

Runoff coefficient - C

Void ratio - D

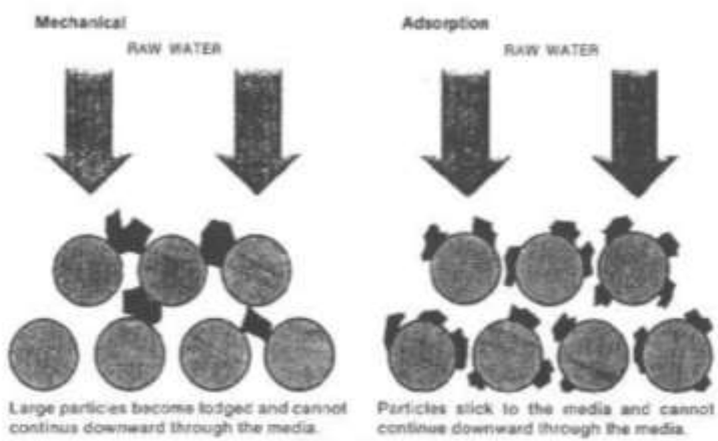
Required capacity = Q = A x Pr x C x D

Length of recharge trench = Q / bxd

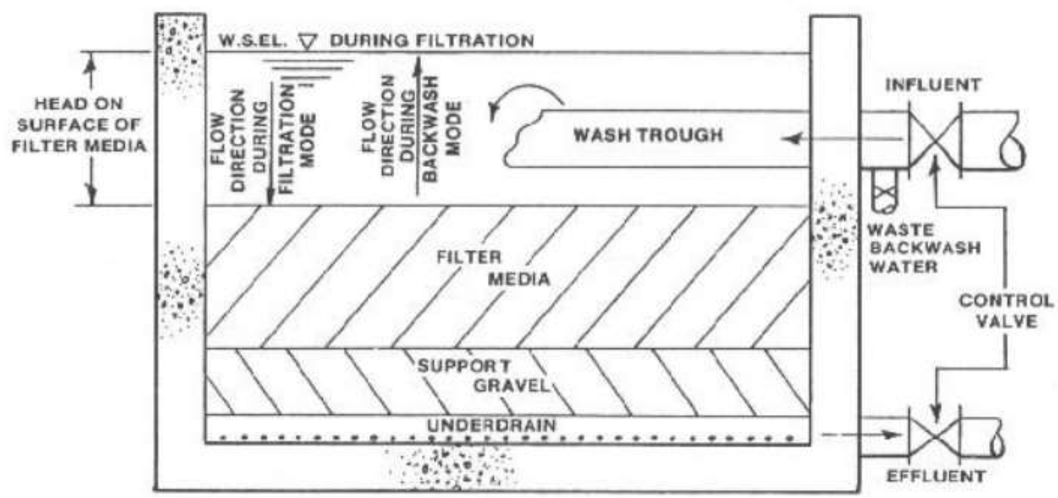
(Where b is width and d is depth of trench)

Guide to sizing FILTERS for rainwater harvesting systems

- ❑ Gravity Filters (Rapid Sand or High Rate-Dual media-Multi-media)
- ❑ RSF - filter rates 40 times (8 to 16 cum/sqm/hr) of SSF
- ❑ RSF contain 24-30 inches depth of sand
- ❑The sand used is generally 0.4 to 0.6 mm in diameter
- ❑ L x B of tanks are determined by the flow rate desired by the filters



The Two Removal Mechanisms



GRAVITY FILTER MODULE

Guide to sizing FILTERS for rainwater harvesting systems- RSF

A flow of between 4 – 21 m/h can be expected from a rapid sand filter, which is somewhere between 20 and 50 times faster than the range of slow sand filtration.

Rapid sand filters are made using graded sand, sometimes with an additional coarser layer of material on top of the sand to increase the flow rate (for example, anthracite), in which case they become known as dual-media filters. The effective size for rapid filters is usually greater than 0.55mm with a Uniformity Coefficient of less than 1.5.

Guide to sizing FILTERS for rainwater harvesting systems

SSF: The length and breadth of the tanks are determined by the flow rate desired by the filters, which typically have a loading rate of 200 to 400 litres per hour per square metre (or 0.2 to 0.4 cubic metres per square metre per hour)

The filter chamber is usually made out of reinforced concrete, filled with sand and gravel to the height of 1.5-2 metres

4’000 – 12’000 litres per hour per square metre of surface (WHO 1996); generally only removes solids and suspended particles; requires pre-treatment (coagulation-flocculation) and post-treatment (disinfection)

Guide to sizing of downpipes for rainwater harvesting systems

The pipe sizing can be determined using a well known practical formula known as Thomas-Box equation given as follows:

$$q = \sqrt{\frac{d^5 \times H}{25 \times L \times 10^5}}$$

where

q = discharge through the pipe (liter/s)
d = diameter of pipe (mm)
H = head of water (m)
L = total length of pipe (m)

Gutters

- Gutters are channels all around the edge of a sloping roof to collect and transport rainwater to the storage tank.
- A carefully designed and constructed gutter system is essential for any roof catchment system to operate effectively.
- When the gutters are too small considerable quantities of runoff may be lost due to overflow during storms.
- The size of the gutter should be according to the flow during the highest intensity rain. It is advisable to make them 10% to 15% oversize.

Gutters (2)

- A general rule of thumb is that 1 cm^2 of guttering is required for every m^2 of roof area.

- Gutters can be semi-circular or rectangular and could be made using a variety of materials:

  - Locally available material such as plain galvanised iron sheet (20 to 22 gauge), folded to required shapes.

  - Semi-circular gutters of PVC material can be readily prepared by cutting those pipes into two equal semi-circular channels.

  - Bamboo or betel trunks cut vertically in half.

  - Wood or plastic

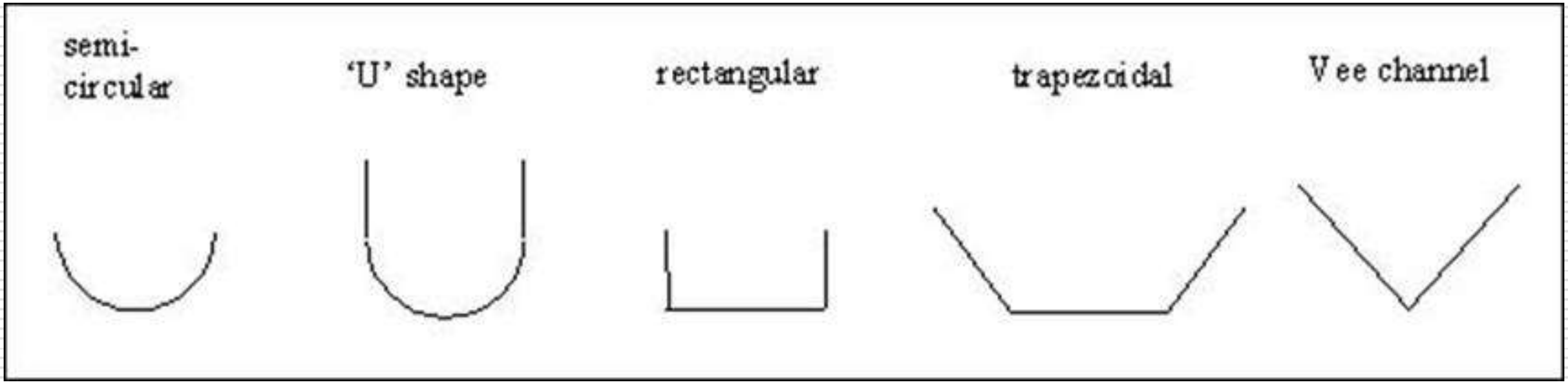
Gutters (3)

- Gutters need to be supported so they do not sag or fall off when loaded with water.

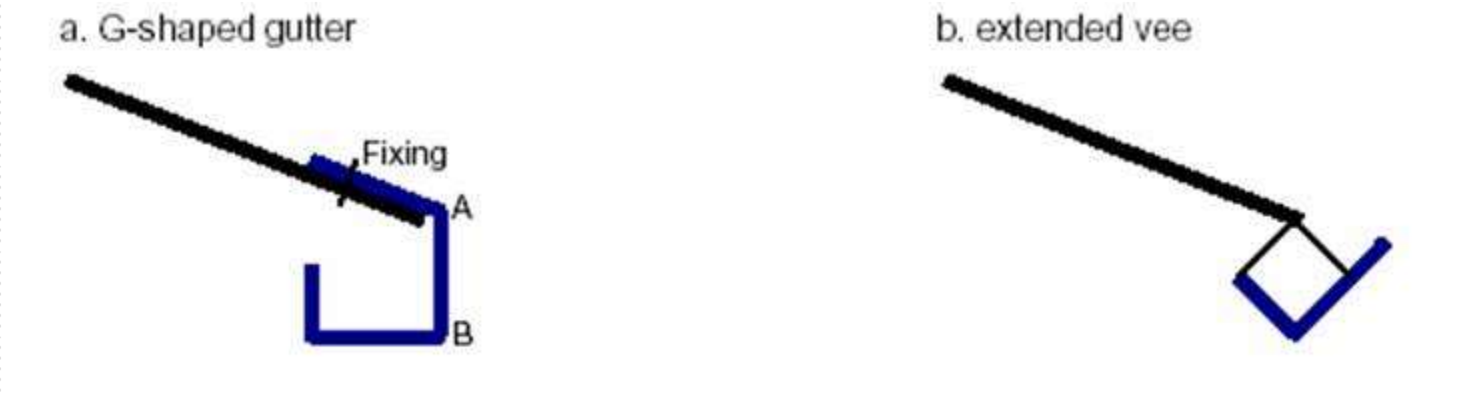
- The way in which gutters are fixed depends on the construction of the house;
  - it is possible to fix iron or timber brackets into the walls, but for houses having wider eaves, some method of attachment to the rafters is necessary.

- A properly fitted and maintained gutter-downpipe system is capable of diverting more than 80% of all runoff into the storage tank, the remainder being lost through evaporation, leakage, rain splash and overflow.

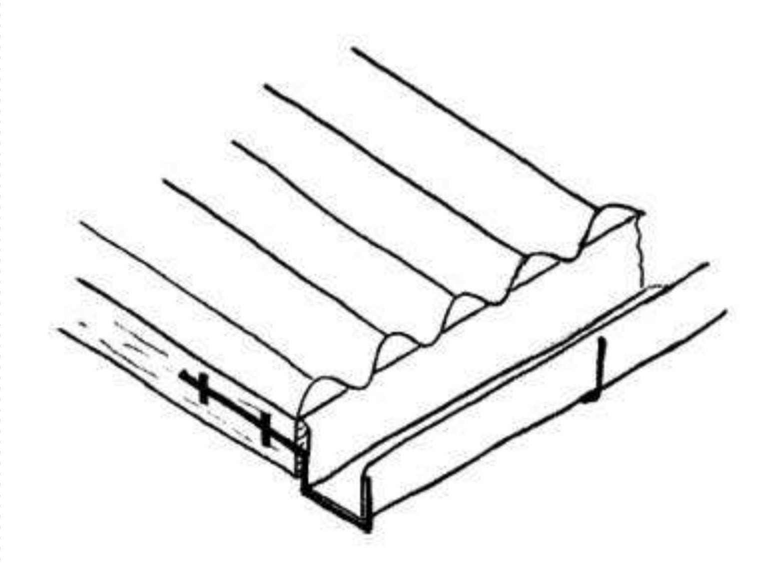
Gutters - Shapes and Configurations

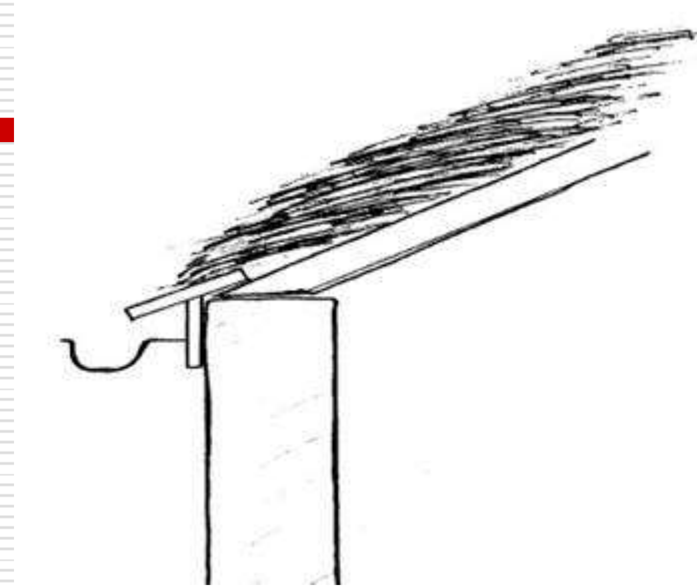


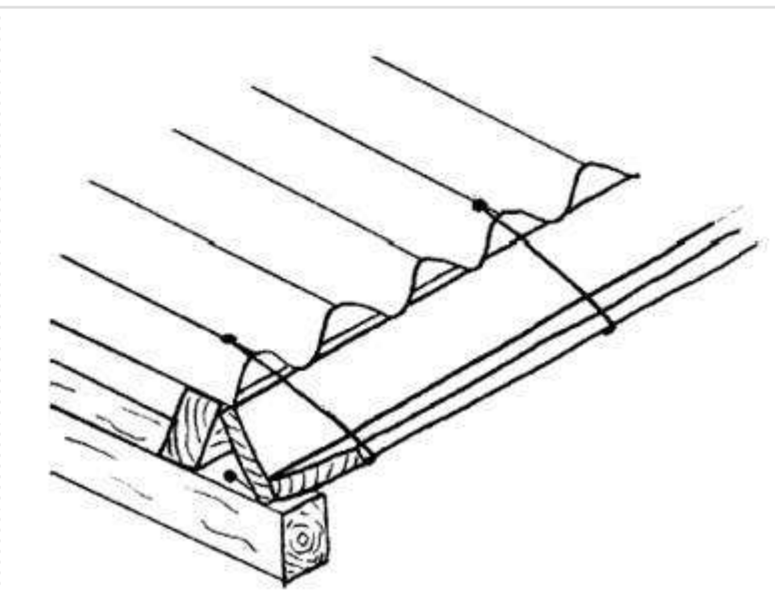
Gutter configurations

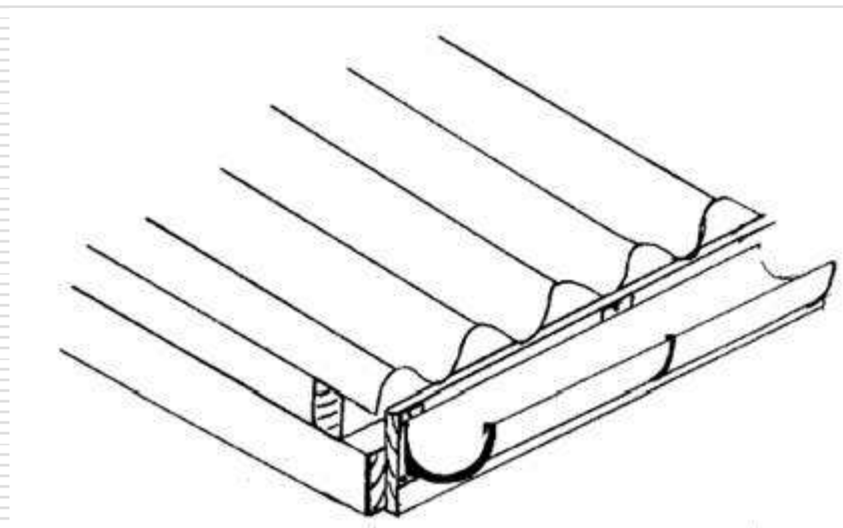


Gutters - Shapes and Configurations









Gutter screens






Source: http://www.rainharvesting.com.au

Gutter sizing

Recommended gutter widths for use in humid tropics

Gutter width (mm)	Roof area (m^2) served by 1 gutter
55	13
60	17
65	21
70	25
75	29
80	34
85	40
90	46
95	54
100	66

Source: (Still and Thomas, 2002)

Gutter sizing

Optimum roof area drainable by square gutters (considering only conveyance)

Square gutters	Slope (%)			
	0.5	1	2	4
Gutter width	**Optimum roof area served by gutter (m^2)**			
33 mm	10	14	20	28
50 mm	29	42	60	85
75 mm	88	125	177	250
100 mm	190	269	380	538

Source: (Still and Thomas, 2002)

Guttering for a 60 m² roof

	Square 0.5% slope	Square 1% slope	Half round 1.0% slope	45° Triangle 1.0% slope
Material use (mm)	214	189	150	175
Gutter width at top (mm)	71	63	96	124
Cross sectional area (cm^2)	47	39	36	38

Source: http://www.eng.warwick.ac.uk/DTU/rwh

Guide to sizing of gutters and downpipes for rainwater harvesting systems in tropical regions

Source: www.sopac.org

Roof area (m^2) served by one gutter	Gutter width (mm)	Minimum diameter of downpipe (mm)
17	60	40
25	70	50
34	80	50
46	90	63
66	100	63
128	125	75
208	150	90

First flush system (1)

- Debris, dirt, dust and droppings will collect on the roof of a building or other collection area.
- When the first rains arrive, this unwanted matter will be washed into the tank. This will cause contamination of the water and the quality will be deteriorated.
- Many RWH systems therefore incorporate a system for diverting this ‘first flush’ or ‘foul flush” water so that it does not enter the storage tank.
- Several first flush system are in use. The simplest one is a manually operated arrangement whereby the inlet pipe is moved away from the tank inlet and then replaced again once the initial first flush has been diverted.

First flush system (2)

- For an average roof catchment it is suggested that the first 20–25 L could be diverted or discarded.
- First flush devices should be regarded as an additional barrier to reduce contamination and should not be used to replace normal maintenance activities designed to keep roof catchments reasonably clean.
- The inlet pipe to all rainwater tanks should be easily detachable so that, when necessary, the tank can be bypassed. Manual detachment could be used as an alternative to an engineered first flush device, although the level of control will not be as good.

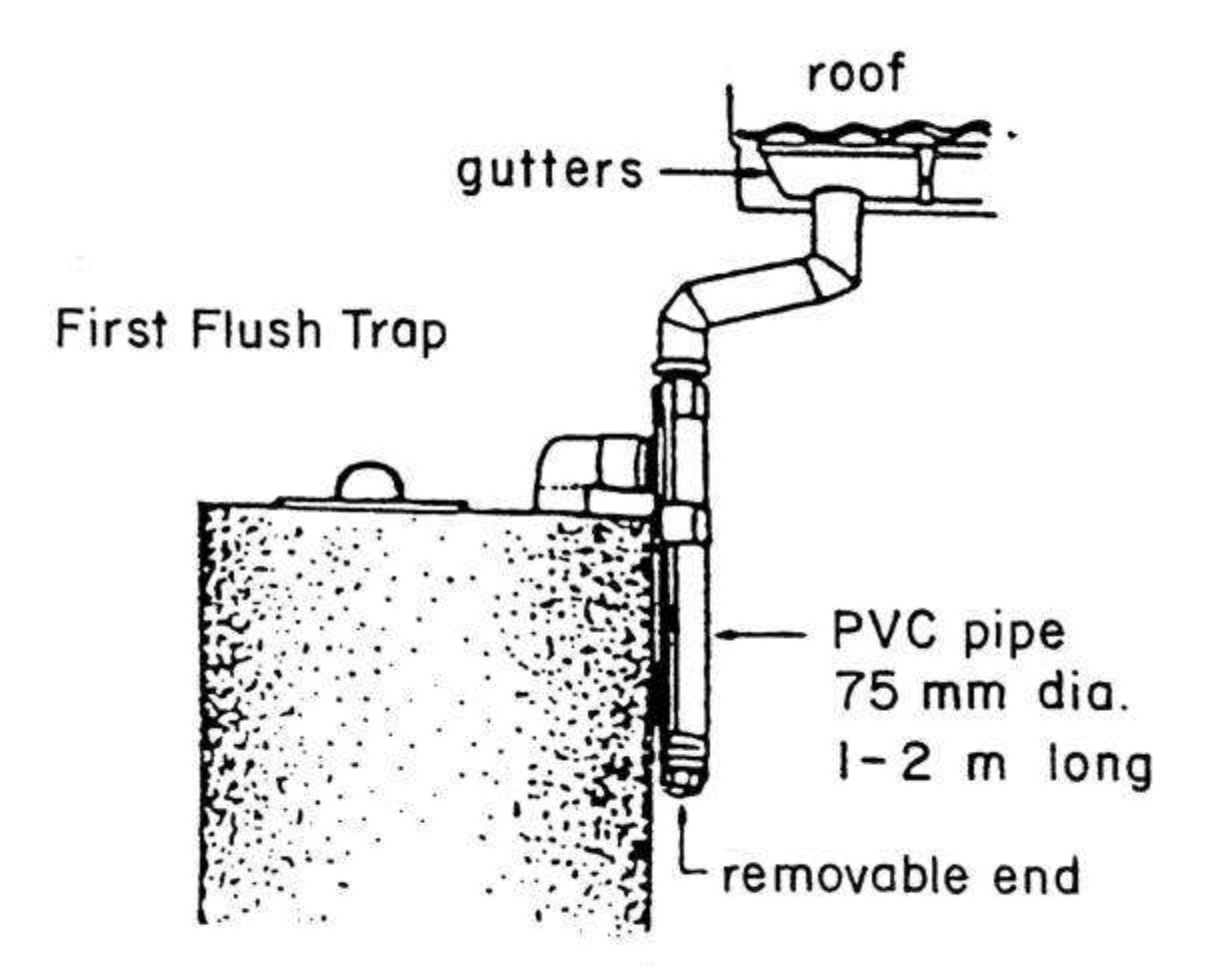
Design of First flush system (3)

The sizing of the FF devices can follow a simple equation relating to the collection area and estimated pollution load on the roof.

Flush Volume (L) = Roof Area (m^2) x Pollution Factor x 100 [3.1]

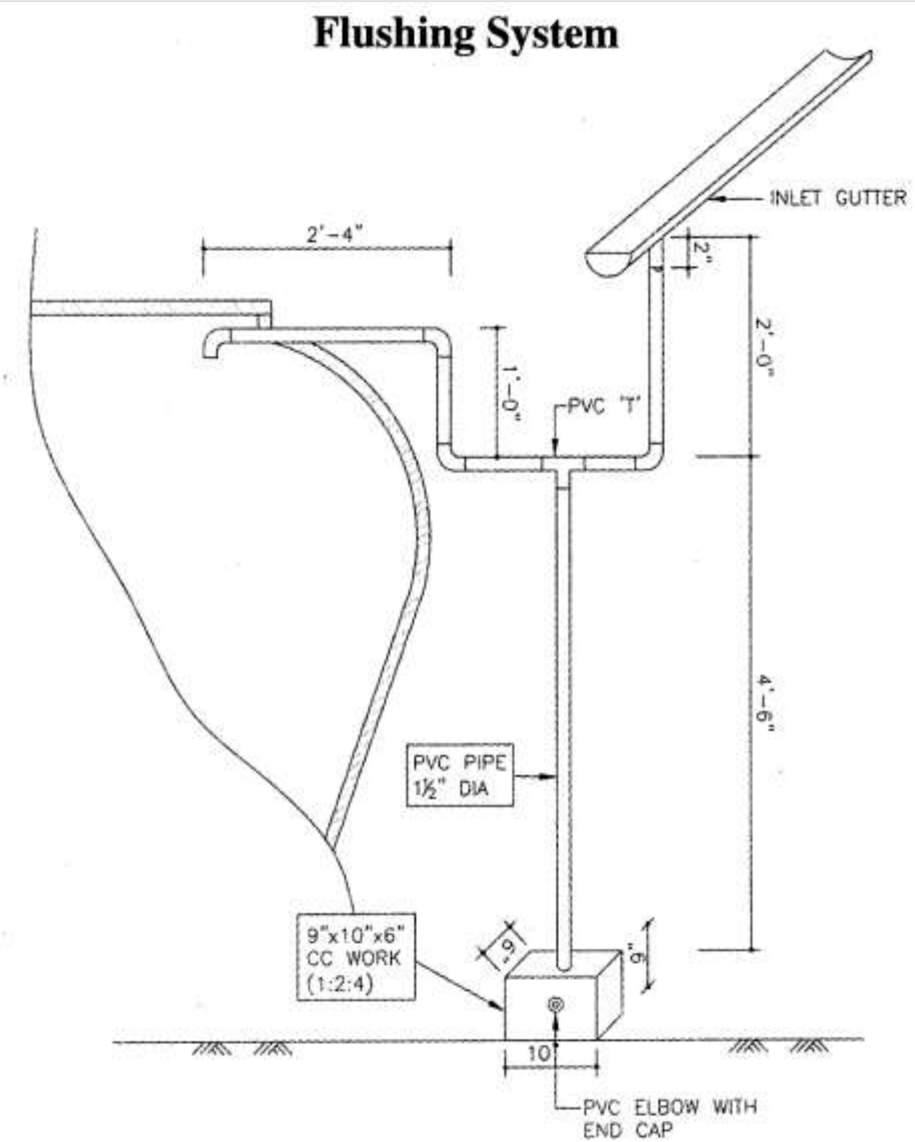
Pollution factors are 0.0005, for nil to light pollution, and 0.001 to 0.002, for heavily polluted sites. This corresponds to 1 mm to 2 mm of initial rainfall (Zobrist, 2000). As a rule of thumb, the first 1 mm rainfall on a catchment area is to be released through the FF device.

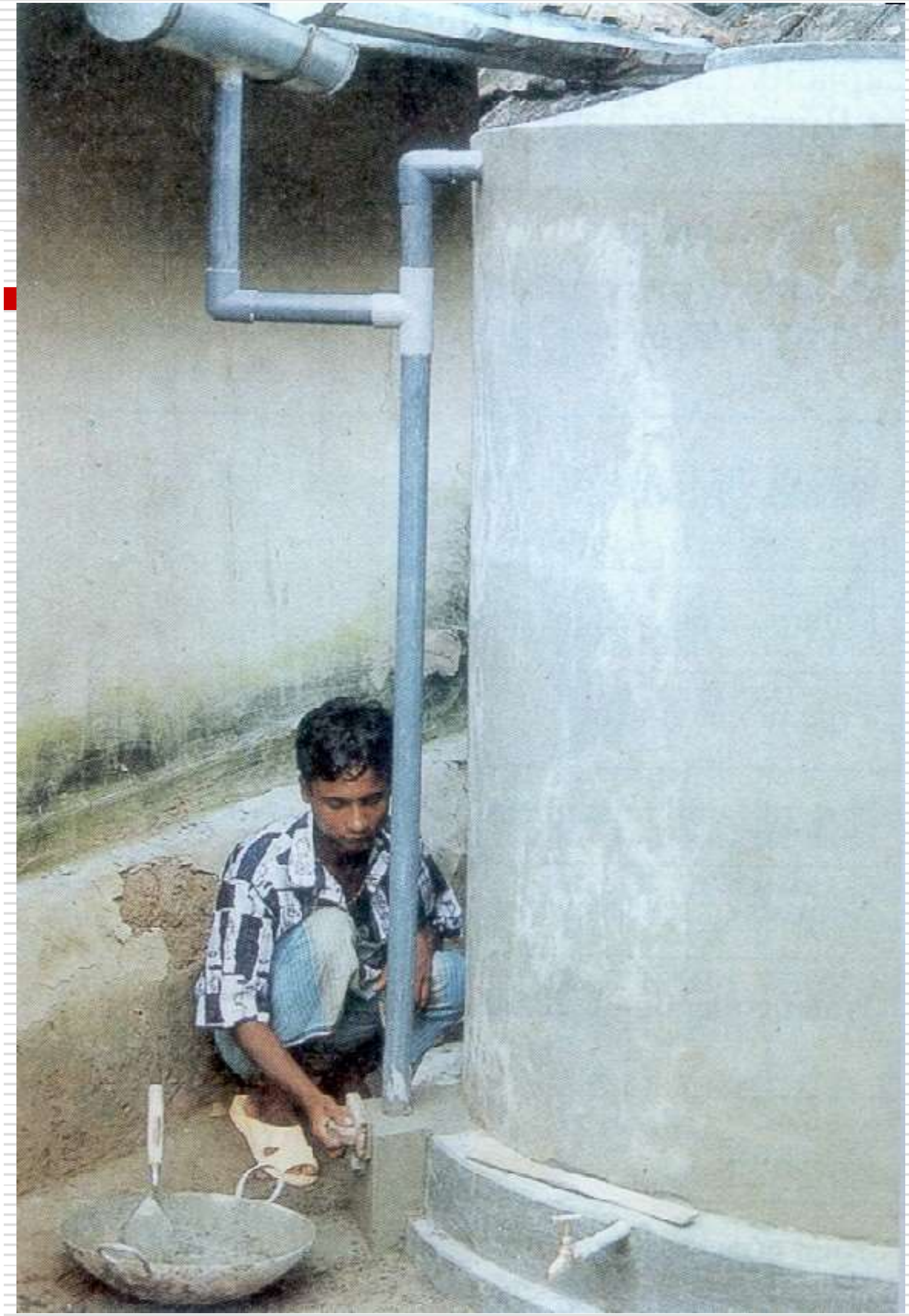
First flush system (3)



Developed by Khon Kaen University, Thailand

First flush system (4)





Part 4

QUALITY ASPECTS OF RWH

Quality of Rainwater (1)

- The quality of rainwater is relatively good but it is not free from all impurities.
- Analysis of stored rainwater has shown some bacteriological contamination.
- The rainwater is essentially lacking in minerals, the presence of which is considered essential in appropriate proportions.
- Cleanliness of roof and storage tank is critical in maintaining good quality of rainwater.
- The storage tank requires cleaning and disinfection when the tank is empty or at least once in a year.

Quality of Rainwater (2)

- The extraction system (e.g. taps/faucets, pumps) must not contaminate the stored water.
- The first run off from the roof should be discarded to prevent entry of impurities from the roof.
- Some devices and good practices have been suggested to store or divert the first foul flush away from the storage tank.
- In case of difficulties in the rejection of first flow, cleaning of the roof and gutter at the beginning of the rainy season and their regular maintenance are very important to ensure better quality of rainwater.

Quality of Rainwater - Bacteriological

- Dust from the soil, and droppings of birds and animals could be the source of contamination by the bacteria.

- When first flush eliminating devices are absent, all the indicator bacteria are generally present in water samples in numbers beyond what is acceptable by any standards.

- Tree hanging in the vicinity, definitely enhances the possibility of contamination due to increased access of the roof to birds and animals. Also leaves contribute to organic loading of the water samples, which in turn act as nutrient for bacterial growth.

Disinfecting rainwater

- Rainwater is generally of very good chemical quality. However, it may not meet WHO drinking water quality standards, specifically microbiological quality standards, hence some disinfection is recommended.

- Rainwater can be used for drinking, if it is clear, has no or very little taste or smell and is from well maintained system.

- Disinfection can be done by:
  - boiling the water in before consumption
  - adding chlorine compounds/bleaching powder in required quantity to the water stored in the tank
  - using slow sand filtration
  - solar disinfection (SODIS)

Disinfecting rainwater (2)

- For disinfection using bleaching powder, the general dosage recommended is 10 mg of bleaching powder containing 25% of free chlorine per litre of water. This meets the required standard of 2.5 mg of chlorine per litre of water.

- After adding the bleaching powder, the water should be stirred thoroughly for even distribution of the disinfectant agent. The water should be kept without use for about 30 minutes after adding bleaching powder.

Operation and maintenance

- The simple operation and maintenance of RWH systems is one of the most attractive aspects of the technology.
- The extent of maintenance required by a basic privately owned household RWH system includes
  - Regular cleaning of the roof tops and gutters
  - Frequent cleaning of storage tanks
  - Inspection of gutters and feeder pipes and valve chambers to detect and repair leaks
- When ground catchment is used for collection and/or ground tank is used for storage, proper fencing of both is recommended to keep the children and animals away, thus avoiding contamination and risks of falling into the tank.

One example of a flat screen over the gutter to keep large debris out of the tank.

A problem with gutter screens is that they require a lot of maintenance to keep leaves and debris from piling up and blocking the screens.

Also, dirt on the leaves can still be washed into the storage tank.

Source: Guidelines on Rainwater Catchment Systems for Hawaii

Tank de-sludging and cleaning (1)

- Accumulated sediments can be a source of chemical contamination and off-tastes and odours. All tanks should be examined for accumulation of sediments every 2–3 years.

- Sludge can be removed by siphoning without emptying the tank. Sludge may also be pumped from the tank with minimum loss of water by using a suitable motor-operated pump and attachments.

- Sludge can also be removed by draining and cleaning the tank. If a drain plug is provided at the base of the tank, water can be run to waste to discharge the sludge. Once the tank is empty, the remaining sludge can be scooped up and removed through the access opening.

Tank de-sludging and cleaning (2)

- It is important to check the structural condition of the tank before choosing a method of cleaning.
- Cleaning should generally be limited to removing accumulated sediments, leaf litter etc. Harsh (chemical) cleaning methods may accelerate deterioration, for example, removing the protective layer on the inside walls of a steel tank will lead to tank corrosion.
- After cleaning, it is recommended that the internal walls and floor of the tank be rinsed with clean water. Rinse water and sediment should be run to waste.
- Where cleaning necessitates entering the tank, take care to ensure adequate ventilation is provided and an additional person is in attendance.

Catch the water where it falls

Thanks