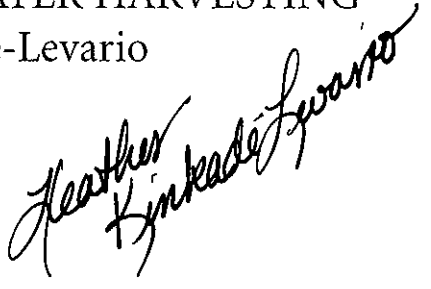
Forgotten Rain

REDISCOVERING RAINWATER HARVESTING

Heather Kinkade-Levario



Appendix A
Rainwater Harvesting System Components

This appendix describes passive and active rainwater harvesting techniques and components. Passive rainwater harvesting, using such techniques as site grading and permeable surfaces, diverts and retains stormwater so that it benefits the landscaped elements of a site. Active rainwater harvesting not only diverts the stormwater, but also stores it for later use: it makes use of such features as architectural amenities, first-flush diverters, and storage systems. The appendix concludes with examples of hand-constructed tanks from Uganda and Sri Lanka. Details provided in this book are meant to be starting points for any system: individual systems and components should be customized for specific sites.

Passive Rainwater Harvesting

Using proper techniques, both on-site runoff and off-site flows can be harvested using passive means. Planning for this type of harvesting requires an integrated design process where all team members—including the owner, developer, engineer, architect, landscape architect, contractor, and maintenance personnel—work together to attain effective harvesting. The following pages describe and illustrate various techniques that can be used.

Passive rainwater harvesting starts by managing stormwater at the top of the watershed. A project might have multiple watersheds within its boundaries, all of which can assist in slowing and spreading the stormwater. Proper site grading can make maximum use of watersheds.

Rainwater will erode less soil and percolate more when its velocity is reduced and it is spread out over a permeable surface. There are numerous ways to slow and direct stormwater, including microbasins, swales, French drains, rain gardens, permeable pavements, and curb and road grading design. To prevent the possible destabilization of sloped areas, it is best to consult an engineer if any of these techniques are used on or adjacent to slopes over 10 percent.

Microbasins are small catchment areas that are best for low volumes of stormwater. By slowing stormwater, they allow infiltration rates to increase. They can be located in a line or in an alternating pattern that allows overflows to be repeatedly slowed to allow additional infiltration. The microbasins can be

Passive rainwater harvesting: curb cuts on a commercial site allow runoff to enter landscaped area.

Passive rainwater harvesting: curb cuts at entry drive allow runoff to return to desert vegetation.

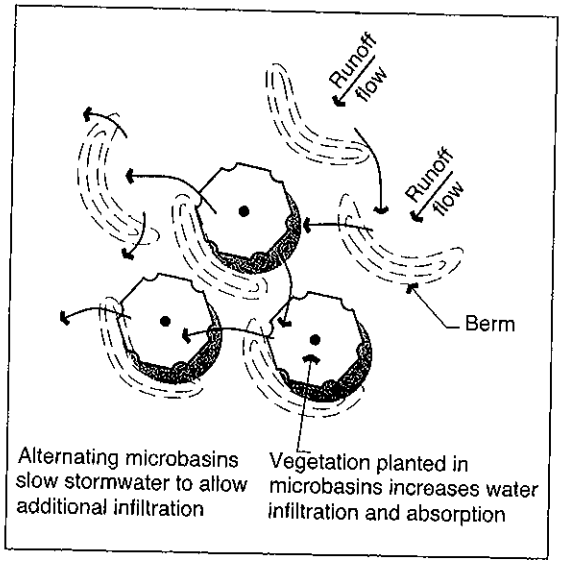
tree wells, planter islands—with curb cuts allowing stormwater to enter—or just small depressions next to a path or drive.

Swales are small depressions meant to slow sheet flow and to allow longer standing/infiltration periods. They are best for low to medium volumes of stormwater. Swales can be located next to sidewalks, paths, and driveways—typically they direct stormwater towards vegetation and away from buildings.

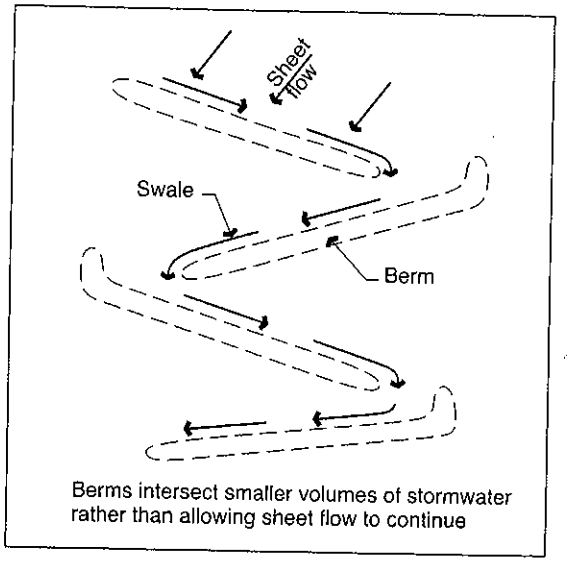
French drains and rain gardens are designed to absorb stormwater rapidly from the surface. French drains are lined transport channels that lead to below-grade storage or infiltration areas. Rain gardens are landscaped areas that are designed to direct stormwater to a central storage or infiltration area.

Permeable pavement can also be used to slow stormwater and allow more infiltration to occur. Streets, patios, sidewalks, crosswalks, and parking lots can consist of pavers that allow stormwater to pass between them to a sand or gravel sub-base that leads to a natural soil sub-base material.

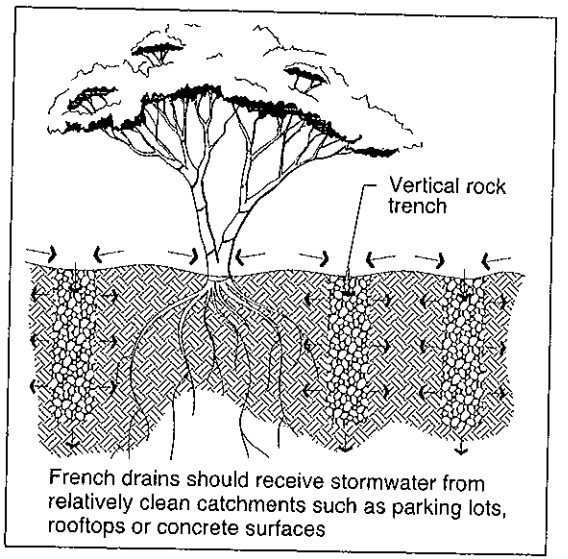
Finally, passive rainwater harvesting techniques can include the grading of a site to allow stormwater to pass over or through curbs to enter depressed planter islands in parking lots or adjacent landscape tracts. Sidewalks and driveways can be graded towards a landscaped area instead of towards a storm drain.



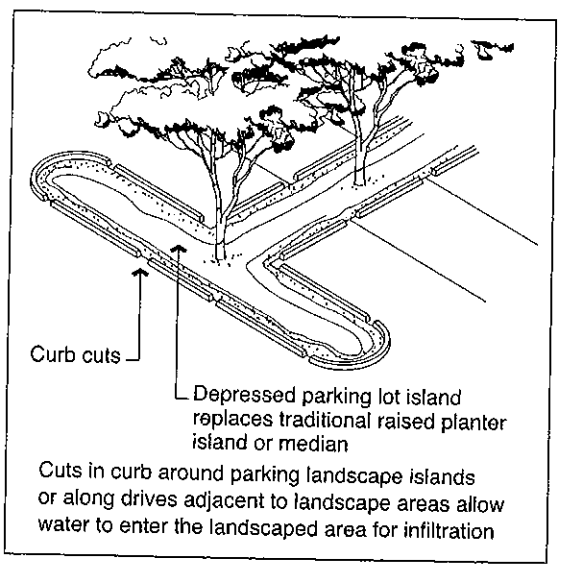
Microbasins



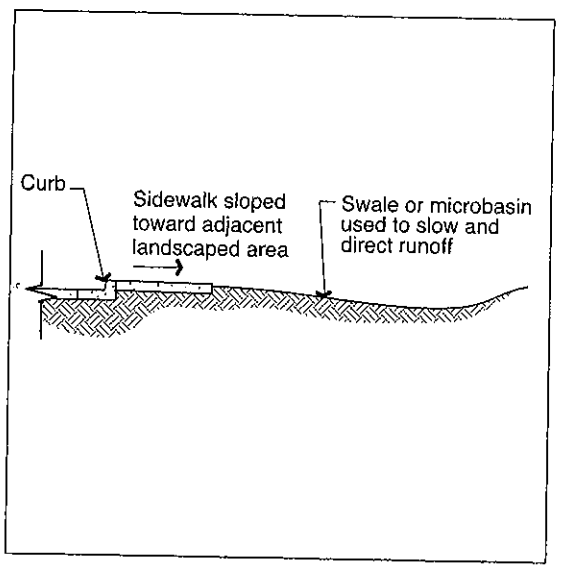
Swales



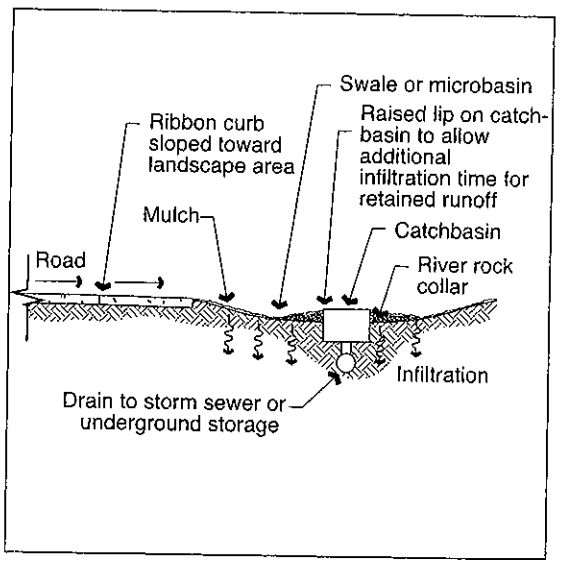
French drains



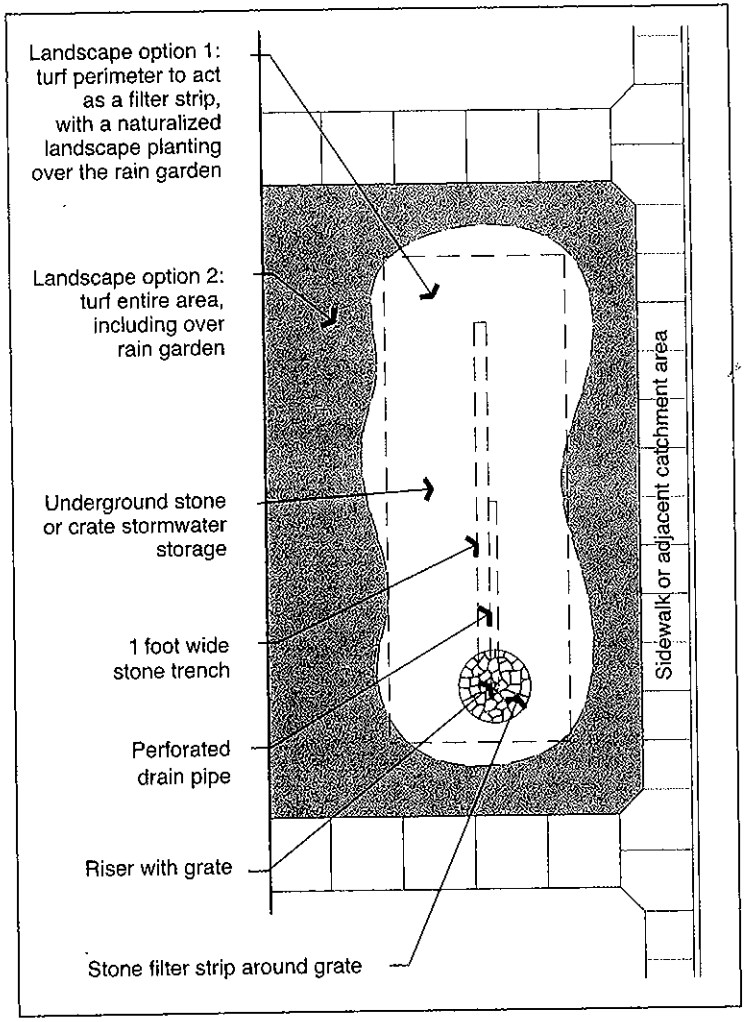
Depressed parking lot landscape island



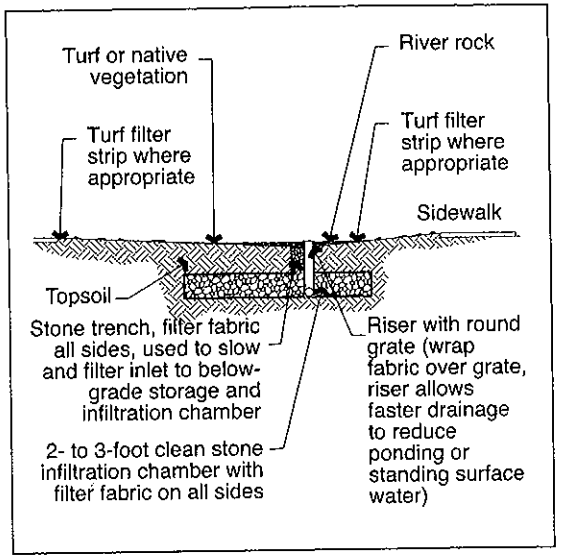
Sidewalk grading



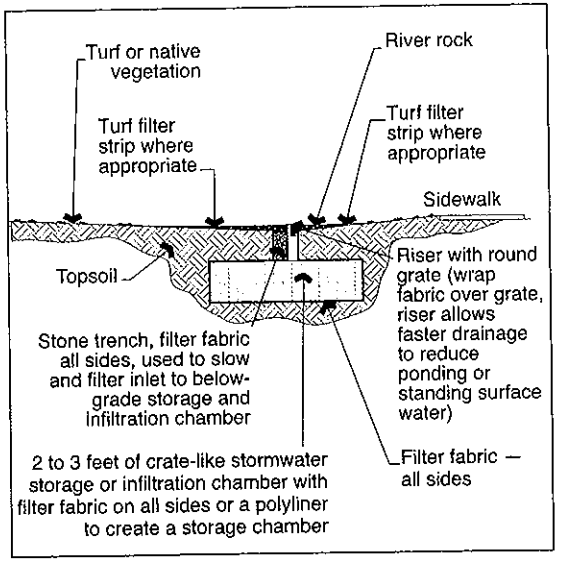
Roadway grading



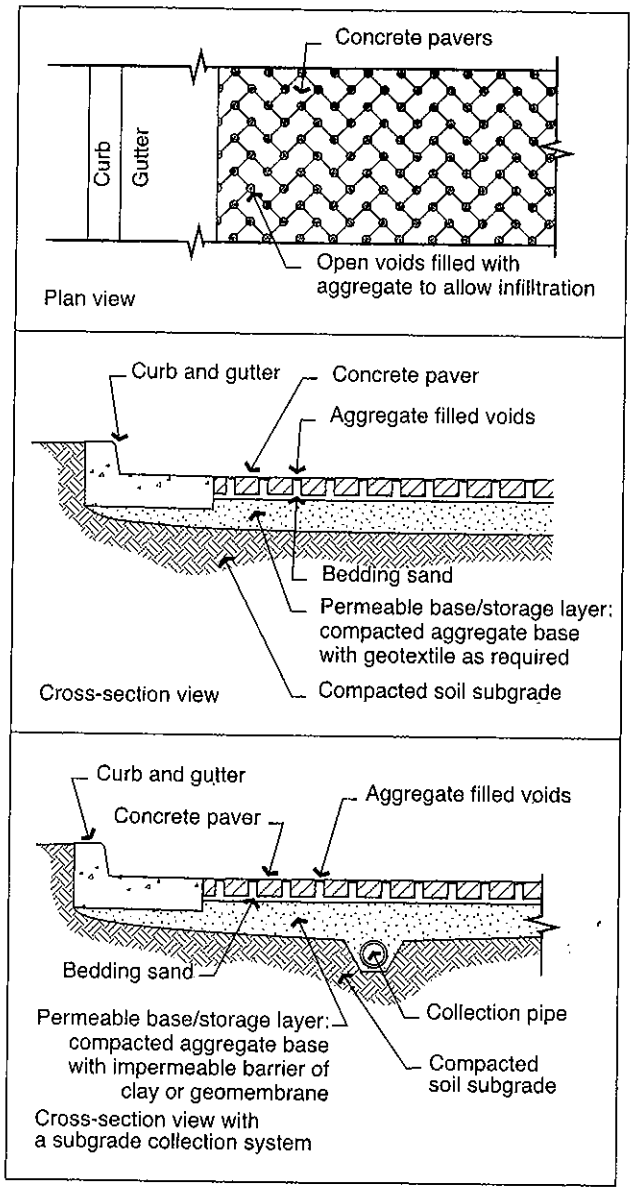
Rain garden, plan view



Rain garden, section with natural stone



Rain garden, section with crates



Concrete unit pavers

Maintenance of Passive Rainwater Harvesting Features

1. Keep microbasins and swales free of debris while maintaining surface mulch. (Mulch reduces evaporation.)
2. Block and/or repair any erosion trails that develop at overflows and spillways.
3. As plants grow, expand basins feeding them to encourage wide root development.
4. Supplement rainwater system with irrigation until plants are established, then wean plants off irrigation water.
5. Fine-tune landscape contours to control spillways, aesthetics, and functionality.
6. Inspect site before and after each rain event.
7. Inspect rain gardens for failure or unwanted erosion prior to and after each rain event. Maintain clear riser grates and stone trenches.
8. Sweep permeable pavers with a street-sweeping machine every three to five years; follow manufacturer's guidelines.

Following are three blank worksheets to be used in calculating runoff quantities, landscape irrigation requirements, and a water budget.

RUNOFF WORKSHEET

Month	Area 1	Area 2	Area 3	Area 4	Total Monthly
January					
February					
March					
April					
May					
June					
July					
August					
September					
October					
November					
December					
Total Monthly Gallons					

Formula: *Area of Catchment Sq. Ft. (Length x Width)* X *Amount of Rainfall in Feet (Inches/12)* X *Catchment Efficiency (%)* X *Conversion Factor Gal./Cu. Ft (7.48)* = *Runoff in Gallons (Total)*

LANDSCAPE IRRIGATION REQUIREMENTS WORKSHEET

Plant Type	Number of Plants Per Type	Jan 31 Days	Feb 28 Days	Mar 31 Days	Apr 30 Days	May 31 Days	Jun 30 Days	Jul 31 Days	Aug 31 Days	Sep 30 Days	Oct 31 Days	Nov 30 Days	Dec 31 Days	Total Annual Gallons Per Plant Type
Tree 25'D														
Tree 15'D														
Shrubs 3'D														
Shrubs 5'D														
G.C. 3'D														
G.C. 1'D														
Total Monthly Gallons														

Formula: Multiply number of plants times water quantity and frequency required for specific plant type to attain gallons required per specific month.

D = Diameter of canopy, G.C. = Groundcover

NONPOTABLE WATER BUDGET WORKSHEET

Month	**Total landscape irrigation requirement for established plants**	**Available runoff supply**	**Runoff minus landscape irrigation requirement**	**Excess runoff to storage** (Not used each month)	**Accumulative storage**	**Irrigation requirement from storage** (Required to supplement irrigation requirement)	**Irrigation requirement from municipal supply** (No rainwater in storage tank)
January							
February							
March							
April							
May							
June							
July							
August							
September							
October							
November							
December							
Total Monthly Gallons							

Rooftops, Gutters, and Downspouts

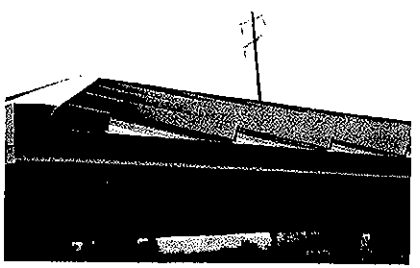
Rooftops, gutters, and downspouts can capture and direct rainfall and protect buildings from water damage. Gutters and downspouts also transport rainwater away from sensitive areas such as doors, walkways, and protected soils. Gutters are typically only used on residential buildings, but downspouts are used on both residential and commercial buildings.

When buying metal gutters, the thickest metal available and primary or virgin materials should be chosen; secondary or recycled materials are often inconsistent in thickness and may contain dissolvable nonpotable substances. Thin materials may be damaged or crushed by falling branches or ladders that are leaned up against them, though damage through maintenance can be avoided by careful use of ladders and other maintenance equipment. Vinyl or plastic gutters are susceptible to damage by maintenance equipment, but are impervious to rust and rot. Vinyl gutters can become brittle in extreme hot and cold climates. Steel and aluminum gutters are the most common materials used in residential systems. Galvanized steel gutters are the most economical choice and are stronger than aluminum gutters, but they may eventually rust. Stainless steel gutters, though they are the most expensive, are the strongest, remain rust-free, and maintain a high sheen for years.

All gutter sections should be attached to downspouts via drop outlets and should have end caps and corner pieces. Individual gutter sections can be connected or joined with snap-in-place connectors. Joining two sections of gutter together always allows a potential spot for leaks: the use of seamless or continuous gutter will help to eliminate this problem. Gutters come in numerous shapes, sizes, and colors. Downspouts are typically round or square and can match the gutter color.

Gutter covers and protectors defend the gutter from potential clogging and sagging due to debris weight or standing water caused by items that may enter the gutter, such as plant materials, animals, or toys. They can be found in numerous forms, including snap-on screens, grates, louvered (stepped or slotted filters), and helmet-like (which allow rainwater to enter through a thin linear slot between gutter and cover). One final note: copper roofs are not suggested for any type of collection systems and galvanized roofs, which contain zinc, are not appropriate for potable collection systems.

Red clay tile roof

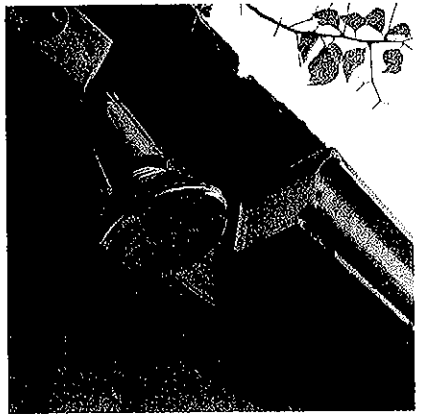


Standing seam metal roof

Grey flat tile roof

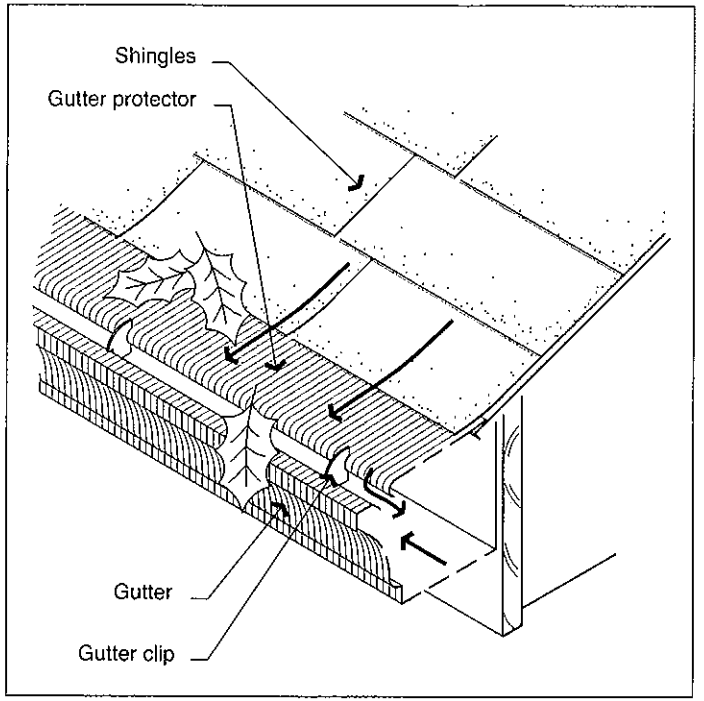
Maintenance of Roof Gutters and Downspouts

1. Conduct a visual inspection of gutters and downspouts every six months to ensure that all clips and brackets are secure and are not broken. Any broken or missing components should be repaired. Check slope of gutters to maintain positive drainage.
2. At six-month intervals remove accumulated debris and clogs. Where vegetation overhangs gutters, inspect them every three months for leaf accumulation, rust, and mold.
3. Inspect gutter system before and after each rainy season.
4. Trim trees and vines away from gutters to maintain a minimum 24-inch clear zone.
5. When gutter covers are used, inspect to eliminate any openings that may allow birds or other animals to enter and build nests. Inspect all cover clips to ensure the guards will not collapse and cause a blockage in the system. Inspect gutter cover for debris accumulation; dry accumulated debris may become a fire hazard and must be eliminated.
6. Downspouts and outlets located in landscape areas should be inspected every six months to ensure that splash pad placement is correct and that there is positive drainage away from the outlet and adjacent buildings; maintain a minimum of 2 percent slope for the first 5 feet. Check for animal inhabitations and clogs. Check landscape growth every two weeks during growing periods to protect from overgrowth, which could obstruct positive drainage.
7. Flush gutters and downspouts once all debris is removed to wash away any remaining dirt or materials.
8. Keep subsurface drains clear of debris. Remove all accumulated mud or dirt that could enter drainage system.

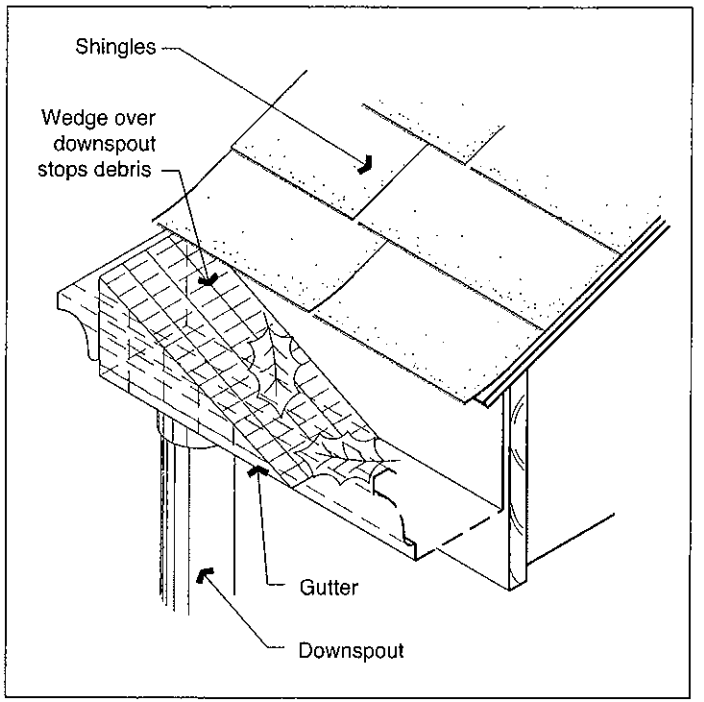


Gutter end

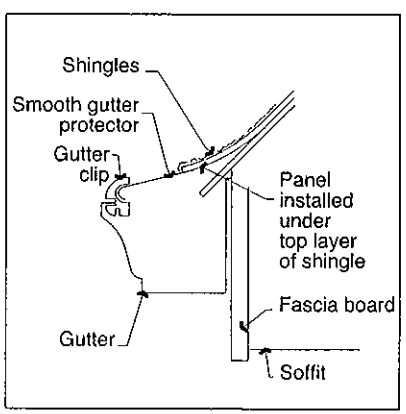
Downspout attached to a gutter



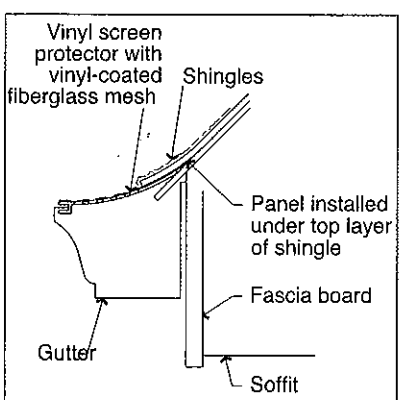
Gutter



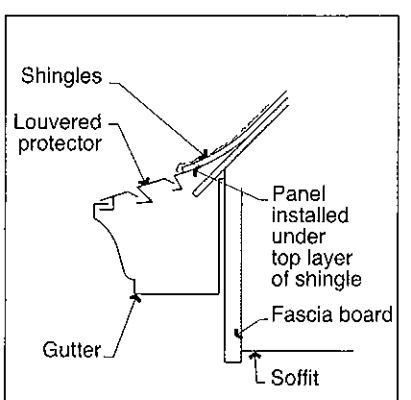
Gutter wedge



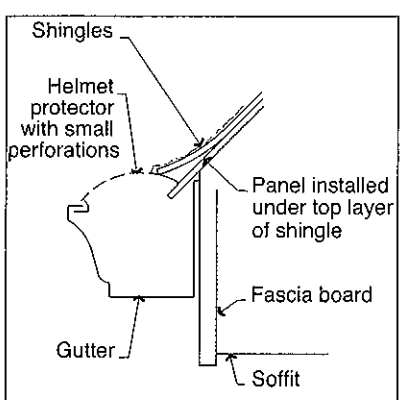
Snap-on gutter protector



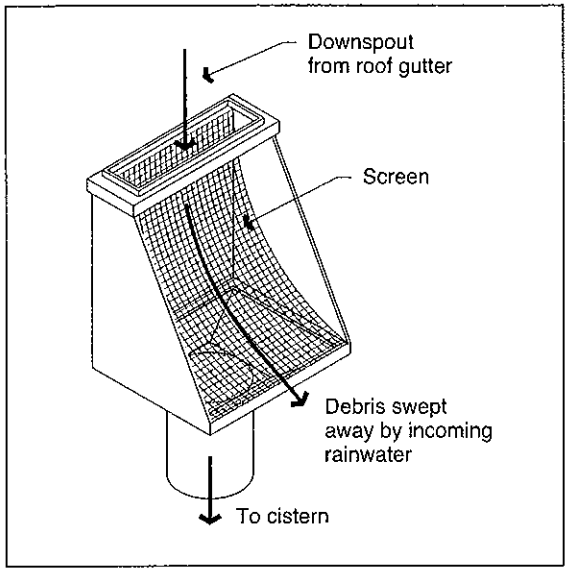
Perforated gutter protector with mesh screen



Louvered gutter protector



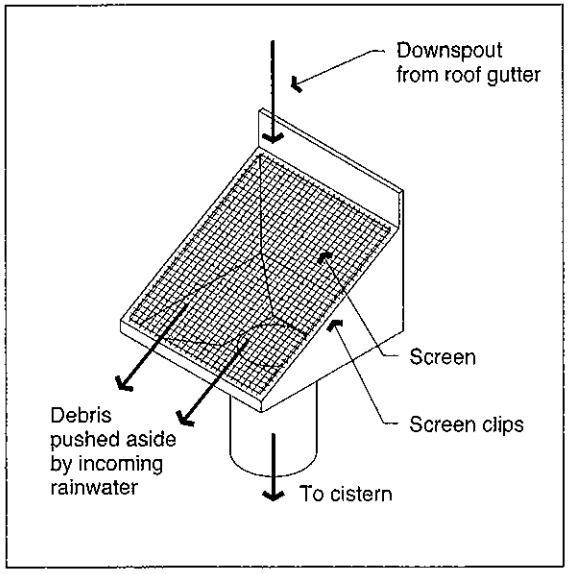
Helmet-like gutter protector



Australian Leaf Beater Rain Head

A high-performance rain head with adjustable elliptical primary screen. Contains interior stainless steel low-flow-rate secondary screen for use when connected to an under-eaves tank.

Source: Adapted from Environmental Conservation Planning and Consultancy Pty. Ltd. 1999



Australian Leaf Eater Rain Head

A high performance rain head for heavy rainfall areas—also used as a debris-removing device in urban areas. Contains primary and secondary screens.

Source: Adapted from Environmental Conservation Planning and Consultancy Pty. Ltd. 1999

Downspout Filters

Downspout filters such as the Leaf Beater and the Leaf Eater provide a second chance to capture and remove debris that might enter a rainwater storage system. They can be used inline prior to a roof washer or first-flush diverter. First-flush devices isolate the first runoff from a catchment surface while allowing the additional runoff to pass by. They can use floating balls, sinking balls, flaps, or can be based on the capacity of a vessel.

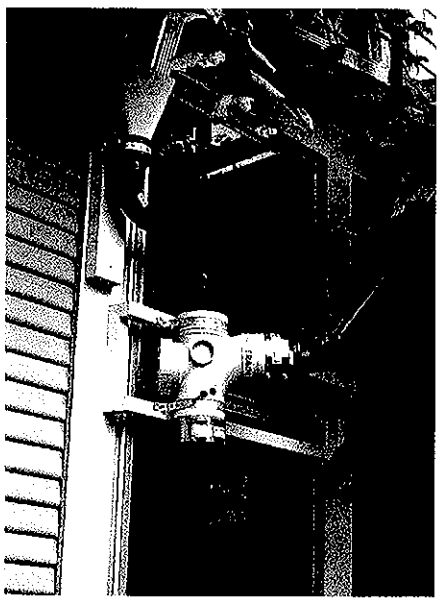
Maintenance of Downspout Filters

1. Clean filter with warm soapy water or rinse well every three to six months.
2. Check that the drop from gutter remains vertical. Check to ensure bulk of water is landing centrally and towards the back of the leaf and debris filter screen.
3. Check for any obstructions and signs of damage to the leaf and debris filter.

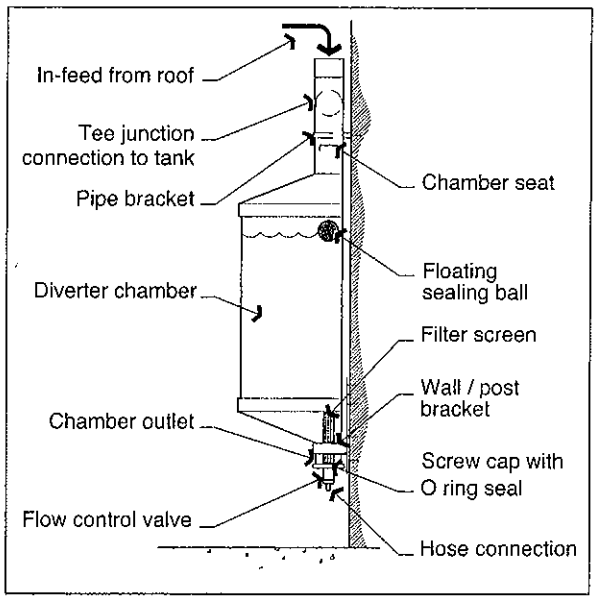
Typical stand-pipe first-flush
Source: Adapted from Environmental Conservation Planning and Consultancy Pty. Ltd. 1999

First-flush Devices and Roof Washers

First-flush devices range in size to meet the demand of the rainwater catchment system. These diversion devices can be part of the downspout, be separate from a tank or cistern, or be attached to a tank or cistern. They can be below grade for large stormwater collection systems where the harvested water is used for nonpotable systems such as landscape irrigation, carwash supply, or toilet flushing. The size and volume depend on the amount of water being diverted to a storage system and the ultimate use of the harvested water. For any first-flush diversion device to work efficiently—especially for potable systems—the contaminated water must be sealed off so the rainwater flowing on to the storage cistern(s) does not siphon off the contaminated water from the first-flush device chamber.



SafeRain© Vertical Diversion Valve
Source: SafeRain 2003



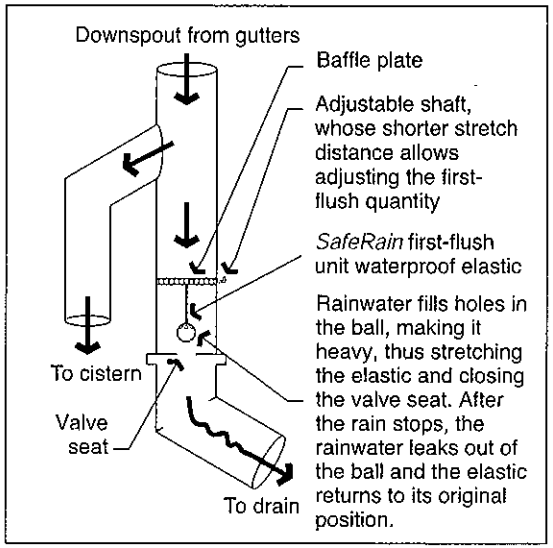
Australian first-flush
Source: Adapted from Environmental Conservation Planning and Consultancy Pty. Ltd. 1999

Guidelines for residential first-flush quantities

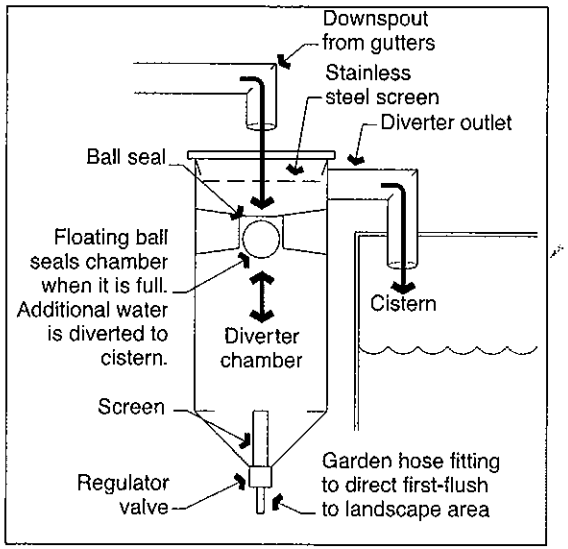
Rooftops of 1,000 square feet or smaller ..... 5–10 gallons
Rooftops of 1,000 square feet or larger ..... 10 gallons/1,000 square feet

Guidelines for surface catchment or for very large rooftops

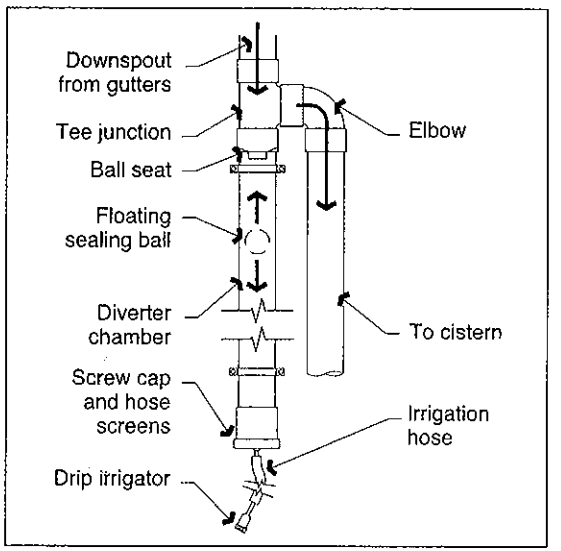
Rooftop or surface catchment of 43,560 square feet or larger ..... 500 gallons (1,000 gallons if surface contains excessive soil, dust, or debris). Multiple first-flush devices instead of a larger first-flush may be required depending on slope of the catchment surface and time required for rainwater to reach the first-flush device.



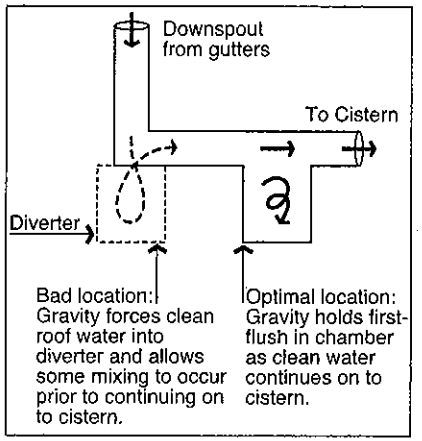
Baffle first-flush
Source: Adapted from SafeRain ©2003



Floating ball first-flush
Source: Adapted from Environmental Conservation Planning and Consultancy Pty. Ltd. 1999

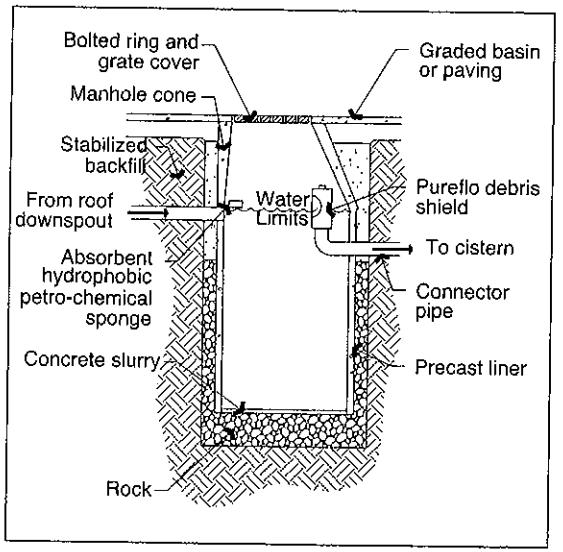


Typical stand-pipe first-flush
Source: Adapted from Environmental Conservation Planning and Consultancy Pty. Ltd. 1999

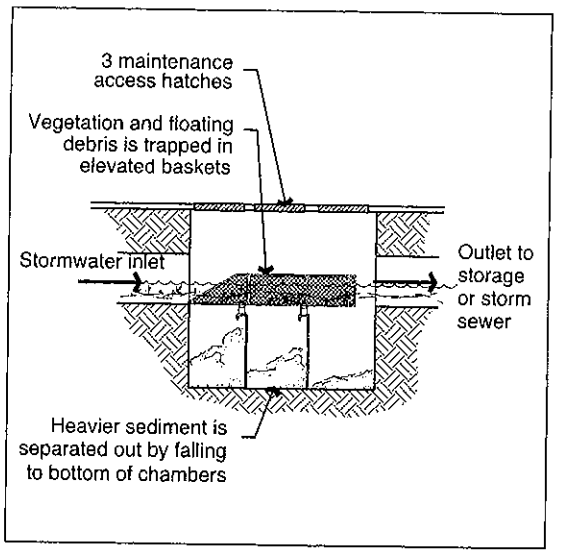


First-flush location without a self-sealing device

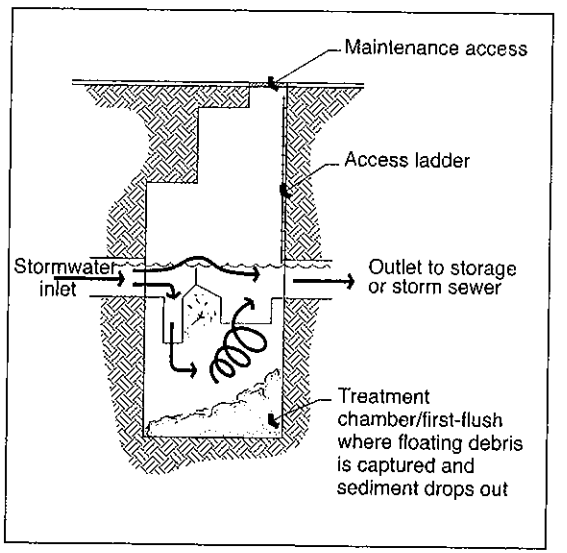
First-flush diverters should operate on a predetermined and set volume and the contaminated water should be sealed off from the flow of clean water. First-flush diverters that operate on an estimated open flow rate are typically accurate enough to guarantee that most bacteria have been flushed from the roof prior to closure. Since the goal is to not waste valuable clean water, the most efficient and safest way to ensure that the appropriate amount of water is diverted is to assess the contamination on the roof and calculate a diversion amount based on that assessment. A set pre-sized diverter chamber with a free-floating ball and seat incorporating a flow control release valve is the optimum diversion unit. If the water diverter does not have a self-sealing device, it is best to have it drop off a horizontal length of pipe away from the downspout so that the roof water does not drop directly into the water diverter and pick up contaminants as it travels to the cistern.



Below-grade drywell first-flush conversion (for nonpotable use)



Below-grade stormwater first-flush (for nonpotable use)
Source: Adapted from Suntree Technologies 2003



Below-grade stormwater first-flush (for nonpotable use)
Source: Adapted from Stormceptor 2001

Maintenance of First-flush Devices and Roof Washers

1. Contaminated water in the first-flush device should be drained either manually or automatically after each rainfall event.
2. Check for clogs and working ability of roof washers prior to rainy season.
3. If device is not self-cleaning, check roof washers immediately after each rainfall event to empty any standing water.
4. Large below-grade systems should allow evaporation or infiltration of first-flush water.
5. If petroleum absorbant pillows are added to first-flush chamber they should be evaluated for saturation/absorption capacity every year to evaluate quantity of materials washed off the catchment surface to the first-flush device. Multiple petroleum pillows may be needed; follow manufacture's guidelines.
6. Large first-flush devices should be evaluated yearly for sediment and debris content and cleaned if needed.
7. Debris shields and vegetation traps should be evaluated to guarantee unrestricted flows prior to rainy seasons.

Downspout Diversion to a Rainbarrel or Rainchain

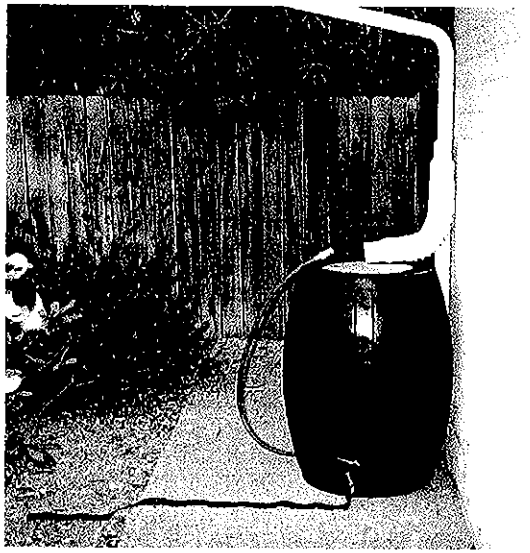
Rainbarrels collect rainwater for nonpotable uses. Even the lightest of rainfall can fill a rainbarrel. Rainbarrels should have a top mesh screen or a plastic lid to act as a barrier to mosquitos. Even with barriers, insect eggs may enter a barrel with rainwater that has been sitting on a catchment surface or in a gutter for a period of time. Mosquito dunks can be used in rainbarrels as well as in a cistern to kill mosquito larva. It is recommended that gutter guards or protectors and leaf screens be used prior to rainbarrel storage. Rainbarrels should be equipped with overflow outlets, hose connections, possible multiple barrel attachment devices, and a drain plug and should be placed on a stable foundation.

Rainchains should be securely attached to the gutter and, in potentially windy areas, attached to the ground.

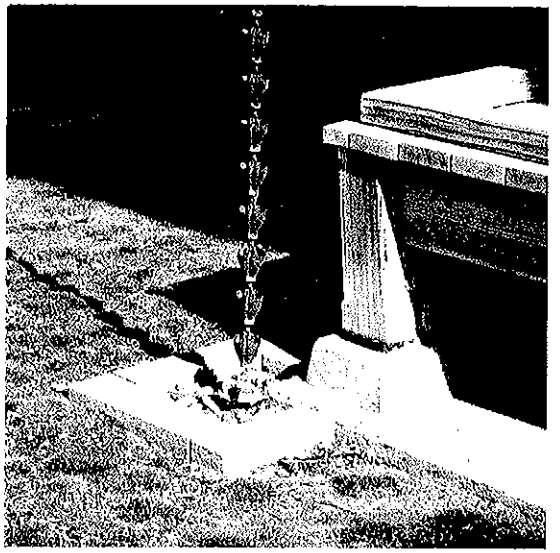
Maintenance of Rainbarrels and Rainchains

1. Check rainbarrel before rainy season to ensure overflow is clear and directed to the appropriate location.
2. Check rainbarrel before rainy season for leaks and cracks and check all connection hoses for wear.
3. Check rainbarrel top mesh for holes and debris accumulation. Remove all obstructions and replace torn screens.
4. Add mosquito dunk as listed by manufacturer for capacity of rainbarrel.
5. Regularly inspect rainchain connections at gutter and ground level for wear and tear and to guarantee positive drainage.
6. If rainchains are leading rainwater to a subsurface drain, inspect drain inlet for debris accumulation.
7. Inspect splash pad for proper placement and positive drainage away from adjacent buildings.

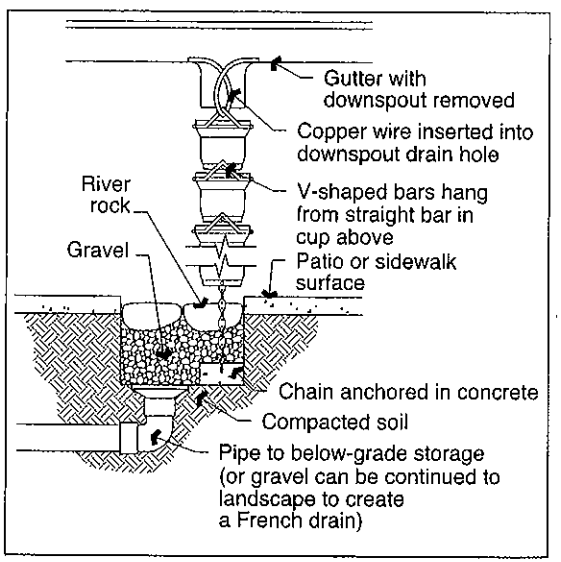
Rain cups



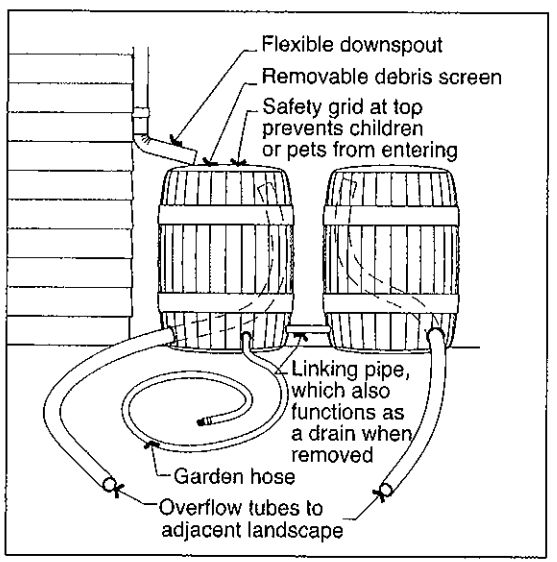
Rainbarrel



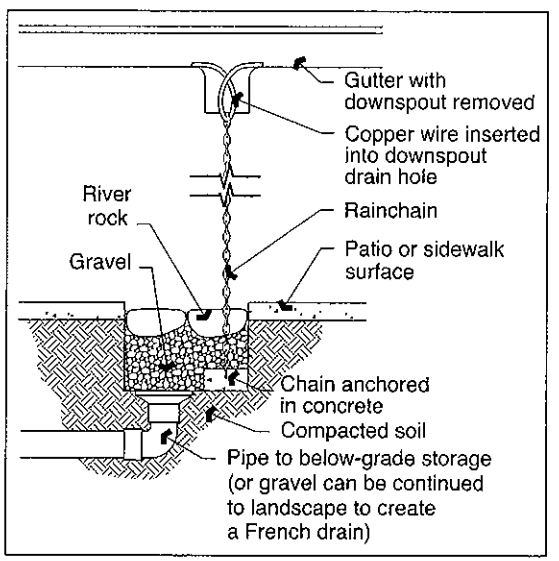
Rainchain/rain cup ground connection



Rain cups

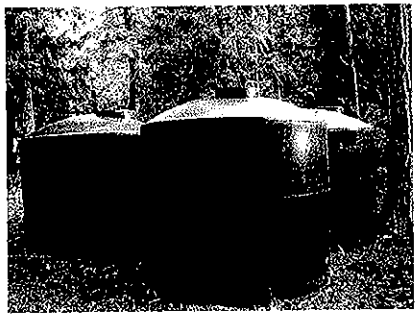


Linked rainbarrels



Rainchain ground connection

Storage Systems



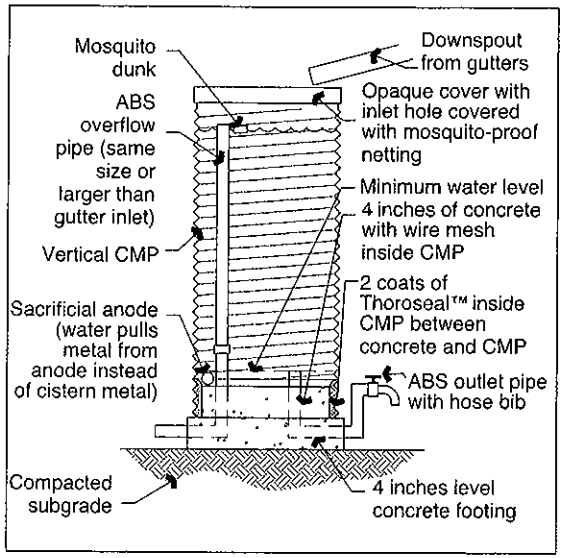
Three black poly water storage tanks, 2,340 gallons each

Cisterns and tanks on the market range widely in size and material. No matter what type of storage system is selected, the base or footing must be level and compacted. Steel tanks, which contain liners, typically require a concrete base. Concrete, fiberglass, or plastic tanks do not require a concrete base or a liner. Some sites will not accommodate large storage units below the elevation of the structure or surface receiving the rainwater and therefore require a smaller storage unit from which the initially harvested water can be pumped to the main units.

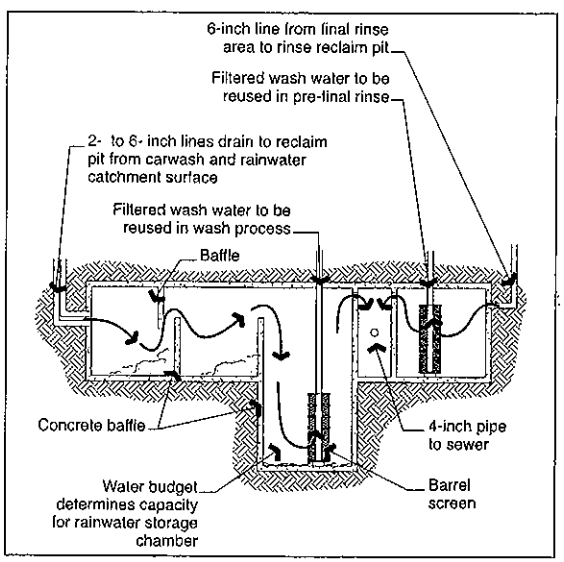
Tanks and cisterns are not meant to be airtight. Some venting is required to allow pressure adjustments in the storage system. Below-ground tanks and cisterns must be able to withstand surface loads. One-piece units should be tested for leakage prior to installation. Permanent-access ladders to above- or below-ground tanks and cisterns are optional.

Maintenance of Storage Systems

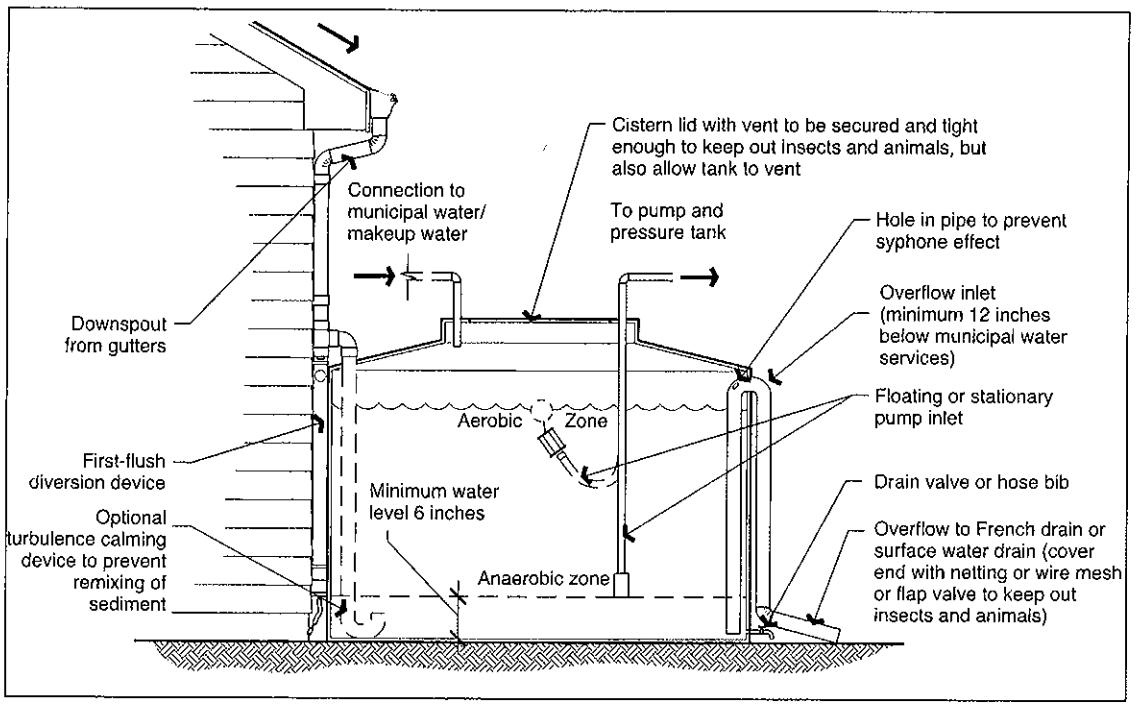
1. Inspect all inlets and outlets before and after each rain event to remove blockages or repair broken parts. Clean any and all screens.
2. Inspect all access lids to ensure seals are tight enough to deter insects and animals.
3. Inspect above-grade tank sides for damage and leaks. Repair any problem areas.
4. Check foundation/base for any settling or cracking, initially after each rain event, eventually on a yearly basis.
5. Check all seams for leaks.
6. For potable supplies, check water quality monthly.
7. Maintain mosquito control if mosquitoes are breeding.
8. Empty below-grade tanks periodically (every 3 to 5 years) to check for leaks, waterproofing damage, and any structural damage. Checking at the lowest storage point may also be efficient.
9. Check all pumps and other working equipment—such as alternative water supply on/off switch—every six months to guarantee working condition.
10. Maintain air gap if alternative water source is used to fill tanks or cisterns during dry periods.



Vertical corrugated metal pipe (CMP) cistern
Source: Adapted from detail by Cado Daily 2003



Carwash reclaim pit



Above-grade cistern

Potable Water Treatment Technologies

Ultraviolet light filter

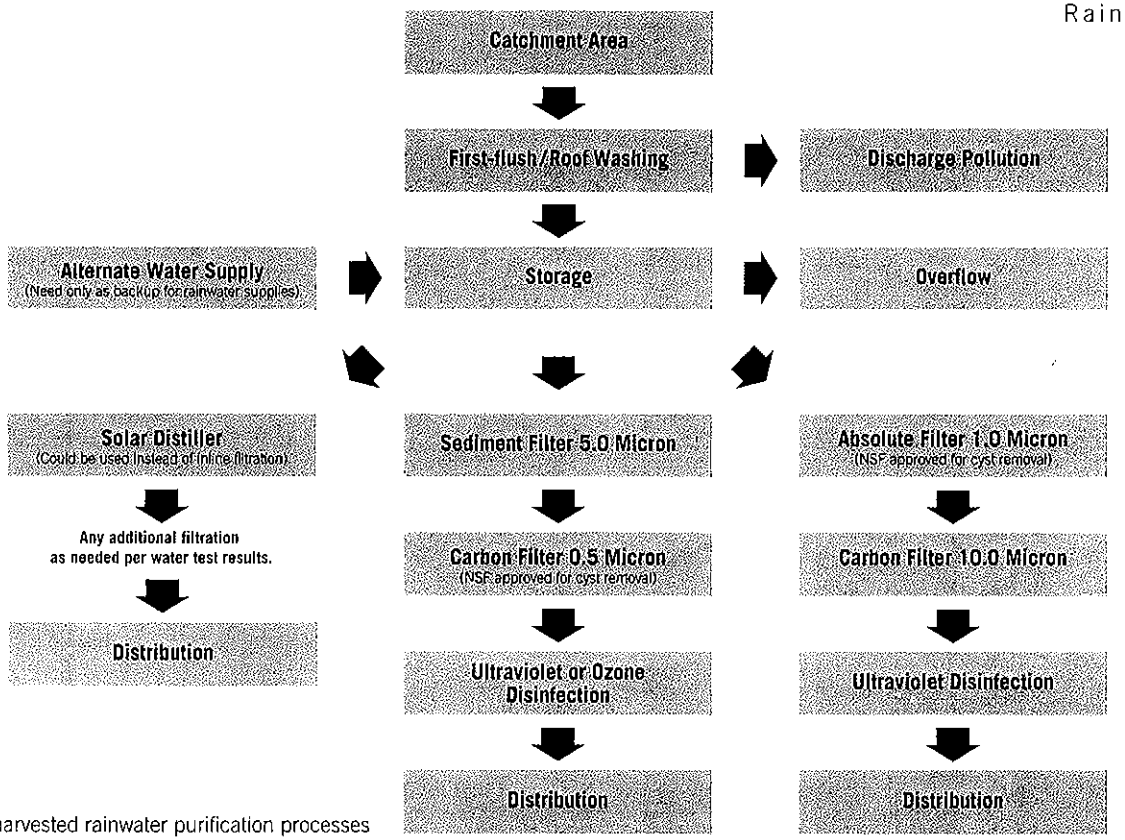
Harvested rainwater can be purified for drinking water supplies. An initial water test must be conducted to evaluate harvested water content. As mentioned earlier, the rainwater content will be dependent on the catchment surface, gutter, and downspout materials. Below are typical water treatment technologies; additional steps and filters may be required for various systems.

Absorption:	Carbon filters provide absorption.
Ultraviolet light:	Ultraviolet light disinfects water by reducing the amount of heterotrophic bacteria present in the water.
Reverse osmosis:	Water passes from a more concentrated solution to a more dilute solution through a semipermeable membrane. Most systems should incorporate a cyst and particulate pre- and post-filter in addition to the membrane.
Distiller:	Water is heated to the boiling point and the water vapor is collected as it condenses, leaving many of the contaminants behind, particularly the heavy metals.
Ozone:	Naturally occurring allotrope of oxygen has the highest oxidation potential of all available oxidants. Inorganic and organic materials can be oxidized by ozone more rapidly and at lower residual concentrations than by other chemical means. Ozone is typically aspirated via high efficiency injectors while the cistern water is circulated through a side stream contacting system or through a bottom of cistern diffusion grid.

There are two styles of water treatment:

Point-of-entry system	Water is treated prior to entering the building.
Point-of-use system	Water is treated for single use, such as kitchen or bathroom, and can include the following systems:

Bottled water	Pour-through products or gravity drip
Faucet mounted	Counter-top manual fill
Countertop connected to sink faucet	Plumbed to separate tap



Various harvested rainwater purification processes

Maintenance of Drinking Water Filtration Devices

1. Test water quality frequently, every six months minimum.
2. Change filters more often than suggested in manufacturers' guidelines.
3. Check for leaks daily, or weekly at a minimum.
4. Ozone treatment of water stored in cisterns is an option for maintaining water quality.
5. All disinfection should occur after filters and prior to distribution, as filters can become infected.

Following is a sample potable water budget worksheet.

Note: The example shown here would require several catchment areas such as a house, patio, any sheds, and possibly any paved drives. It may not be possible to assemble an 11,720 sq. ft. catchment area, which means an alternate water source would be required for a potable system.

Source: Pope, Tim (Northwest Water Source) 2002

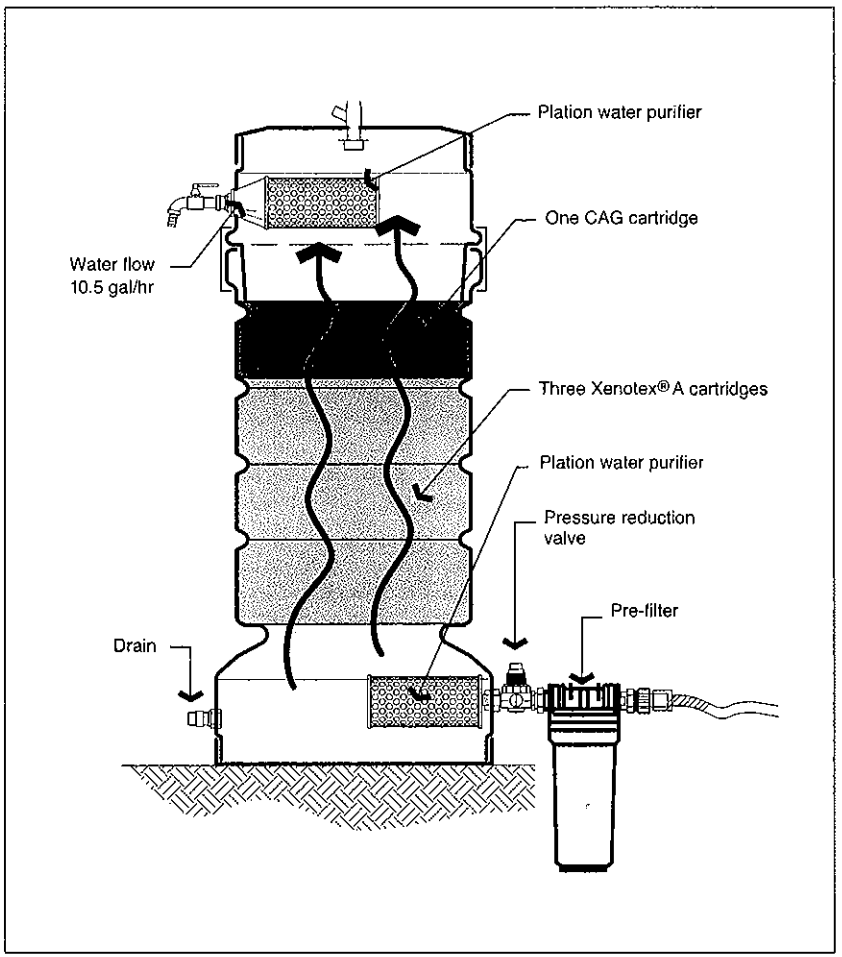
POTABLE WATER BUDGET WORKSHEET

Step 1	Number of Users	2	
	Gallons per day/person	70	
	Gallons required per day	140	*(users x gpd/p =)*
Step 2	Days in residence/year	365	
	Total water use per year	51,100	*(gpd x days =)*
Step 3	Rainfall (inches)	7	
	Water per sq.ft./inch of rain	0.623	
	Gallons water/sq. ft./year	4.36	*(rainfall x 0.623 =)*
Step 4	Total water needed per year	51,100	
	Gallons water/sq. ft./year	4.36	
	sq.ft. collection area needed	11,720	*(water needed/g sq.ft./year =)*
Step 5	Days storage required (varies)	90	
	Gallons required per day	140	
	Gallons of storage required	12,600	*(days stg x gpd =)*

System requirements for the above budget are as follows:

Rooftop catchment collection area required for this design based on rainfall in the surrounding area: 11,720 sq.ft.

Storage capacity required to supply system for periods without rain (summer): 12,600 gallons



RainPC features
Source: AquaEst International. 2004.

The RainPC, made in the Netherlands, is a miniature water treatment plant that can provide household water security. Impurities and contaminants are removed from the stored rainwater as it passes upward through the RainPC's five-stage purification process. The rainwater first flows through a pre-filter that takes out all particles larger than 5 microns. It then passes through a drum-cage containing ceramic spheres with silver colloids and then through three activated natural mineral composite Xenotex-A cartridges, an activated carbon filter with silver particles, and finally a specially developed low-pressure MF membrane filter. After passing through this compact unit, which requires only low gravity pressure to function, the water is ready to drink. A RainPC should be placed at an elevation lower than the cistern or the cistern water could be pumped to an elevation higher than the RainPC to allow gravity to push the rainwater through the unit.

RainPC Technical Data

Dimensions
Height: 32 inches
Diameter body: 12.4 inches
Diameter assembled: maximum 18.8 inches

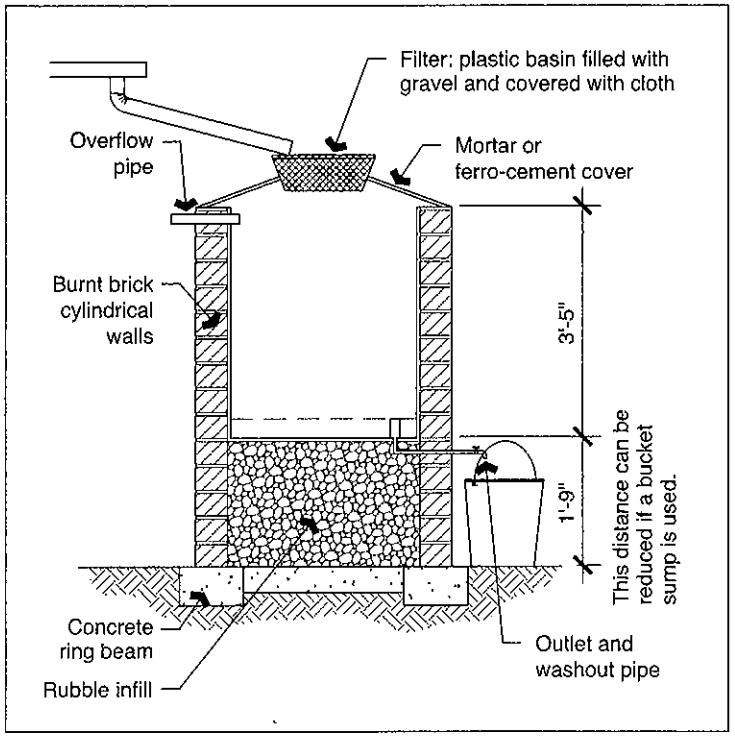
Weight
Unit assembled, including cartridges: 55 lbs
Xenotex-A cartridge: 6.6 lbs
CAG cartridge: 4.4 lbs

Materials
uPVC house bottom, body and top
Steel clamping ring
Nickelbrass faucet
Brass water meter

Pressure Reduction Valve
For maximum 6 bar to 0.2 bar

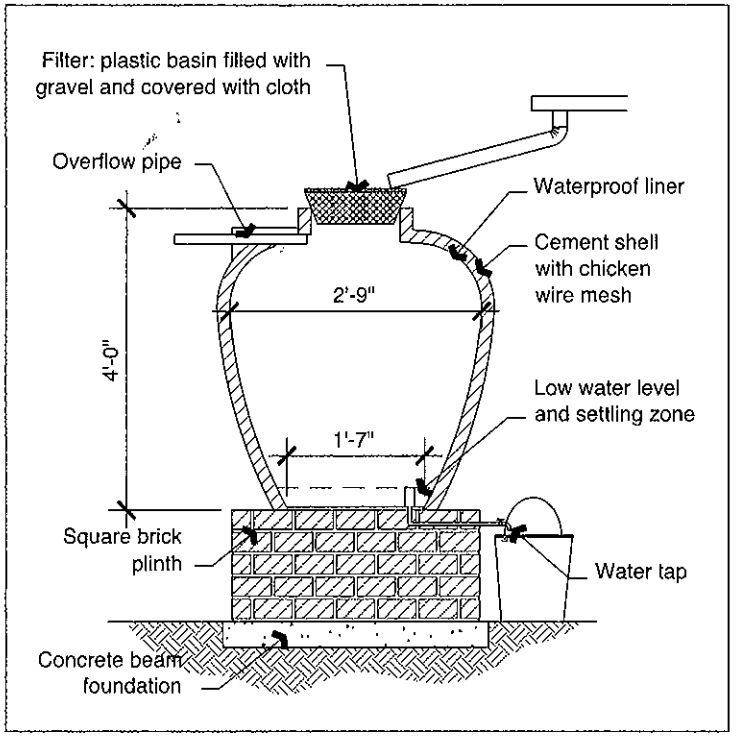
Connections
Drinking water outlet valve, diameter 1/2 inch
Rainwater inlet, diameter 1/2 inch
Drain outlet, diameter 1/2 inch
Water meter outlet, diameter 3/4 inch

Handmade Tanks



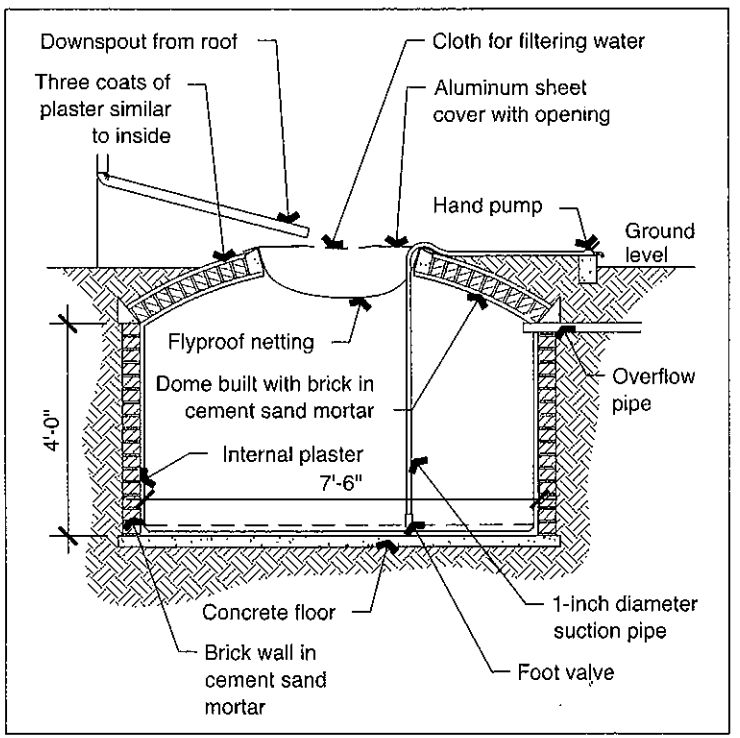
Brick jar from Uganda

Source: Adapted from School of Engineering, University of Warwick, January 2001

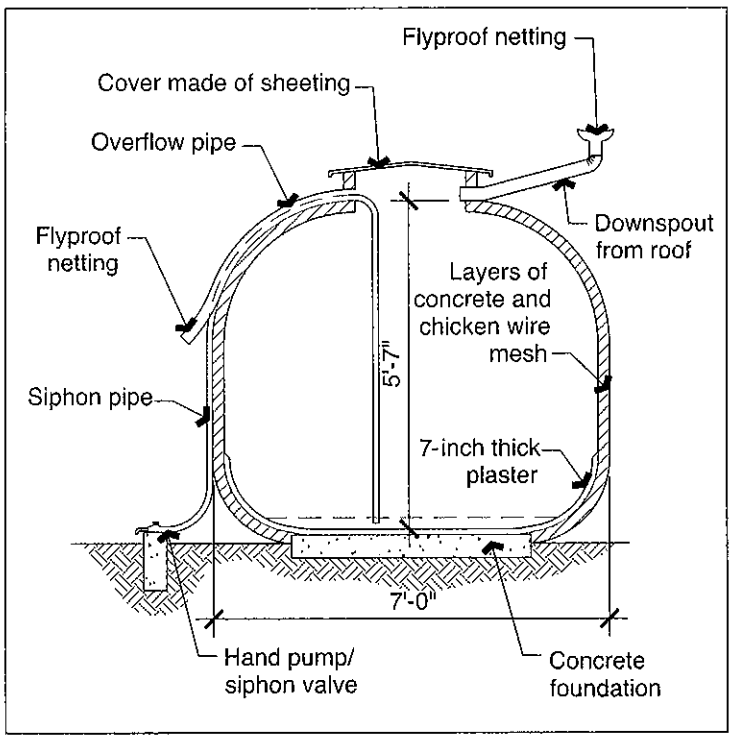


Ferro-cement jar from Uganda

Source: Adapted from School of Engineering, University of Warwick, January 2001



Underground brick dome tank from Sri Lanka
Source: Adapted from School of Engineering, University of Warwick, January 2001



Pumpkin tank from Sri Lanka
Source: Adapted from School of Engineering, University of Warwick, January 2001