REPORT OF THE
DEPARTMENT OF ENVIRONMENTAL QUALITY
AND THE DEPARTMENT OF HEALTH

GRAY WATER USE AND RAINWATER CAPTURE

TO THE GOVERNOR AND
THE GENERAL ASSEMBLY OF VIRGINIA

HOUSE DOCUMENT NO. 93

COMMONWEALTH OF VIRGINIA
RICHMOND
1998

COMMONWEALTH *of* VIRGINIA

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MEMORANDUM

To: Members of the General Assembly

From: Dennis H. Treacy, Acting Director of the Department of Environmental Quality

Dr. Randolph L. Gordon, Commissioner of the Department of Health

Subject: House Joint Resolution 587, Gray Water reuse and Rainwater Capture

Date: 5/29/98

In response to water conservation concerns, the 1997 General Assembly passed House Joint Resolution (HJR) 587, requesting the Department of Environmental Quality and the Department of Health to develop a report examining the potential reuse of gray water and use of rainwater by Virginia households. The study was to include examples of water reuse and conservation programs in the United States and an examination of any documented adverse impacts of such programs, in order to determine if similar programs could be implemented in Virginia. The Department of Environmental Quality prepared the following document in response to HJR 587. The Department of Health assisted the Department of Environmental Quality by providing literature references, expert contacts, reviews and comments on the draft report.

During the 1998 session of the General Assembly, House Bill (HB) 912 was introduced and passed. This bill amended the *Code of Virginia (Code)* Article 10, chapter 6 of Title 32.1 to add Section 32.1-248.2. This section of the *Code* requires the Department of Health to develop guidelines by January 1999, regarding the use of gray and rain water, that describe the conditions under which gray and rain water may be appropriately used and for what purposes. The guidelines are to include categories of used water and are to include a definition of gray water that does not include used toilet water. In addition, the Department of Health and the Department of Environmental quality are to promote the use of gray and rain water, as a means to: (1) reduce fresh water consumption, (2) promote conservation and (3) ease demands on water and wastewater treatment works.

The following document has been prepared in accordance with HJR 587 regarding gray water and rainwater as a means of alleviating water problems in Virginia. We hope that the following is useful in your deliberations concerning the role of gray water reuse and rainwater use in Virginia.

INTRODUCTION

In 1997 the General Assembly of Virginia adopted House Joint Resolution 587 requesting the Department of Environmental Quality and the Department of Health to study examples of water reuse and conservation programs in the United States to determine if similar programs could be implemented in Virginia. This report is provided in accordance with House Joint Resolution 587.

I. NEEDS FOR WATER CONSERVATION MEASURES IN VIRGINIA

Water use in Virginia averaged about 7,900 million gallons per day (MGD) over the past 5 years. This figure includes all withdrawals, except hydropower. It is estimated that there is an additional withdrawal of approximately 10% more, mainly by self-supplied rural areas and irrigators who are not required to report withdrawals. Virginia's water is collected from streams and rivers (60%), reservoirs (26%), wells (11%) and springs (3%). (Source 1) The 6.5 million citizens of Virginia consume approximately 650 million gallons of potable water a day in their households. (Sources 2,3,4)

Although not a water poor state, Virginia still suffers from overburdened treatment facilities, strained septic tank systems and areas where weather conditions make seasonal water restrictions a necessity. Furthermore, population growth and economic development have put increasing demands on water supply and treatment capacities.

In 1980 Virginia's population was approximately 5.35 million and by 1985 it had increased by about 350,000. More than 70% of the State's population growth during this period occurred in Northern Virginia, Central Virginia and Hampton Roads' urban areas. The State's population is projected to increase to about 8 million in 2030. The concentration of recent population growth in currently urbanized areas puts additional demands on these area's local central water supply systems. Some of these areas have a very limited capacity to handle added demands. The percentage of the population served by central systems (greater than 10,000 Gallons per day capacity) is projected to increase from 71.5% in 1980 to 78.5% in the year 2030. (Source 1) Water demand for domestic/commercial/institutional uses is projected to increase 51% by 2030. Water that is supplied by central systems is estimated to increase 64%.

Of the 542 community water supply systems evaluated in the State Water Control Board's most recent summary from 1988, 134 systems (25%) are expected to experience problems between now and 2030. A single community system may experience more than one problem. Source problems predominate, affecting 94 waterworks. There are 21 community water supply systems which are projected to experience treatment capacity deficits. System problems will affect 57 community systems. Another 33 systems are expected to have other problems, the most prevalent being source quality problems. (Source 1)

Solving these problems could involve one or more of the following strategies:

- Development of an alternative source, such as a new intake point, additional wells, reservoir construction, or importing from another system or jurisdiction.

- Expansion of the treatment capacity.
- Increased pumping capacity.
- Increased finished water storage capacity.
- Development of a regional system.
- Implementation of water conservation measures.

This report indicated that there is not a sufficient amount of local fresh water to meet projected future demand within James City County, York County, and the cities of Williamsburg, Newport News, Hampton and Poquoson, on the north side of Hampton Roads; or within Norfolk, Portsmouth, Virginia Beach, Chesapeake, and Suffolk on the south side. The major local alternatives available in these areas involve desalinization of either ocean, bay or estuarine waters, or brackish ground water, or the transfer of fresh water from a system, jurisdiction or basin that is located outside the locality or service area. (Source 1)

II. WATER CONSERVATION OPTIONS

While there are several water conservation options that could be implemented by individuals, developers or businesses, two which have received very little attention to date in Virginia are gray water reuse and rainwater capture.

A. GRAY WATER REUSE

Gray water is untreated water from bathtubs, showers, bathroom wash basins, washing machines and laundry tubs. Gray water does not include wastewater generated from toilets, kitchen sinks, dishwashers, and laundry water from soiled diapers, which is classified as blackwater. Almost half of indoor water can be reused as gray water to irrigate and fertilize gardens and provide water for toilet flushing. The use of gray water conserves water, drought- proofs the landscape, offers more freedom of water usage during droughts and reduces demands upon water supply and wastewater treatment plants. Gray water use also offers potential financial advantages to regional treatment faculties because their capital and operational expenses may decrease because gray water use diminishes sewer flows, thereby lessening the need to expand such facilities.

B. RAINWATER CAPTURE

Rainwater harvesting provides a source of soft, high quality water that can augment domestic water resources and reduce reliance on wells. A rainwater harvesting system concentrates and collects rain falling on a house, from catchments such as gutters, and stores it in a tank for later use. Collected and stored rainwater can be used in evaporative coolers, toilet flushing and surface irrigation, especially in food gardens. Rainwater collection in urban and suburban areas could intercept storm water before it reaches pavement, reducing potential for toxics in storm water and could reduce the volume of storm water directed to combined sewer operations. A number of Virginia's district health department managers have indicated that cisterns are used commonly in their districts.

Virginia Polytechnic Institute and State University conducted a pilot study of rainwater use in Dickenson County, Virginia where a large number of cisterns are used. Many communities in the southwest Virginia coalfields lack safe and adequate drinking water supplies. Extending public water lines to these communities is generally cost-prohibitive because of the rough and elevated terrain and the low number of households in each community. To meet domestic water needs, alternate water sources such as roof top collection of rainfall and cistern storage, and water hauling have been used for many years.

The pilot study conducted in Dickenson County by Virginia Polytechnic and State University indicates that rainfall harvesting is a viable option to help alleviate water problems in southwest Virginia, however proper maintenance is essential. The survey indicated that more than 30 % of the households in the surveyed areas depend on cisterns for their drinking water needs, and that 20% of the cisterns run dry at least once a month. Cistern waters, in general, are of good quality. However, because of poor maintenance, more than 65% of the cisterns tested for coliform bacteria failed to meet the federal drinking water standards established by the U.S. EPA for public water systems. This was the only water quality parameter tested and found to indicate a potential health threat to cistern water users in the study.

C. COMPARISONS

Gray water is a fairly predictable and dependable water source. Household water use occurs consistently, producing various, but regular amounts of gray water. Rainwater harvesting lacks this dependability, relying instead on the variability and vicissitudes of the climate for its water source.

A gray water storage system does not have to be very large because it is a dependable source and, therefore, is more readily stored than rain water with less cost. Because rainfall fluctuates and may be infrequent at times, it requires a larger storage capacity so supplies can carry over between rainfall events. Nevertheless, Virginia has a relatively regular rainfall, which makes it possible to have a smaller storage system.

On average, a Virginia household (3 persons) used 300 gallons a day in 1996. (Sources 2,3,4) An estimated 30-40% of water from sinks, showers, tubs, and laundry is of a high enough quality that it may be reused. These applications can be accommodated with appropriate plumbing and storage systems. A rain water collection system on a 1500 square foot household, with the average annual rainfall of Virginia (42 inches a year), could collect 35,393 gallons a year, providing a household with about 100 gallons of rainwater a day.

D. GRAY WATER REUSE AND RAINWATER CAPTURE INITIATIVES IN OTHER STATES

Guidelines adopted by other states regarding the use of gray water and rainwater use can be found in Attachments 1-5 which contain information from these states, including a description of the conditions under which gray and rain water may be appropriately used and for what purposes, and categories of used water which are appropriate for reuse.

III. PROTECTION OF HUMAN HEALTH

A common concern regarding gray water reuse are the potential health risks it poses. However, studies and pilot programs indicate that capturing gray water for use in landscape irrigation or for flushing toilets can be done safely if certain precautions are taken. It is imperative that the public is educated on the principles, guidelines, and initiatives of owning a gray water system to insure that health hazards do not occur.

The Virginia Department of Human Health regulates the management and transfer of sewage to ensure protection of Virginia's citizens. These regulations are designed to minimize the health risks posed by bacterial regrowth, bacterial toxins, and other issues that sewage management poses. Any initiatives to promote gray water reuse and rainwater collection will have to meet the requirements of the Department of Health. One reason that the gray water and rainwater options have received little attention is the existing regulations. Current regulatory definitions of sewage include gray water and under current regulations, re-use is only for closed system toilet flushing (e.g., as in the Cycle-Let system). In addition, these guidelines would need to consider variables such as the type and permeability of soils, topography, potential for soil build-up, applicable laundry detergents, maintenance and personal responsibility, differences between gray water and black water (homes with babies or ill individuals can generate wastewater that is classifiable as blackwater out of clothes washers) types of systems, and system capacity. Guidance for the proper reuse of gray water will need to address the possibility for ground and surface water contamination, public exposure, and animal exposure which might result from improper disposal.

IV. CONCLUSIONS

The success of any water conservation initiative will depend upon efforts to educate the public on the environmental advantages and cost effectiveness of water conservation. The development of proper safeguards to ensure that efforts such as gray water use are done safely is essential. To that end, the 1998 General Assembly enacted House Bill 912 which directs the Virginia Department of Health to develop guidelines for the reuse of gray water by January 1999 and directs the Virginia Department of Health and the Department of Environmental Quality to promote these activities.

REFERENCES

Literature

Source 1: Virginia's Water Supply Statewide Summary and Technical Data. Richmond, Virginia, March 1988, State Water Control Board

Interview

Source 2: Brady, P., Department of Public Utilities. Henrico County. June 1997

Source 3: Gregory, R., Patron, E., Martin, C. DEQ May 1997

Source 4: Harksen, F., Department of Public Utilities. City of Richmond. June 1997

Attachments

Attachment 1 Texas Guide To Rainwater Harvesting. Second Edition, Austin, Texas, 1997

Attachment 2 City of Austin, Sustainable Building Sourcebook, City of Austin Environmental and Conservation Services Department, Austin Texas 1998; Section 6, Harvested Rainwater

Attachment 3 City of Austin, Sustainable Building Sourcebook, City of Austin Environmental and Conservation Services Department, Austin Texas 1998; Section 5, Greywater Irrigation

Attachment 4 Graywater Guide. California, December 1994

Attachment 5 Revised Graywater Standards., Appendix G Gray Water Systems, Title 24, Part 5, California Administrative Code., March 18, 1997

Attachment 6 General Assembly of Virginia., House Joint Resolution No. 587. February 19,1997

Attachment 7 General Assembly of Virginia., House Bill No. 912. January 26, 1998

Attachment 8 Evaluation of Rooftop Rainfall Collection-Cistern Storage Systems in Southwest Virginia. Virginia Polytechnic Institute and State University 1998, Virginia Water Resources Research Center

ATTACHMENT 1

Texas Guide to Rainwater Harvesting, Second Edition, Austin Texas, 1997

TEXAS GUIDE TO RAINWATER HARVESTING

Texas Water Development Board
in Cooperation with the
Center for Maximum Potential Building Systems

Second Edition

TEXAS GUIDE TO RAINWATER HARVESTING

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in Cooperation with the
Center for Maximum Potential Building Systems

Second Edition

1997
AUSTIN, TEXAS

SECOND EDITION ACKNOWLEDGMENTS

This is the second edition of this publication. In this edition, the staff of the Texas Water Development Board have added several significant new pieces of information and have modified others as more information becomes available in this rapidly changing field. This has resulted in a text which differs somewhat from the original text written by the Center for Maximum Potential Building Systems. As new information becomes available, the Board staff will make appropriate changes in future additions as time and funds permit. In addition to the recognition of contributors presented in the original acknowledgment below, the Texas Water Development Board staff would like to recognize Matthew Bachardy, Harley and Pam Rose, Peter Pfeiffer, Kate Houser, Duncan Echelson, Jeff Reich, and others who helped contribute to the second edition's technical content.

ORIGINAL ACKNOWLEDGMENTS

The *Texas Guide to Rainwater Harvesting* was developed by the Center for Maximum Potential Building Systems, Austin, Texas, under the direction of Gail Vittori, with funds provided by the Texas Water Development Board Contract #95-483-136. The *Guide* was researched and written by Wendy Price Todd, AIA and Gail Vittori, and edited by Bill Hoffman, P.E., Ken Heroy and Janie Hopkins. Graphic design and production was provided by Worldwise Design Creative Director Harrison Saunders. Spanish translation by Cristina Villarreal.

The Center for Maximum Potential Building Systems, established in 1975 and based in Austin, Texas, is a non-profit education, research, and demonstration organization dedicated to sustainable planning, design and development. For more information on the Center's activities, contact us at 8604 F.M. 969, Austin, TX 78724, 512-928-4786.

The authors would like to thank the following agencies and individuals for their valuable assistance: Laurence Doxsey, City of Austin Green Builder Program; Marcia Roberts, Lower Colorado River Authority; Mike McElveen; Mary Sanger, Texas Center for Policy Studies; Hugo Gardea, Texas Historical Commission; Ron Bearden and Wendi White, Texas Natural Resource Conservation Commission; Dennis J. Lye, U.S. Environmental Protection Agency; Yu-Si Fok, University of Hawaii; Phillip S. McClay, Water Filtration Company; Joe Henderson, Water Quality Association; the contractors listed in the Resource section; and the participants in the Case Studies.

CONTENTS

IS RAINWATER HARVESTING FOR YOU?

The *Texas Guide to Rainwater Harvesting* is a primer of the basic principles of captured rainfall, with an emphasis on residential and small-scale commercial applications. If you are considering rainwater harvesting as a partial or total source of your water supply for new construction or remodeling, this *Guide* and accompanying videotape provide the essential information to enable you to design a system that meets your needs.

Most Texans have not had to operate their own water system. Your utility has done that for you. If you plan to use a rainwater harvesting system for your source of drinking water and for other direct human purposes, you must be willing to make a commitment to its long term, proper operation and maintenance, or you could endanger your family's and friends' health. Your local health department and city building code officer should also be consulted concerning safe, sanitary operations and construction of these systems.

As you read this manual, seriously consider what you want your system to do and how you will provide back-up water if you are designing the system as a supplemental water source, or in the event of severe drought. The case studies, covering several dozen installations operating in Texas, provide an excellent snapshot of current systems.

What makes rainwater harvesting the preferred water source for some Texans today? While large, sophisticated systems are not cheap, some Texans have devised innovative approaches that are both effective and affordable. Rainwater catchment systems provide a source of soft, high quality water, reduce reliance on wells and other water sources, and, in many contexts, are cost-effective. Systems can range in size from a simple rain barrel to a contractor designed and built system costing thousands of dollars. However, rainwater harvesting systems are inherently simple in form, and can often be assembled with readily available materials by owner-builders with a basic understanding of plumbing and construction skills. If you plan to use the water for human consumption, it is wise to consult or employ experts. Texans with the time and the inclination to build their own system can save a significant portion of costs associated with labor. Regardless of whether you intend to hire a contractor or build a system yourself, we recommend that you read through the entire manual before starting a catchment system of your own.

INTRODUCTION

For centuries in Texas and throughout the world, people have relied on rainwater harvesting to supply water for household, landscape, livestock, and agricultural uses. Before large, centralized water supply systems were developed, rainwater was collected from a variety of surfaces—most commonly roofs—and stored on site in tanks known as cisterns. With the advent of large, reliable community treatment and distribution systems and more affordable well drilling equipment, rain harvesting systems have been all but forgotten, even though they offer a source of pure, soft, low sodium water. A renewed interest in this time-honored approach has emerged in Texas and elsewhere due to:

- the escalating environmental and economic costs of providing water by centralized water systems or by well drilling;
- health concerns regarding the source and treatment of polluted waters;
- a perception that there are cost efficiencies associated with reliance on rainwater.

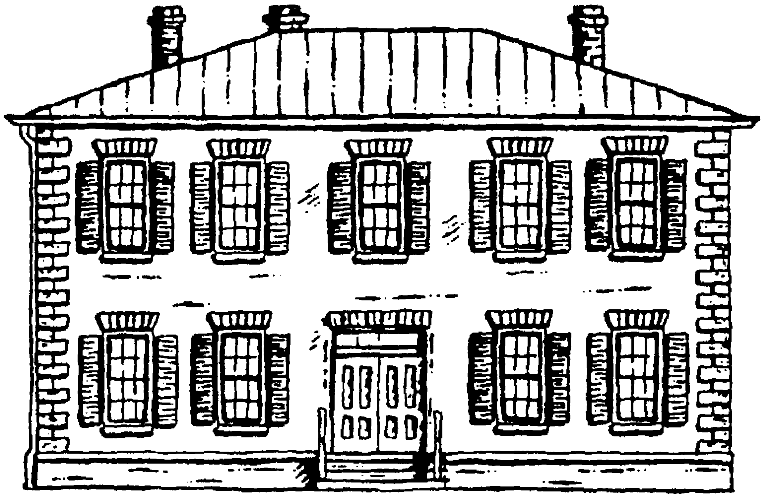
From rock cisterns to hollowed out tree trunks, historical precedents abound that trace people's reliance on rainwater collection. The Hueco Tanks in west Texas are natural rock basins that trapped rainwater for the native dwellers, from the archaic hunters to the Mescalero Apaches, and later became a stopping point for stagecoach travelers. In south Texas and the Rio Grande Valley, central plazas were often not only the place where the townspeople congregated for social affairs, but also were the collection surfaces for vast underground tanks that collected and stored water for use by adjacent shops and homes. Such notable historic structures as the Stillman House in Brownsville, the Fulton Mansion near Rockport, the Freeman Plantation near Palestine and the Carrington-Couvert House in Austin collected rain from their roofs, and then guttered and piped the water into an aboveground tank or cellar cistern. While many of these systems are no longer in use, they signify the importance that early Texas settlers placed on captured rainfall for sustenance.

Today, island states such as Hawaii and entire continents such as Australia promote rainwater harvesting as the principal means of supplying household water. In Bermuda, the U.S. Virgin Islands and other Caribbean islands where rainwater is the most viable water supply option, public buildings, private houses, and resorts collect and store rainwater. And in Hong Kong, skyscrapers collect and store rainwater to supply the buildings' water requirements.

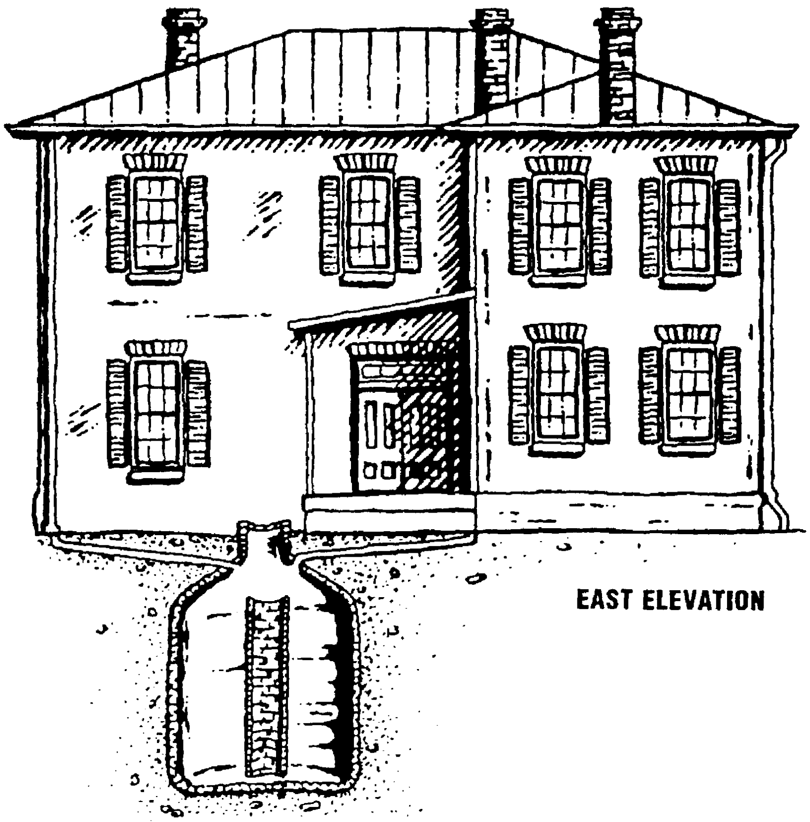
As with other natural systems, rainfall maintains its own cycles and patterns as evidenced by the severe droughts that devastated the Texas landscape in the 1950's, as well as the floods of 1981 and 1993 that ravaged east, south, and central Texas. These extremes underscore the importance of designing your rainwater catchment system with a thorough understanding of the basic principles and essential information contained in this Guide.

As you will see in the following pages, many Texans today are putting their dollars behind a life-long investment in a rainwater harvesting system over other options. A decision to reduce household water consumption to live within your means is a commitment that may not be for everyone, but it may be for you.

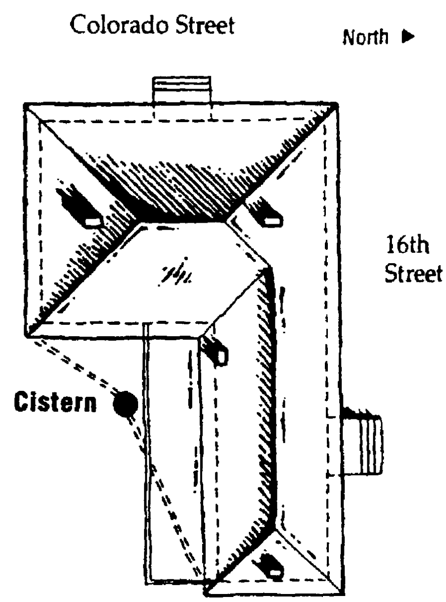
THE CARRINGTON-COUVERT HOUSE
(1857)
Colorado Street, Austin, Texas



WEST ELEVATION



EAST ELEVATION

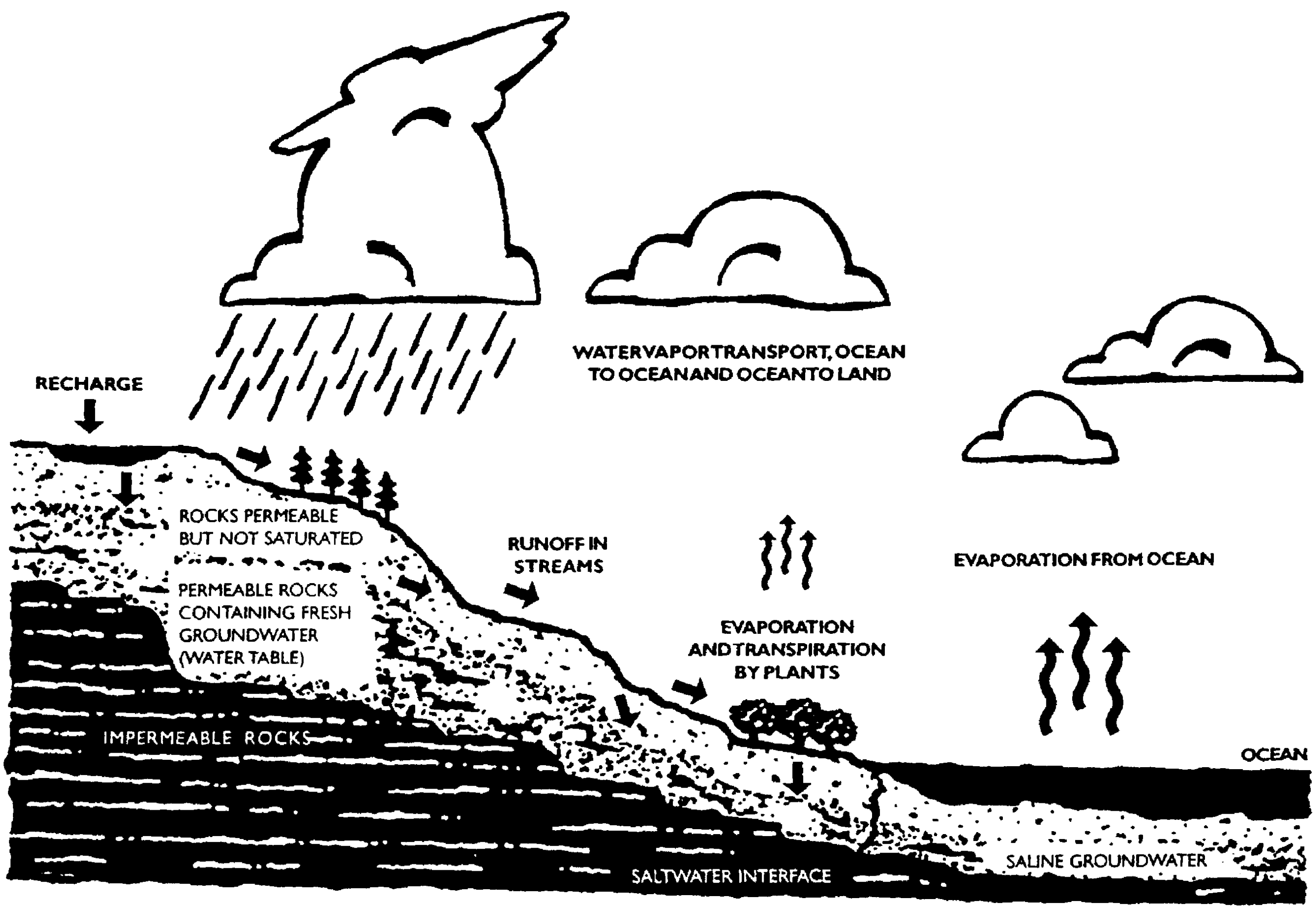


ROOF PLAN

I. THE WATER CYCLE

The never-ending exchange of water from the atmosphere to the oceans and back again is known as the hydrologic cycle. This cycle is the source of all forms of precipitation (hail, rain, sleet, and snow), and thus of all water. Precipitation stored in streams, lakes, and soil evaporates while water stored in plants transpires to form clouds which store the water in the atmosphere.

Currently, about 75% to 80% of conventional water supplies from lakes, rivers, and wells are developed and in use in Texas. Making the most efficient use of our State's limited and precious resources is essential. This includes using appliances and plumbing fixtures that conserve water, not wasting water, and taking advantage of alternative water sources such as greywater reuse and rainwater harvesting.



II. ADVANTAGES OF RAINWATER

For some Texans, rainwater's environmental advantages and purity over other water options make it their top choice, even with their knowledge that precipitation cycles can fluctuate from year to year.

ENVIRONMENTAL ADVANTAGES

Collecting the rain that falls on a building to be used nearby is a simple concept. Since the rain you harvest is independent of any centralized system, you are promoting self-sufficiency and helping to foster an appreciation for this essential and precious resource. Collecting rainwater is not only water conserving, it is also energy conserving since the energy input required to operate a centralized water system designed to treat and pump water over a vast service area is bypassed. Rainwater harvesting also lessens local erosion and flooding caused by runoff from impervious cover such as pavement and roofs, as some rain is instead captured and stored. Thus, stormwater run-off, the normal consequence of rainfall which picks up contaminants and degrades our waterways, becomes captured rainfall which can then fulfill a number of productive uses. Policymakers may wish to reconsider present assumptions regarding impervious cover and consequent run-off management strategies when rainwater harvesting systems are installed.

QUALITATIVE ADVANTAGES

A compelling advantage of rainwater over other water sources is that it is one of the purest sources of water available. Indeed, the quality of rainwater is an overriding incentive for people to choose rainwater as their primary water source, or for specific uses such as watering houseplants and gardens. Rainwater quality almost always exceeds that of ground or surface waters: it does not come into contact with soil and rocks where it dissolves salts and minerals, and it is not subject to many of the pollutants that often are discharged into surface waters such as rivers, and which can contaminate groundwater. However, rainwater quality can be influenced by where it falls, since localized industrial emissions affect its purity.. Thus, rainwater falling in non-industrialized areas can be superior to that in cities dominated by heavy industry, or in agricultural regions where crop dusting is prevalent.

Rainwater is soft and can significantly reduce the quantity of detergents and soaps needed for cleaning, as compared to typical municipal tap water. Additionally, soap scum and hardness deposits disappear, and the need for a water softener, often an expensive requirement for well water systems, is eliminated. Water heaters and pipes will be free of deposits caused by hard water and should last longer. Rainwater's purity also makes it an attractive water source for certain industries for which pure water is a requirement. Thus, industries such as computer microchip manufacturing and photographic processing may also wish to examine this source of water.

III. WATER QUALITY CONSIDERATIONS

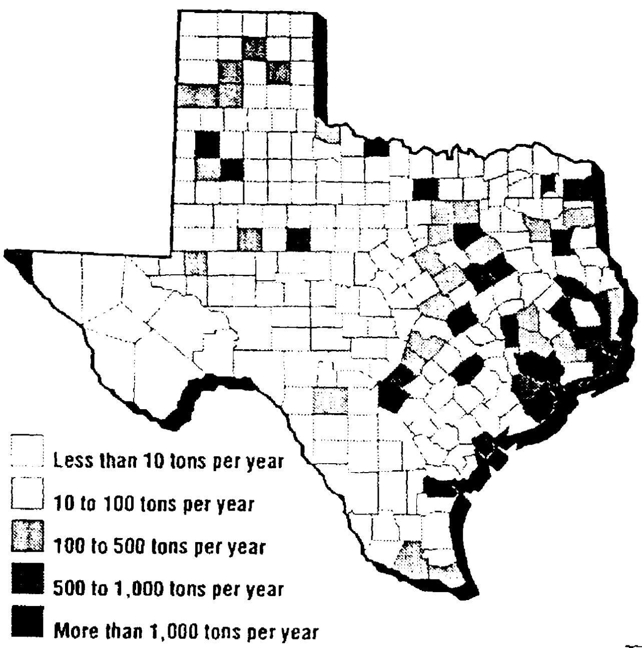
People who relied on rainwater systems 30 to 40 years ago may well recall contamination as a serious concern. Because the construction methods and materials used to build many of the rural cisterns were not in compliance with today's standards, and because of inadequate treatment procedures, illnesses associated with drinking unhealthful water were not uncommon. However, rainwater can provide clean, safe, and reliable water so long as the collection systems are properly built and maintained, and the water is treated appropriately for intended uses.

PRIMARY WATER QUALITY CRITERIA – HEALTH CONCERNS

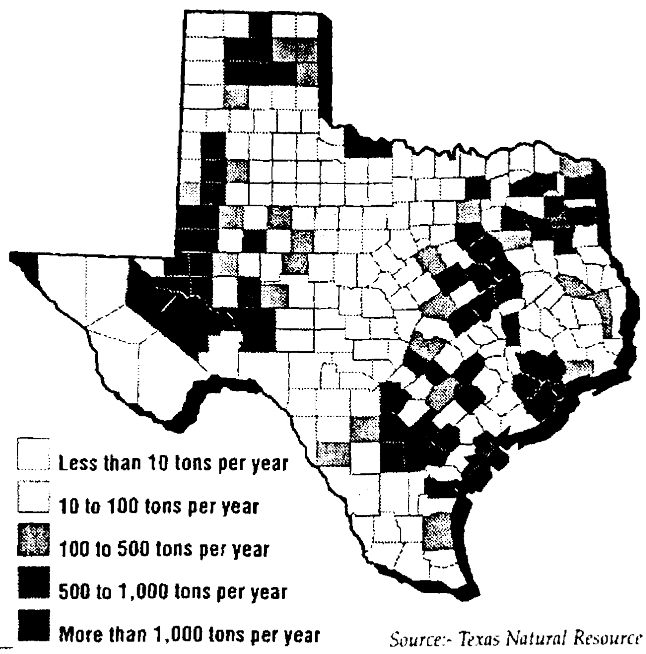
Once rain comes in contact with a roof or collection surface, it can wash many types of bacteria, molds, algae, protozoa and other contaminants into the cistern or storage tank. Indeed, some samples of harvested rainwater have shown detectable levels of these contaminants. Health concerns related to bacteria, such as salmonella, e-coli and legionella, and to physical contaminants, such as pesticides, lead, and arsenic, are the primary criteria for drinking water quality analysis. Falling rain is free of most of these hazards. Common sense takes a lot of the guess work out of proper treatment procedures.

For example, if the rainwater is intended for use *inside* the household, either for potable uses such as drinking and cooking or for non-potable uses including showering and toilet flushing, appropriate filtration and disinfection practices should be employed. If the rainwater is to be used *outside* for landscape irrigation, where human consumption of the untreated water is less likely, the presence of

ANNUAL PARTICULATE MATTER (PM_{10}) EMISSIONS IN TEXAS BY COUNTY, 1994



ANNUAL SULFUR DIOXIDE (SO_2) EMISSIONS IN TEXAS BY COUNTY, 1994



Source:- Texas Natural Resource Conservation Commission contaminants may not be of major concern and thus treatment requirements can be less stringent or not required at all.

Depending on where the system is located, the quality of rainwater itself can vary, reflecting exposure to air pollution caused by industries such as cement kilns, gravel quarries, crop dusting, and a high concentration of automobile emissions.

SECONDARY WATER QUALITY CRITERIA – AESTHETIC CONCERNS

Aesthetic concerns such as color, taste, smell, and hardness comprise the secondary testing criteria used to evaluate publicly supplied water. When assessed according to these characteristics, rainwater proves to be of better quality than well or municipal tap water. Inorganic impurities such as suspended particles of sand, clay, and silt contribute to the water's color, and smell. Proper screening and removal of sedimentation help to decrease problems caused by these impurities.

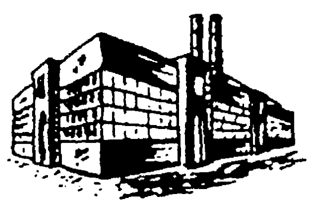
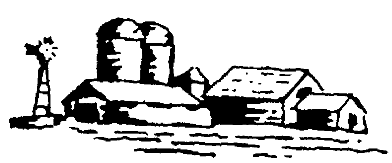
Rainwater is the softest natural occurring water available, with a hardness of zero for all practical purposes. In central and west Texas, dust derived from limestone and alkaline soils can add as much as one or two milligrams per liter (mg/L) of hardness to the water, although these amounts are negligible compared to the average hardness (about 200 to 400 mg/L) of groundwater in some areas. As mentioned above, a benefit of the soft water is that faucets and water heaters last longer without the build-up of mineral deposits.

Rainwater contains almost no dissolved minerals and salts and is near distilled water quality. Total dissolved minerals and salts levels average about 10 milligrams per liter (mg/L) across Texas. Total Dissolved Solids (TDS) can range as high as 50 mg/L and as low as 2.0 mg/L. These values are very low when compared to city tap water across Texas, which typically is in the 200 to 600 mg/L range, making rainwater virtually sodium free. For people on restricted salt diets, this represents a decisive advantage over other water sources.

The pH of rainfall would be 7.0 if there were nothing else in the air. However, as rain falls through the air, it dissolves carbon dioxide that is naturally present in the air and becomes slightly acidic. The resultant pH is 5.6; however, any sulfates or nitrates dissolved from the air will lower this number below pH 5.6. According to National Atmospheric Deposition Program data, the pH of rainfall in Texas ranges from 4.6 in east Texas to 5.6 or above

WATER QUALITY PROPERTIES RELATED TO SPECIFIC USES

DOMESTIC	INDUSTRIAL	IRRIGATION
Taste	pH	Boron
Odor	Acidity	Alkalinity
Poisons	Alkalinity	Sodium-Calcium Ratio
Flouride	Silica	Dissolved solids
Nitrate	Hardness	
Iron	Sediment	
Hardness	Dissolved solids	
Sediment		
Dissolved solids		

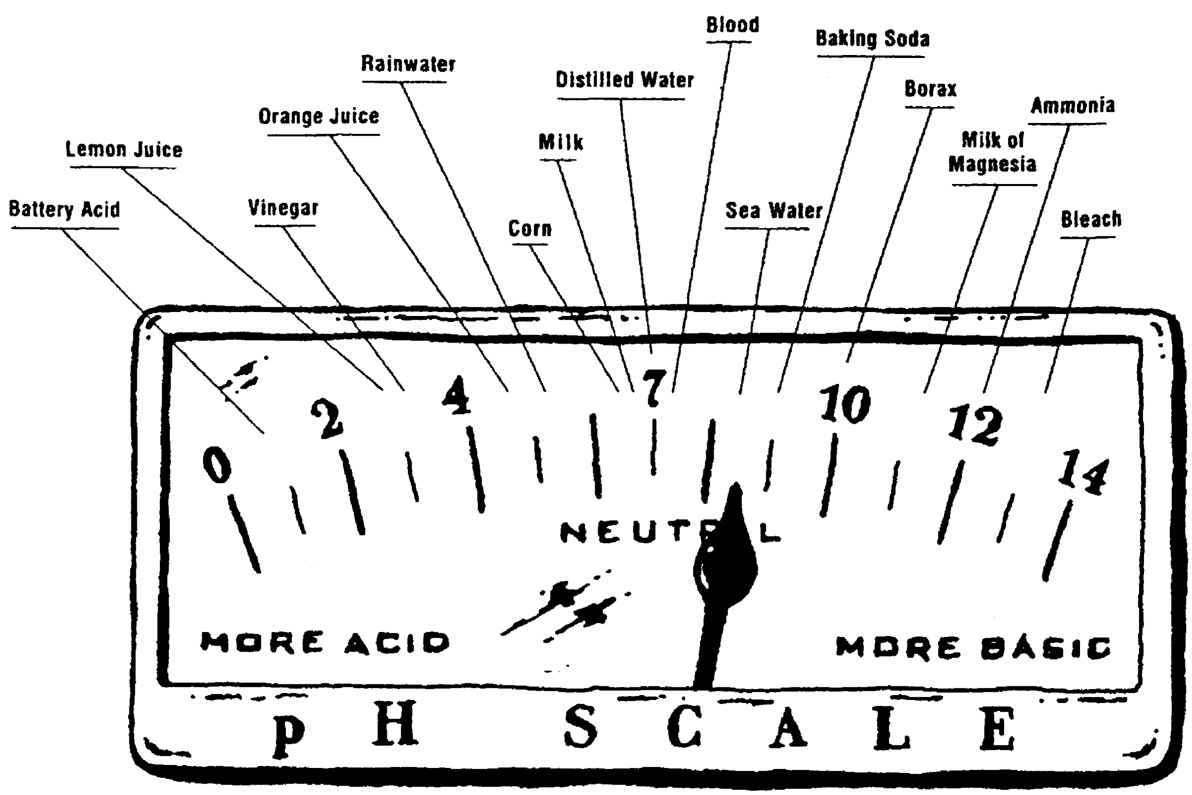
in west Texas. While northeast Texas experiences an even lower pH than found in other parts of the state, acid rain is still not considered a serious concern throughout Texas.

Although the pH of rain is below neutral, it is only slightly acidic, and the smallest amount of buffering can neutralize the acid. The low total dissolved salts and minerals levels found in rainwater permit even very small amounts of something like baking soda (one level tablespoon per 100 gallons) to adjust the pH to near neutral.

The Texas Natural Resource Conservation Commission (TNRCC) monitors municipal water quality and has adopted Drinking Water Standards in accordance with the Federal Safe Drinking Water Act. If you plan to use your harvested rainfall for drinking water, have the water tested by a laboratory certified by the Texas Department of Health (TDH) or Environmental Protection Agency (EPA). A list of drinking water testing criteria can be obtained from TNRCC or TDH. The Texas Department of Health performs tests for coliform bacteria for a nominal fee at locations around the state. At least 100 ml. of water are required to perform the test; results are available within five days.

PH SCALE FROM BASIC TO ACID

pH is the measure of acidity or alkalinity. In a scale from 0 to 14, 7 is neutral, values less than 7 represent more acid conditions, values greater than 7 represent more basic or alkaline conditions. The determination of whether water is acidic, neutral, or basic, is referred to as pH, which is a measure of the hydrogen ion concentration in water. The desired pH of potable water is pH 7, while the scale ranges from values of less than pH 7 down to pH 1 as increasingly acidic and greater than pH 7 up to pH 14 as increasingly basic. Soda pop and vinegar have a pH of about 3.0.



IV. HOW DOES A RAINWATER HARVESTING SYSTEM WORK?

SYSTEM COMPONENTS

Whether the system you are planning is large or small, all rainwater harvesting systems are comprised of six basic components:

A. **Catchment Area/Roof,** the surface upon which the rain falls;

B. **Gutters and Downspouts,** the transport channels from catchment surface to storage;

C. **Leaf Screens and Roofwashers,** the systems that remove contaminants and debris;

D. **Cisterns or Storage Tanks,** where collected rainwater is stored;

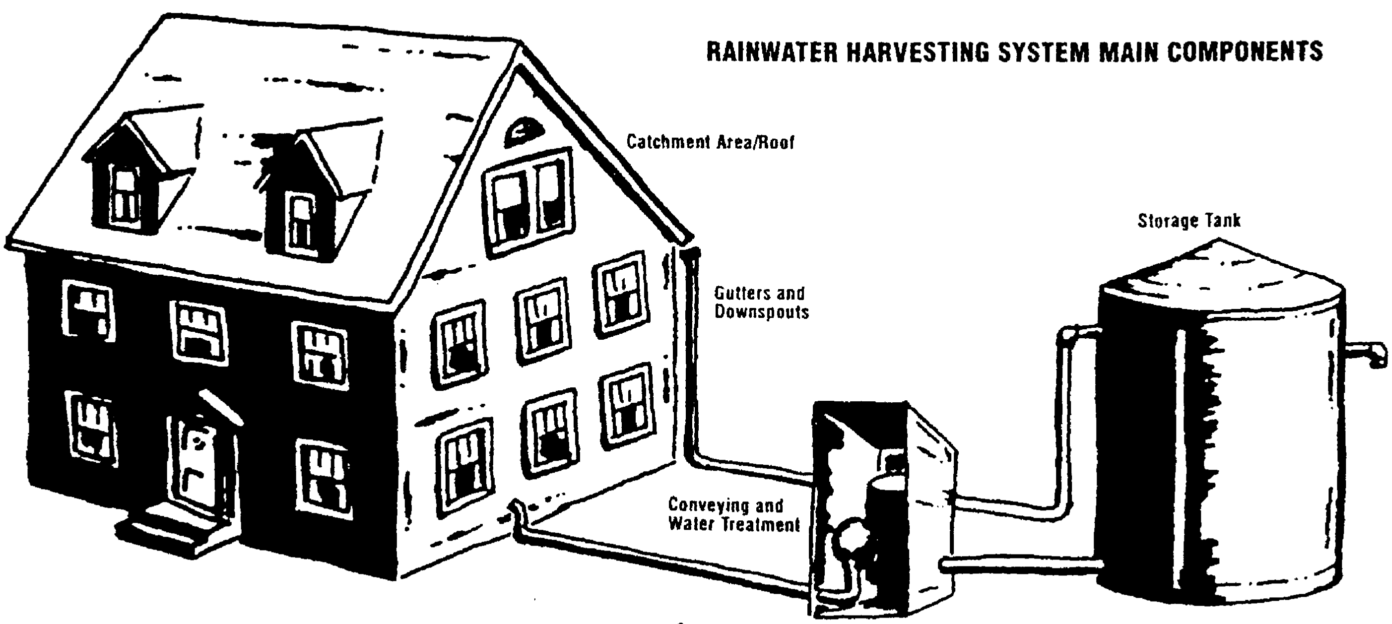
E. **Conveying,** the delivery system for the treated rainwater, either by gravity or pump; and

F. **Water Treatment,** filters and equipment, and additives to settle, filter, and disinfect.

A. CATCHMENT AREA

The catchment area is the surface on which the rain that will be collected falls. While this Guide focuses on roofs as catchment areas, channeled gullies along driveways or swales in yards can also serve as catchment areas, collecting and then directing the rain to a french drain or bermed detention area. Rainwater harvested from catchment surfaces along the ground, because of the increased risk of contamination, should only be used for lawn watering. For in-home use, the roofs of buildings are the primary catchment areas, which, in rural settings, can include outbuildings such as barns and sheds. A "rainbarn" is a term describing an open-sided shed designed with a large roof area for catchment, with the cisterns placed inside along with other farm implements.

RAINWATER HARVESTING SYSTEM MAIN COMPONENTS



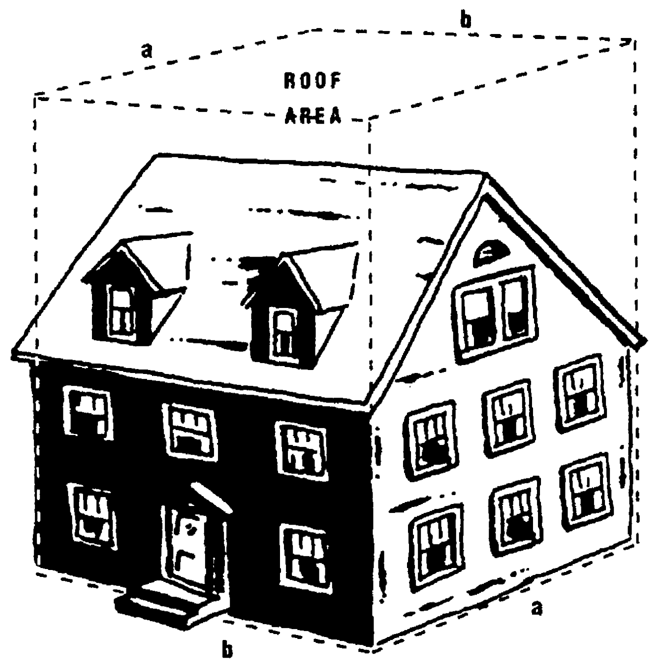
Rainwater yield varies with the size and texture of the catchment area. A smoother, cleaner, and more impervious roofing material contributes to better water quality and greater quantity. While loss is negligible for pitched metal roofs, concrete or asphalt roofs average just less than 10% loss, and built up tar and gravel roofs average a maximum of 15% loss. Losses can also occur in the gutters and in storage. Regardless of roofing material, many designers assume up to a 25% loss on annual rainfall. These losses are due to several factors: the roofing material texture which slows down the flow; evaporation; and inefficiencies in the collection process.

WHAT TYPE OF ROOFING MATERIAL?
If you are planning a new construction project, metal roofing is the preferred material because of its smooth surface and durability. Other material options such as clay tile or slate are also appropriate for rainwater intended to be used as potable water. These surfaces can be treated with a special painted coating to discourage bacterial growth on an otherwise porous surface. Because composite asphalt, asbestos, chemically treated wood shingles and some painted roofs could leach toxic materials into the rainwater as it touches the roof surface, they are recommended only for non-potable water uses.

For systems intended as potable water sources, no lead is to be used as roof flashing or as gutter solder as the slightly acid quality of rain can dissolve the lead and thereby contaminate water supply. Existing houses and buildings should be fully examined for any lead content in the planning stages of any rainwater collection project.

CATCHMENT AREA SIZE
The size of a roof catchment area is the building's footprint under the roof. The catchment surface is limited to the area of roof which is guttered. To calculate the size of your catchment area, multiply the length times the width of the guttered area (See Chapter VI for more detail).

CALCULATING CATCHMENT AREA

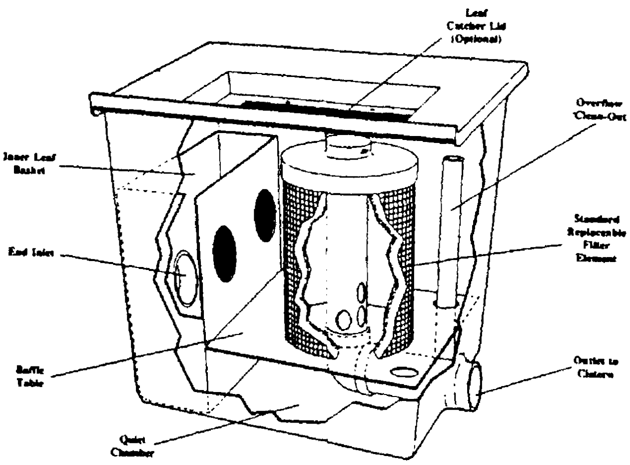


B. GUTTERS AND DOWNSPOUTS

These are the components which catch the rain from the roof catchment surface and transport it to the cistern. Standard shapes and sizes are easily obtained and maintained, although custom fabricated profiles are also available to maximize the total amount of harvested rainfall. Gutters and downspouts must be properly sized, sloped, and installed in order to maximize the quantity of harvested rain.

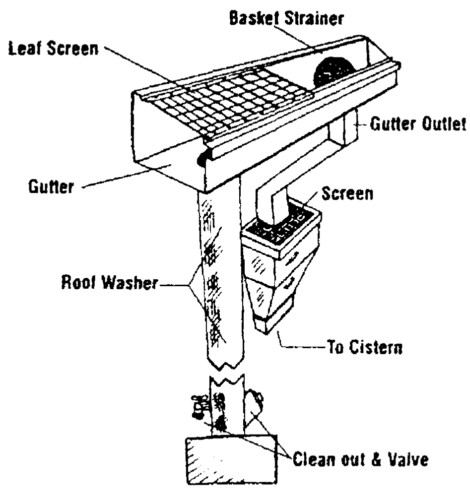
MATERIALS AND SIZES.
The most common material for off-the-shelf gutters is seamless aluminum, with standard extrusions of 5 inch and 6 inch sections, in 50 foot lengths. A 3 inch downspout is used with a 5 inch gutter and a 4 inch downspout is used with a 6 inch gutter. Galvanized steel is another common material which can be bent to sections larger than 6 inches, in lengths of 10 feet and 20 feet. A seamless extruded aluminum 6 inch gutter with a 4 inch downspout can handle about 1,000 square feet of roof area and is recommended for most cistern installations. For roof areas that exceed 1,000 square feet, larger sections of gutters and downspouts are commonly fabricated

EXAMPLE OF A COMMERCIALLY AVAILABLE ROOF WASHER WITH FILTER SYSTEM



Courtesy of Water Filtration Company

EXAMPLE OF A STANDPIPE TYPE ROOF WASHER



from galvanized steel or the roof area is divided into several guttered zones. Downspouts are designed to handle 1.25 inches of rainfall during a 10 minute period.

Copper and stainless steel are also used for gutters and downspouts but at far greater expense than either aluminum or galvanized steel. Downspouts are typically the same material as the gutters but of a smaller cross section. The connection between the downspout to the cistern is generally constructed of Schedule 40 PVC pipe.

To keep leaves and other debris from entering the system, the gutters should have a continuous leaf screen, made of 1/4 inch wire mesh in a metal frame, installed along their entire length, and a screen or wire basket at the head of the downspout. Gutter hangers are generally placed every 3 feet. The outside face of the gutter should be lower than the inside face to encourage drainage away from the building wal Where possible, the gutters should be placed about 1/4 inch below the slope line so that debris can clear without knocking down the gutter.

As with the catchment surface, it is important to ensure that these conduits are free of lead and any other treatment which could contaminate the water. Check especially if you are retrofitting onto older gutters and downspouts that may have lead solder or lead-based paint.

ROOF WASHERS

Roof washing, or the collection and disposal of the first flush of water from a roof, is of particular concern if the collected rainwater is to be used for human consumption, since the first flush picks up most of the dirt, debris, and contaminants, such as bird droppings that have collected on the roof and in the gutters during dry periods. The most simple of these systems consists of a stand pipe and a gutter downspout located ahead of the downspout from the gutter to the cistern. The pipe is usually 6 or 8 inch PVC which has a valve and clean out at the bottom. Most of these types of roofwashers extend from the gutter to the ground where they are supported. The gutter downspout and top of the pipe are fitted and sealed so water will not flow out of the top. Once the pipe has filled, the rest of the water flows to the downspout connected to the cistern. These systems should be designed so that at least 10 gallons of water are diverted for every 1000 square feet of collection area. Rather than wasting the water, the first flush can be used for non-potable uses such as for lawn or garden irrigation. Several types of commercial roof washers which also contain filter or strainer boxes are available.

Consider trimming any tree branches that overhang the roof. These branches are perches for birds and produce leaves and other debris.

C. STORAGE TANKS

Other than the roof, which is an assumed cost in most building projects, the storage tank represents the largest investment in a rainwater harvesting system. To maximize the efficiency of your system, your building plan should reflect decisions about optimal placement, capacity, and material selection for the cistern.

SITING

In Texas, recently installed cisterns are placed both above and below ground. While above ground installations avoid the costs associated with excavation and certain maintenance issues, cisterns that are below ground benefit from the cooler year-round ground temperatures. To maximize efficiency, cisterns should be located as close to both the supply and demand points as possible. And, to facilitate the use of gravity or lower stress on a pump, the cistern should be placed on the highest level that is workable.

While the catchment area (roof) should not be shaded by trees, the cistern can benefit from the shade since direct sunlight can heat the stored rainwater in the tank and thereby encourage algae and bacterial growth, which can lower water quality.

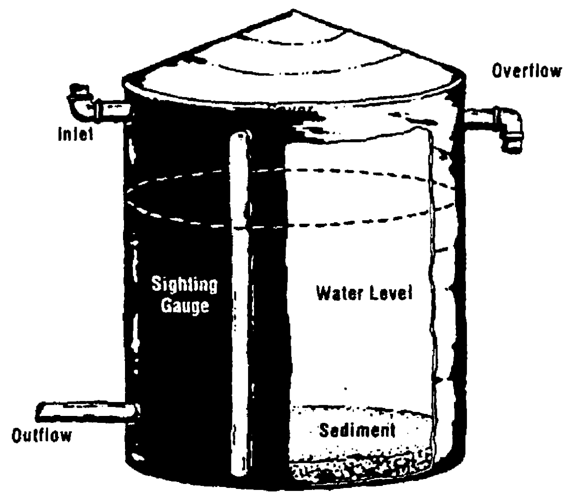
Texas does not have specific regulations concerning rainwater systems; however, to ensure a safe water supply, cisterns should be sited at least 50 feet away from sources of pollution such as animal stables, latrines, or, if the tank is below ground, from septic fields.

Tank placement should also take into consideration the possible need to add water to the tank from an auxiliary source, such as a water truck, in the event your water supply is depleted due to over-use or drought conditions. For this reason, the cistern should be located in a site accessible to a water truck, preferably near a driveway or roadway, and positioned to avoid crossing over water or sewer lines, lawns or gardens.

DESIGN FEATURES

Regardless of the type of tank material you select, the cistern should have a durable, watertight exterior and a clean, smooth interior, sealed with a non-toxic joint sealant. If the water is intended for potable use, the tank should be labeled as FDA-approved (Food and Drug Administration), as should any sealants or paints used inside the tank. A tight-fitting cover is essential to prevent evaporation, mosquito breeding, and to keep insects, birds, lizards, frogs and rodents from entering the tank. If the cistern is your only water source, an inflow pipe for an alternate water source is advisable. All tanks, and especially tanks intended for potable use, should not allow sunlight to penetrate or algae will grow in the cistern. A settling compartment, which encourages any roof run-off sediment that may enter the tank to settle rather than be suspended in the tank, is an option that can be designed into the bottom of the cistern.

A TYPICAL STORAGE CISTERN



Designing a system with two tanks provides some flexibility that may be of value. In most cases, an additional tank represents added cost, regardless of whether it represents increased capacity. This is because two smaller tanks of, for example, 1,500 gallons each are generally more expensive than a single 3,000 gallon tank. The primary benefit of a multi-tank system is that the system can remain operational if one tank has to be shut down due to maintenance or leaking.

Regardless of tank type chosen, regular inspection and proper maintenance are imperative to ensure reliability and safe, efficient operation. Remember that water is heavy. A 500 gallon tank of water will weigh more than two tons, so a proper foundation and support are essential.

MATERIALS

Tanks are available in a range of materials and sizes, new and used, large and small, to accommodate your system design and budget. For small installations, readily available new and used tanks, including whiskey barrels, 55-gallon drums, and horse troughs can be fashioned into supplemental do-it-yourself systems. If used tanks are selected, be sure that they did not contain any toxic substances which could affect water quality for many, many years. For large installations, many options exist for manufactured and site-built systems, as described below.

Concrete and Masonry

Concrete. Reinforced concrete tanks can be built above or below ground by a commercial contractor or owner-builder. Because of their weight, they are usually poured in place to specifications and are not portable. However, concrete tanks can also be fashioned from prefabricated components, such as septic tanks and storm drain culverts, and from concrete blocks. Concrete is durable and long-lasting, but is subject to cracking; below-ground tanks should be checked periodically for leaks, especially in clay soils where expansion and contraction may place extra stress on the tank. An advantage of concrete cistern chambers is their ability to decrease the corrosiveness of rainwater by allowing the dissolution of calcium carbonate from the walls and floors.

Ferrocement. Ferrocement is a term used to describe a relatively low-cost steel-mortar composite material. Its use over the past 100 years has been most prevalent in developing countries in a range of low-cost applications, such as water tanks. It has also gained popularity among do-it-yourselfers in Texas and throughout the U.S. Although it is a form of reinforced concrete, its distinctive characteristics relative to performance, strength, and flexible design potentials generally warrant classification of ferrocement as a separate material. Unlike reinforced concrete, ferrocement's reinforcement is comprised of multiple layers of steel mesh (often chicken wire), shaped around a light framework o' rebar, that are impregnated with cement mortar. Because its walls can be as thin as 1", it uses less materials than conventional poured-in-place concrete tanks, and thus can be less expensive. Ferrocement lends itself to low-cost construction projects, since it can take advantage of self-help labor and prevalent, low-cost raw materials such as rebar, chicken wire, cement and sand. Ferrocement tanks are likely to require greater ongoing maintenance than tanks constructed of other materials. Small cracks and leaks can be easily repaired with a mixture of cement and water, and also applied where wet spots appear on the tank's exterior. Some sources recommend that it is advantageous to paint above-ground tanks white to reflect the sun's rays, reduce evaporation, and keep the water cool. Though ferrocement is most commonly a site-built method, commercially available ferrocement tanks are available in some parts of Texas. Check to be sure that the ferrocement mix does not contain any toxic compounds which may make the water unfit for use.

Stone. Across the Texas Hill Country and other parts of the state with abundant rock, site-built stone cisterns were historically a logical approach to tank fabrication since the materials were locally available. The mass of the stone walls helps to keep interior water temperature cool, and the tanks can be designed to blend in with adjacent buildings. Some recent installations, such as the National Wildflower Research Center in Austin, have continued the tradition of stone cisterns. As with cement tanks, these installations are permanent. Construction procedures should be careful to exclude any compounds which may be toxic, such as some types of mortars and sealants, especially if the system is planned for potable water.

Plastic

Fiberglass. Fiberglass tanks are lightweight, reasonably priced, and long lasting, making them one of the most popular tanks in contemporary installations. As with the polyethylene and galvanized tanks, fiberglass tanks are commercially available throughout the state and easy to transport. They are available in a wide range of sizes and can be specified for potable water. Fiberglass tanks should be coated or constructed to prevent penetration of sunlight into the tank.

Plastic Liner. Plastic liners are sometimes used to line concrete tanks or tanks that have developed leaks. These liners can also be used to line low-cost, temporary collection tanks constructed of materials such as plywood. Plastic liners that are specified for potable use are commercially available. It is important to remember when using liners that they must be fully supported since they have no structural strength of their own. If a wooden form is used, remember that it should be protected from the elements since it will tend to rot quickly.

Polyethylene. These tanks are commercially available in a variety of sizes, shapes, and colors, and can be constructed for above or below ground installations. Polyethylene tanks are gaining popularity due to

ROUND CISTERN CAPACITY

DEPTH (feet)	6 FOOT DIAMETER (gallons)	12 FOOT DIAMETER (gallons)	18 FOOT DIAMETER (gallons)
6	1,266	5,076	11,412
8	1,688	6,768	15,216
10	2,110	8,460	19,020
12	2,532	10,152	22,824
14	2,954	11,844	26,628
16	3,376	13,536	30,432
18	3,798	15,228	34,236
20	4,220	16,920	38,040

CISTERN TYPES

MATERIAL	FEATURE	CAUTION
PLASTICS		
Garbage Cans (20-50 gallon)	commercially available, inexpensive	use only new cans
Fiberglass	commercially available, alterable and moveable	degradable, requires interior coating
Polyethylene/Polypropylene	commercially available, alterable and moveable	degradable, requires exterior coating
METALS		
Steel Drums (55 gallon)	commercially available, alterable and moveable	verify prior use for toxics, corrodes and rusts, small capacity
Galvanized Steel Tanks	commercially available, alterable and moveable	possible corrosion and rust
CONCRETE AND MASONRY		
Ferrocement	durable, immoveable	potential to crack and fail
Stone, Concrete Block	durable, immoveable	difficult to maintain
Monolithic/Poured in Place	durable, immoveable	potential to crack
WOOD		
Redwood, Douglas Fir, Cypress	attractive, durable	expensive

their relatively low cost and long life expectancy—they are considered slightly more durable than fiberglass with comparable life expectancy. Their light weight makes them easy to transport and relocate, if needed, while their smooth interior surface makes them easy to clean. Repairs are relatively easy to carry-out—use heat to soften the plastic and reshape as necessary. To ensure their long-life, polyethylene tanks should be chosen which have ultra-violet (UV) inhibitors for outdoor use, or can be placed in an enclosure or painted with a protective surface to provide protection from the sun. Black tanks have the greatest UV resistance, with a life expectancy of 25 years, though will tend to absorb heat and thus can affect water quality. Painting or shading the tank will minimize the effects of UV light and is recommended. Again, light penetration will promote algae growth. If you intend to use the tank for potable water, be sure that it is FDA approved.

Metal

Galvanized Steel. Steel tanks were a predominate choice by those early Texans who did not have stone nearby, and continue to be a popular choice in Texas today. Galvanized steel tanks are commercially available and reasonably priced. They are noted for their strength, yet are relatively lightweight and easy to move. Corrosion can be a problem if exposed to acidic conditions; some suppliers provide an inside liner to guard against this problem. In addition, high and low pH water conditions can result in the release of zinc. As with other tank materials, be sure that any galvanized metal tank used as a potable water source is FDA approved. If salvaging an old metal tank, be aware that these were generally soldered with lead and should not be used as a potable water source.

Wood

Redwood and Cypress. Redwood is considered one of the most durable woods for outdoor use, though is uncommon in Texas since it is not a native wood species. Cypress is a native Texas wood with many of the same properties as redwood. Although cypress was used to construct cisterns in Texas in the early 1900's, cypress tanks are not commercially available today. Redwood has a reputation as durable water storage tank material, and is attractive because it has no resins that could affect the odor or taste of water, has high levels of tannin, a natural preservative which makes the tank resistant to insects and decay, and has a cellular construction which allows for complete saturation from capillary and direct pressure and enhances its capacity to retain moisture. In addition, redwood is an efficient insulator, which keeps water cooler in summer and protects it from freezing temperatures in winter, does not rust or corrode and requires no painting or preserving. Redwood tanks have an average life expectancy of 50 years, with some known to last as long as 75 years.

D. CONVEYING

Remember, water only flows downhill unless you pump it. The old adage that gravity flow works only if the tank is higher than the kitchen sink accurately portrays the physics at work. The water pressure for a gravity system depends on the difference in elevation between the storage tank and the faucet. Water gains one pound per square inch of pressure for every 2.31 feet of rise or lift. Many plumbing fixtures and appliances require 20 psi for proper operation, while standard municipal water supply pressures are typically in the 40 psi to 60 psi range. To achieve comparable pressure, a cistern would have to be 92.4 feet (2.31 feet X 40 psi = 92.4 feet) above the home's highest plumbing fixture. That explains why pumps are frequently used, much in the way they are used to extract well water. Pumps prefer to push water, not pull it.

To approximate the water pressure one would get from a municipal system, pressure tanks are often installed with the pump. Pressure tanks have a pressure switch with adjustable settings between 5 and 65 psi. For example, to keep your in-house pressure at about 35 psi, set the switch to turn off the pump when the pressure reaches 40 psi and turn it on again when the pressure drops down to 30 psi.

E. WATER TREATMENT

Before making a decision about what type of water treatment method to use, have your water tested by an approved laboratory and determine whether your water will be used for potable or non-potable uses.

The types of treatment discussed are filtration, disinfection, and buffering for pH control. Dirt, rust, scale, silt and other suspended particles, bird and rodent feces, airborne bacteria and cysts will inadvertently find their way into the cistern or storage tank even when design features such as roof washers, screens and tight-fitting lids are properly installed. Water can be unsatisfactory without being unsafe; therefore, filtration and some form of disinfection is the minimum recommended treatment if the water is to be used for human consumption (drinking, brushing teeth, or cooking). The types of treatment units most commonly used by rainwater systems are filters that remove sediment, in consort with either an ultraviolet light or chemical disinfection.

FILTERS

Filtration can be as simple as the use of cartridge filters or those used for swimming pools and hot tubs. In all cases, proper filter operation and maintenance in accordance with the instruction manual for that specific filter must be followed to ensure safety.

Once large debris is removed by screens and roofwashers, other filters are available which help improve rainwater quality. Keep in mind that most filters on the market are designed to treat municipal

TREATMENT TECHNIQUES

METHOD	LOCATION	RESULT
SCREENING		
Strainers and Leaf Screens	Gutters and Leaders	Prevent leaves and other debris from entering tank
SETTLING		
Sedimentation	Within Tank	Settles particulate matter
FILTERING		
In-Line/Multi Cartridge	After Pump	Sieves sediment
Activated Charcoal	At Tap	Removes chlorine*
Reverse Osmosis	At Tap	Removes contaminants
Mixed Media	Separate Tank	Traps particulate matter
Slow Sand	Separate Tank	Traps particulate matter
DISINFECTING		
Boiling/Distilling	Before use	Kills microorganisms
Chemical Treatments		
(Chlorine or Iodine)	Within Tank or At Pump (liquid, tablet or granule)	Kills microorganisms
Ultraviolet Light	Ultraviolet light systems should be located after the activated carbon filter before trap	Kills microorganisms
Ozonation	Before Tap	Kills microorganisms

*Should only be used after chlorine or iodine has been used as a disinfectant. Ultraviolet light and ozone systems should be located after the activated carbon filter but before the tap.

water or well water. Therefore, filter selection requires careful consideration.

Screening, sedimentation, and prefiltering occur between catchment and storage or within the tank. A cartridge sediment filter, which traps and removes particles of five microns or larger is the most common filter used for rainwater harvesting. Sediment filters used in series, referred to as multi-cartridge or in-line filters, sieve the particles from increasing to decreasing size.

These sediment filters are often used as a prefilter for other treatment techniques such as ultraviolet light or reverse osmosis filters which can become clogged from large particles.

Unless you are adding something to your rainwater, there is no need to filter out something that is not present. When a disinfectant such as chlorine is added to rainwater, an activated carbon filter at the tap may be used to remove the chlorine prior to use. Remember that activated carbon filters are subject to becoming sites of bacterial growth. Chemical disinfectants such as chlorine or iodine must be added to the water prior to the activated carbon filter. If ultraviolet light or ozone is used for disinfection, the system should be placed **after** the activated carbon filter. Many water treatment standards require some type of disinfection after filtration with activated carbon. Ultraviolet light disinfection is often the method of choice. All filters must be replaced per recommended schedule rather than when they cease to work; failure to do so may result in the filter contributing to the water's contamination.

DISINFECTION

Ultraviolet Light (UV) water disinfection, a physical process, kills most microbiological organisms that pass through them. Since particulates offer a hiding place for bacteria and microorganisms, prefiltering is necessary for UV systems. To determine whether the minimum dosage is distributed throughout the disinfection chamber, UV water treatment units should be equipped with a light sensor. Either an alarm or shut-off switch is activated when the water does not receive the adequate level of UV radiation. The UV unit must be correctly calibrated and tested after installation to insure that the water is being disinfected. Featured in the case studies are several systems which utilize ultraviolet light.

Ozone is the disinfectant of choice in many European countries, but it has not been used in American water treatment facilities until recently. Ozone is a form of oxygen (0_3) produced by passing air through a strong electric field. Ozone readily kills microorganisms and oxidizes organic matter in the water into carbon dioxide and water. Any remaining ozone reverts back to dissolved oxygen (0_2) in the water. Recent developments have produced compact ozone units for home use. Since ozone is produced by equipment at the point of use with electricity as the only input, many rainwater catchment systems owners use it to avoid having to handle chlorine or other chemicals. Ozone can also be used to keep the water in cisterns "fresh". When used as the final disinfectant, it should be added prior to the tap, but after an activated carbon filter, if such a filter is used.

Chlorine or iodine for disinfecting. Private systems do not disinfect to the extent of public water systems where the threat of a pathogenic organism such as e. coli can affect many households. If the harvested rainwater is used to wash clothes, water plants, or other tasks that do not involve direct human consumption or contact, treatment beyond screening and sedimentation removal is optional. However, if the water is plumbed into the house for general indoor use such as for drinking, bathing, and cooking, disinfection is needed.

While filtering is quite common in private water systems, disinfection is less common for these reasons: the Safe Drinking Water Act is neither enforced nor applicable to private systems; chlorine is disliked due to taste, fear associated with trihalomethanes (THMs), and other concerns. Chlorine is the most common disinfectant because of its dependability, water solubility, and availability.

Granular or tablet form is available (calcium hypochlorite), but the recommended application for rainwater disinfecting is in a liquid solution (sodium hypochlorite).

Household bleach contains a 5.0% solution of sodium hypochlorite, and is proven to be reliable, inexpensive and easily obtained. A dose is one liquid ounce of bleach for each 100 gallons (one and a quarter cups of bleach per 1,000 gallons) of rainwater collected will most likely be sufficient to disinfect the collected rainwater. When disinfecting, never overdose with bleach. Mixing occurs naturally over a day or so, but a clean paddle may be used to accelerate the process.

When chlorine bleach is added directly to the storage tank or cistern as described above, the chlorine will have a longer time to kill bacteria thus achieving a better rate of disinfection. Chlorine feed pumps which release small amounts of solution while the water is being pumped can also be used. Chlorine metering pumps inject chlorine into the water only at the time of use.

Chlorine concentrations are easily measured with a swimming pool test kit. A level of between 0.2 mg/L (milligrams per liter) and 1.5 mg/L is recommended. If the level is below 0.2 mg/L, add one liquid ounce of chlorine bleach per 100 gallons of the volume of water in storage (one and a quarter cups per 1,000 gallons) if you are using bleach or adjust the chemical feed pump in accordance with the pump's instructions.

Swimming pool test kit chemicals are toxic and should never be allowed to mix with cistern water. Testing should occur outside the tank.

Chlorine is more effective at higher water temperatures and lower pH levels than iodine. Iodine is another water disinfectant that is less soluble than chlorine although it is effective over a pH range of 5 to 9 and displays greater antibacterial activity in water temperatures of 75 to 98.6 degrees Fahrenheit.

Prolonged presence of chlorine where organic matter may be present may cause the formation of chlorinated organic compounds. If chlorine is used as a disinfectant, be sure to screen all organic material from the tank.

BUFFERING

Baking soda for buffering. The composition and pH of rainwater differs from chemically treated municipal water and mineral rich well water. Controlling the pH of rainwater by buffering can be easily accomplished by adding one level tablespoon of baking soda to the storage tank for each 100 gallons of water collected. (About four ounces by weight of baking soda for every 1,000 gallons of water collected.) An easy method is to mix this amount of baking soda in a jar of water and pour it into the tank. Mixing will occur naturally over a day or two or a clean paddle may be used to hasten the process, but avoid disturbing materials that have settled at the bottom of the cistern.

OTHER TREATMENT

There are a number of other treatment devices available on the market. When selecting additional treatment devices, always ask yourself what is it that you are trying to remove, does it need to be removed, and does this water source contain that contaminant. Commercial and public test laboratories can help in this regard.

Some of the types of treatment available include reverse osmosis (RO) and nano-filtration, and several other "membrane" processes and distillation equipment that are designed primarily to remove dissolved materials such as salts or metals, but rainwater contains extremely low dissolved salts or hardness levels. For the most part, systems such as RO would be redundant and expensive to use. Besides, most home RO units waste three to five gallons of water for every gallon of water produced.

As a word to the wise, consult your local health department before purchasing such devices. Some devices are actually dangerous if used incorrectly.

V. HOW MUCH WATER DO YOU USE?

Assessing your indoor and outdoor water needs will help determine the best use for the rainwater. If you are already connected to a municipal water system, then a rainwater harvesting unit designed to fulfill outdoor requirements such as lawn and garden irrigation may be most cost-effective. If you have already invested in a well-water system, rainwater could augment or enhance the quality of mineralized well water for purposes such as washing, or provide back-up water when underground water sources are low. Some people are installing a full-service rainwater system designed to supply both their indoor and outdoor water needs. If you are considering this option, it is imperative that you employ best conservation practices to ensure a year-round water supply. Three variables determine your ability to fulfill your household water demand: your local precipitation, available catchment area, and your financial budget.

If you are accustomed to simply turning on a tap to get your water and then paying a bill at the end of the month, the switch to a rainwater system will require some adjustment. While the associated tasks are not difficult, they are important to keep your water safe and your family in good health. These responsibilities include regular inspections of all the previously discussed components, including

HOUSEHOLD WATER DEMAND CHART

FIXTURE	USE	FLOW RATE	# OF USERS	TOTAL
Toilet	# flushes per person per day	1.6 gallons per flush (new toilet)*		
Shower	# minutes per person per day (5 minutes suggested max.)	2.75 gallon per minute* (restricted flow head)		
Bath	# baths per person per day	50 gallons per bath (average)		
Faucets	bathroom and kitchen sinks (excluding cleaning)	10 gallons per day	not applicable	
Washing Machine	# loads per day	50 gallons per load (average)	not applicable	
Dishwasher	# loads per day	9.5 gallons per load	not applicable	
			Total	# gallons/day
			multiply (x) 365	# gallons/year

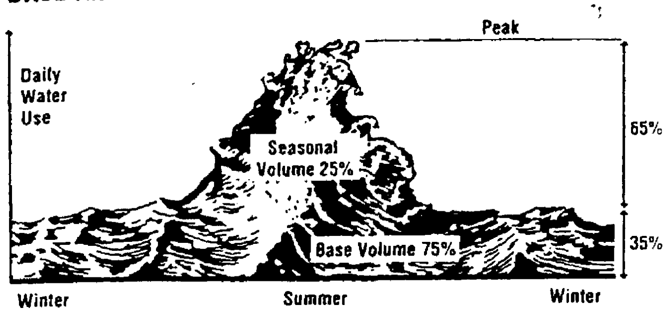
*All of the flow rates shown are for new fixtures. Older toilets use from 3.5 to 7 gallons per flush, and older shower heads have flow rates as high as 10 gallons per minute.

pruning branches that overhang roof, keeping leaf screens clean, checking tank and pump, replacing filters, and testing the water. A maintenance schedule and checklist based upon your particular system are recommended to ensure proper performance.

HOUSEHOLD WATER BUDGET

An easy way to calculate your daily water consumption is to review previous water bills, if you presently receive municipal water. Another method is to account for every water-using activity, including shower, bath, toilet flush, dishwashing run, washing machine load. A conserving household that has low-flow plumbing fixtures such as 1.6 gallon-per-flush toilets and 2.75 gallon-per-minute shower heads, now required by the Texas Plumbing Standards, might use 55 gallons or less of water per day per person and very conservative minded households might be able to reduce water use to as low as 35 gallons per person per day. However, for the purposes of designing a rainwater system, an estimate of 75 gallons per person per day for indoor use is advised to ensure adequate year-round indoor water supply - unless you are sure that all of your

BASE AND SEASONAL WATER USE IN TEXAS

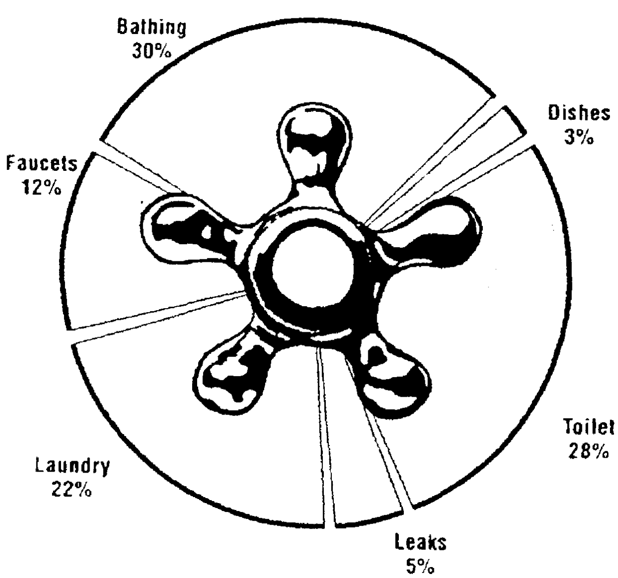


fixtures are the newer, more efficient ones and you plan to follow strict conservation practices. Complete the Household Water Consumption Chart on page 16 to see how your household's water consumption compares with the recommended design allowance. See page 18 for outdoor use estimates.

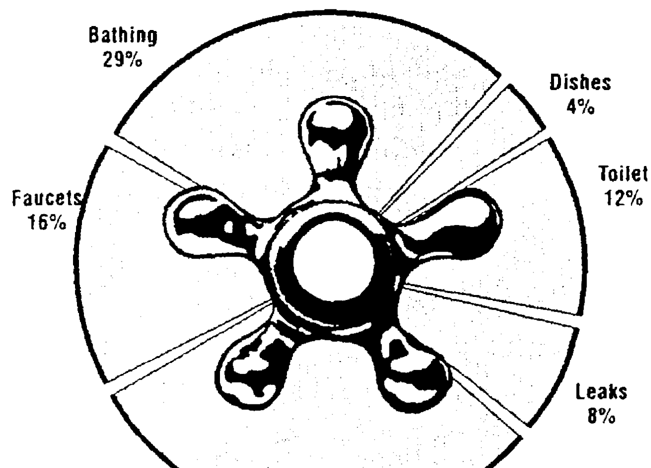
While inside water use remains relatively level throughout the year, total water demand increases during the hot, dry summers due to increased lawn and garden watering, and decreases during the cool, wet winters when the garden is fallow and the lawn needs little attention. To determine your daily water budget, multiply the number of persons in the household times the average water consumption. Estimates of indoor household water use range from less than 55 gallons per person a day in a

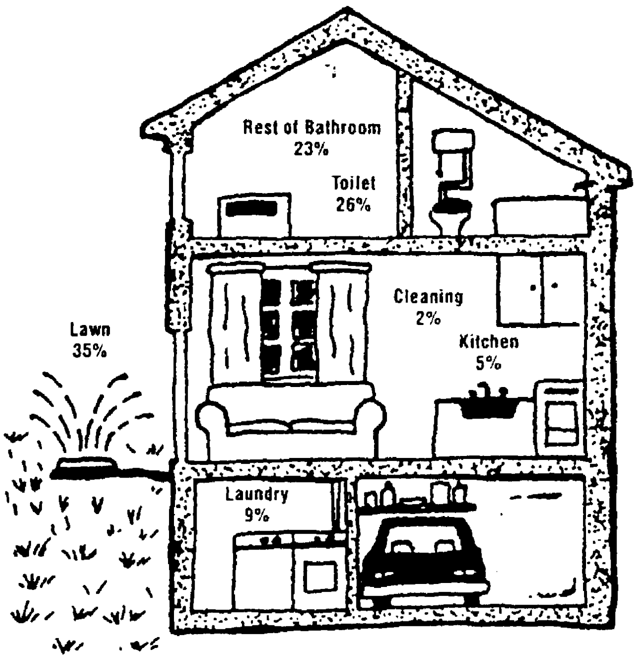
HOME INDOOR WATER USE

Homes with older fixtures use about 75 gallons per person per day (GPCD)



Homes with water-saving fixtures use about 55 gallons per person per day (GPCD)





HOME WATER USE, INDOOR AND OUTDOOR

conservation minded household to well over 75 gallons per person a day in non-conserving households.

LANDSCAPE WATER BUDGET

In order to calculate a water budget for a conventional lawn, you must determine the grass type, the square footage of your lawn, and your annual rainfall. If the average annual rainfall for your area is higher than the required water demands listed below, your annual rainfall is sufficient. If your annual rainfall is lower than the required inches based on grass type, you will need to complete the following chart to determine your lawn watering requirements in order to properly size your cistern.

WATER CONSERVATION TECHNIQUES

While rainwater collection can function well as a stand alone system, its efficiency can be enhanced by working in concert with other water conservation practices. Reducing your water demand results in lowering the up front cost of your rainwater harvesting system.

SAVING WATER INSIDE YOUR HOUSE

If your water budget or water bill indicates usage beyond your collection capacity, common sense water conservation practices might help you to recover those extra gallons. The repair of dripping faucets and leaking toilets, frequently the source of much lost water, is a good start. Installing low-flow showerheads, faucet aerators and toilet dams are other steps that pay for themselves in less than a year through water savings. Water conserving dish washers and clothes washing machines that operate with half as much water as conventional appliances

LANDSCAPE WATER DEMAND CHART

GRASS TYPE AND THEIR WATER DEMAND

St. Augustine	50 inches per year	Bermuda	40 inches per year	St. Augustine/ Bermuda Mix	45 inches per year
Buffalo Grass	25 inches per year	Zoysia	45 inches per year		

1. Multiply the water demand (inches per year) times your lawn size (square feet) and divide by 12. This will give you the cubic feet of of water demand per year. _________ cu. ft.
2. Multiply the number cubic feet of water demand per year (line 1) times a conversion factor of 7.48. This gives you the number of required gallons of water per year. _________ gal.
3. Multiply the inches of natural rainfall for your area (see page 20) times your lawn size (square feet) and divide by 12. This gives you the cubic feet of water supplied by natural rainfall. _________cu. ft.
4. Multiply the cubic feet of natural rainfall times a conversion factor of 7.48. This gives you the gallons of natural rainfall per year. _________ gal.
5. Subtract the gallons of natural rainfall (line 4) from the required water demand for your grass type (line 2). This gives you the gallons required. _________ gal.

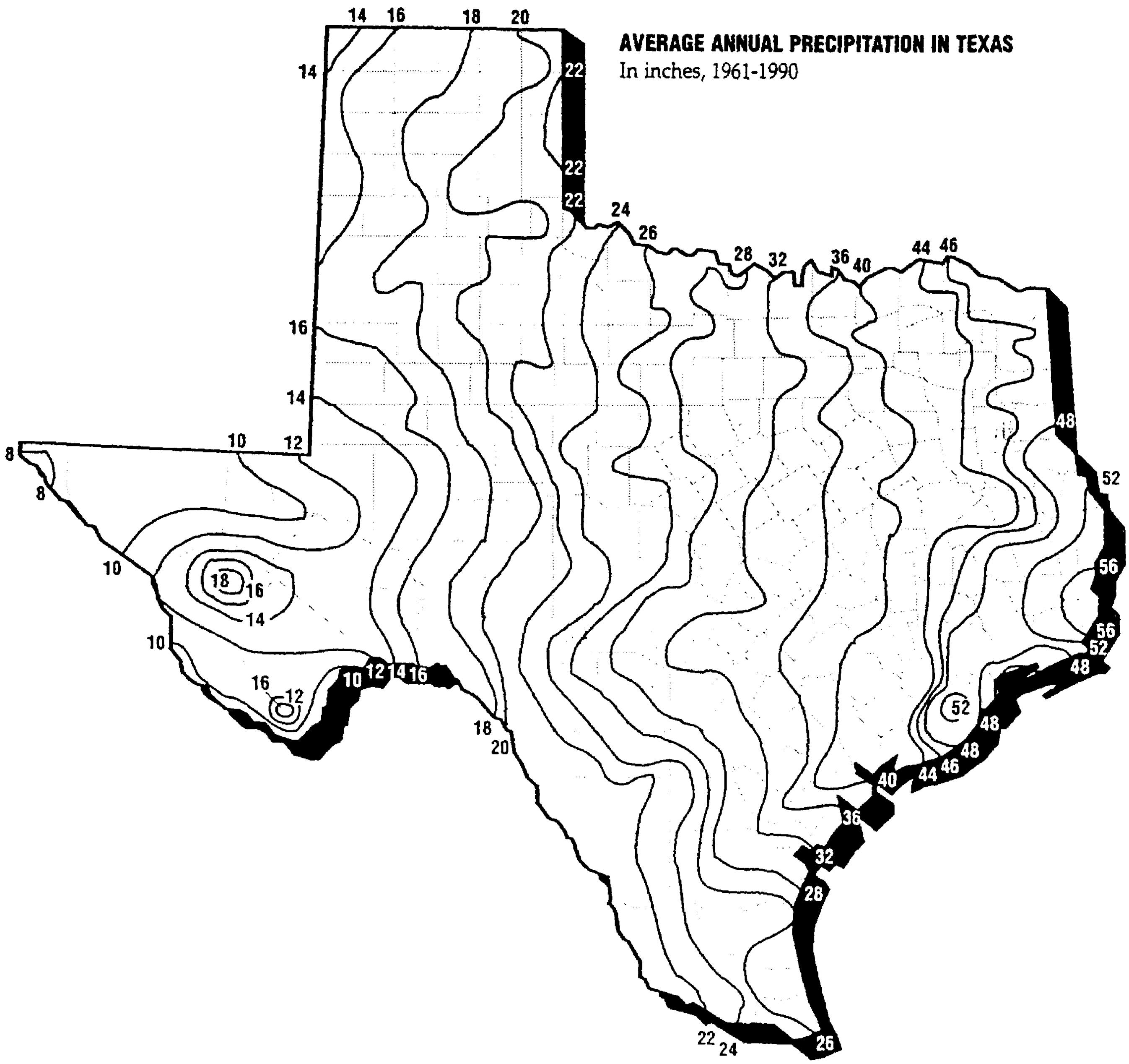
are also available. The Texas Water Development Board and your local water utility have more information on ways to conserve water in your bathroom, kitchen, and laundry.

SAVING WATER OUTSIDE YOUR HOUSE

Landscape irrigation accounts for about one-quarter of all municipal water use in Texas. The most intensive time to irrigate is the summer growing season, which is when temperatures are highest and rainfall is lowest. Rainwater becomes particularly precious during these hot, dry months. Indeed, rainwater used for summer irrigation must be captured earlier in the year. Therefore, a landscape that requires minimum watering, especially in the summer, is most appropriate for rainwater harvested irrigation. The use of regionally-adapted drought tolerant and low water use plants is also a major help.

Drip Irrigation. Trickle or drip irrigation is the frequent, low pressure application of small amounts of water to the soil area directly surrounding the plant roots. A constant level of soil moisture is maintained, even though up to 60% less water

AVERAGE ANNUAL PRECIPITATION IN TEXAS
In inches, 1961-1990



than conventional watering is used by this method. The efficiency and uniformity of a low water flow rate reduces evaporation, run-off, and deep percolation. A common soaker hose, usually installed below ground, is one of the simplest ways to drip irrigate shrub beds, gardens and young trees.

To obtain more information about Water Wise landscaping, drip irrigation, and indoor water conservation techniques, contact the Texas Water Development Board at Conservation, P.O. Box 13231, Austin, TX 78711-3231 or the Texas Department of Agriculture, city utility, river authority, or your county agriculture extension agent.

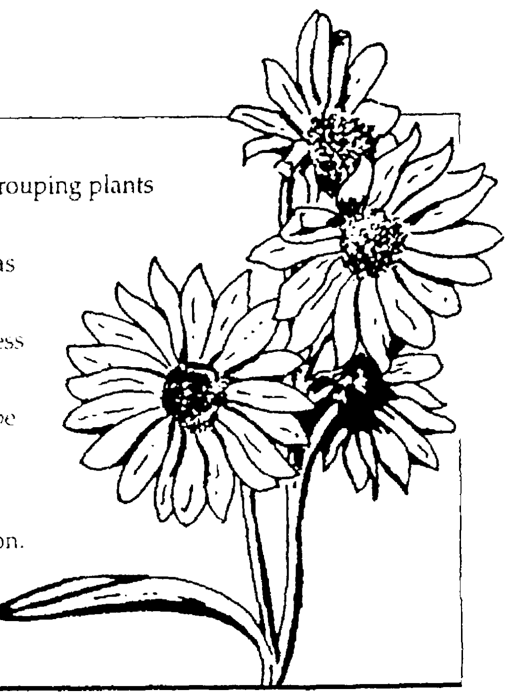
Greywater Reuse. In urban areas, public policy and health codes generally mandate the centralized collection and treatment of household wastewater. Policy discussions relating to greywater reuse are underway, reflecting concern to maximize water use options brought on by droughts, water shortages, and development impacts on existing wastewater treatment facilities. Greywater reuse, which relies on separating the greywater from the blackwater, has many environmental and economic benefits on both the building and regional scales. Because greywater is relatively benign, it can be directed to a number of secondary uses such as toilet flushing and irrigation, thus displacing the need to use higher quality water.

Greywater is household wastewater generated by clothes washing machines, showers, bathtubs, and bathroom sinks. Wastewater from kitchen sinks is excluded from this category since it contains oil, fat, and grease which are difficult to filter, clog distribution pipes, have unpleasant odors, and are likely to attract pests.

Blackwater is the water flushed down toilets and urinals and also includes the discharge from kitchen sinks due to the reasons stated above. If a sanitary sewer connection is not available, blackwater must be treated on site by a septic tank, drain field, or a permitted on-site wastewater treatment system.

Greywater can contain harmful bacteria and therefore also requires filtration and disinfection prior to reuse. Once the greywater is properly treated, it can be reused for irrigation and used to supplement higher quality rainwater. Always consult your local health department.

If you plan to incorporate a greywater system, check with your local health department officials since certain restrictions regarding installation and reuse apply. For example, greywater systems with overflows to public sewer systems cannot be connected to rainwater systems.



7 WATER WISE PRINCIPLES

1. Planning & Design that considers topography, existing vegetation, and grouping plants and grasses by their watering needs.
2. Soil Improvement to prevent erosion and adding organic material, such as compost, to promote water penetration and retention.
3. Appropriate Plant Selection such as native and adapted plants that use less water and are more resistant to diseases and pests.
4. Practical irrigated turf and landscaped areas in appropriate locations to be separately irrigated.
5. Efficient Watering by avoiding watering until absolutely necessary and never watering in the heat of the day or on windy days to avoid evaporation.
6. Use of Mulches to cover and shade soil, minimize evaporation, reduce weed growth and soil erosion.
7. Lower Maintenance by the decreased use of pesticides and fertilizers.

Other Water Reuse Options

Under new rules from the Texas Natural Resources Conservation Commission (TNRCC), water from on-site sewage facilities, such as septic systems, can now be reused for landscape irrigation after proper secondary treatment and disinfection. Contact your local health department or the TNRCC at P.O. Box 13087, Austin, Texas 78711-3087. The applicable rule is 30 TAC285. You can also download the rule from the TNRCC's web site at http://www.tnrcc.state.tx.us.

VI. HOW MUCH RAINFALL CAN YOU COLLECT?

Now that you have a better understanding of the principles of rainwater catchment, the next questions are, how much rain can you expect to collect in your location and how reliable is this rainfall. The simple answer to the first question is that one inch of precipitation (1/12 foot) on one square foot of collection area equals 0.6233 gallons. Many simply round this off to 600 gallons collected per inch of rain on 1,000 square feet. From this basic rule of thumb (600 gallons per inch on 1,000 square feet) the analysis shifts to (1) how efficiently can this rainfall be collected, and (2) how reliable is the rainfall on your specific area. Once these questions are answered, you will need to balance the amount of rainfall than can be collected with the amount of water that will be used. You may be surprised to learn that even with the strictest water conservation measures, rainfall collection can only provide a fraction of the amount of water you use.

The answer to these questions also depends in part on what the harvested rain will be used for. If it is to provide supplemental water for the yard, the answer will be different than if the system will be the sole source of water for a household. One should also keep in mind that the efficiency of the collection system can change depending on design while the question regarding precipitation reliability depends on where you are located.

Collection Efficiency. How efficiently the rainfall can be collected depends on several considerations. Many first assume that "I can collect all of it," but this is never the case. First, there is always a small loss to rainfall needed to wet the roof area and water collected by the roof washer. This is usually a small percentage of the rainfall and will range from about 3/100's to 1/10th of an inch *per rainfall event,* depending on the roof material and the volume the roof washer diverts. Built-up flat roofs can retain as much as half an inch of water depending on their condition and design. Overshot of gutters and spillage during very intensive rainfall events will occur.

Spills and rate of rainfall can also make a difference. If filter type roof washers are used, they will "spill" the excess flow once the filter flow through capacity is exceeded. Finally, you can collect only as much rainfall as your storage system will hold. Depending on your design, most cisterns will become full during especially rainy periods and any additional rainfall collected will spill. Collection efficiencies of 75% to 90% are often used by installers depending on the specific design if the system is to provide water for in-home use. For small systems designed for supplemental plant watering, collection factors of below 50% are common because it is not economic to install the large storage that would be required to increase this factor.

Rainfall Reliability. The reliability of precipitation requires a closer look. The first and simplest parameter to consider is average precipitation. The map on page 19 shows average precipitation for Texas. The first step one should take is to use the average rainfall for your area to determine how much water would be generated from your roof area. The calculation is the roof catchment area times the average rainfall times 600 gallons divided by 1,000.

$$\frac{\text{Area (ft}^2\text{) X Average Rainfall (inches) X 600}}{1{,}000}$$

If you are only interested in supplemental water for plant watering, this may be sufficient knowledge, but if rainwater is to be your sole source of water, you need to know what precipitation rate you can rely on in more detail. Once your system is in, you will need to know the amount of rainfall you can expect from one month to the next.

The figure on page 24 shows annual precipitation for seven cities from across Texas. The annual rainfall is arranged in rank order from the lowest to the highest for each city. This graph also shows the percent of time that rainfall of that magnitude will not be exceeded. For example, the graph shows that in Wichita Falls, rainfall will be greater than 30 inches per year about 35% of the time or lower than 30 inches per year 65% of the time. The graph also indicates that annual rainfall in Wichita Falls will fall between 17 inches but below 37 inches 90% of the time.

As a rule-of-thumb in Texas, if one divides average annual rainfall by two, the resulting answer will be near the 5% percentile rainfall. For example, Austin receives an average of 32 inches a year and only 5% of the time is rainfall less than 17 inches a year. This can help give a quick method of determining if enough rainfall will occur to provide water during very low periods based on annual precipitation. An expample of how annual data can be used is shown below.

The monthly distribution of rainfall is also important information for sizing a system. Using annual data does not tell you how much water one can expect from one month to the next or just as important, once in operation, how much rainfall can one expect in any one given month. These statistics are presented in "Rainfall Data for Selected Communities Across Texas" on page 27.

The use of these data is twofold. First, the 10%, 25% and 50% (median) monthly data present the percent of times that rainfall is less

BASIC METHOD USING ANNUAL DATA

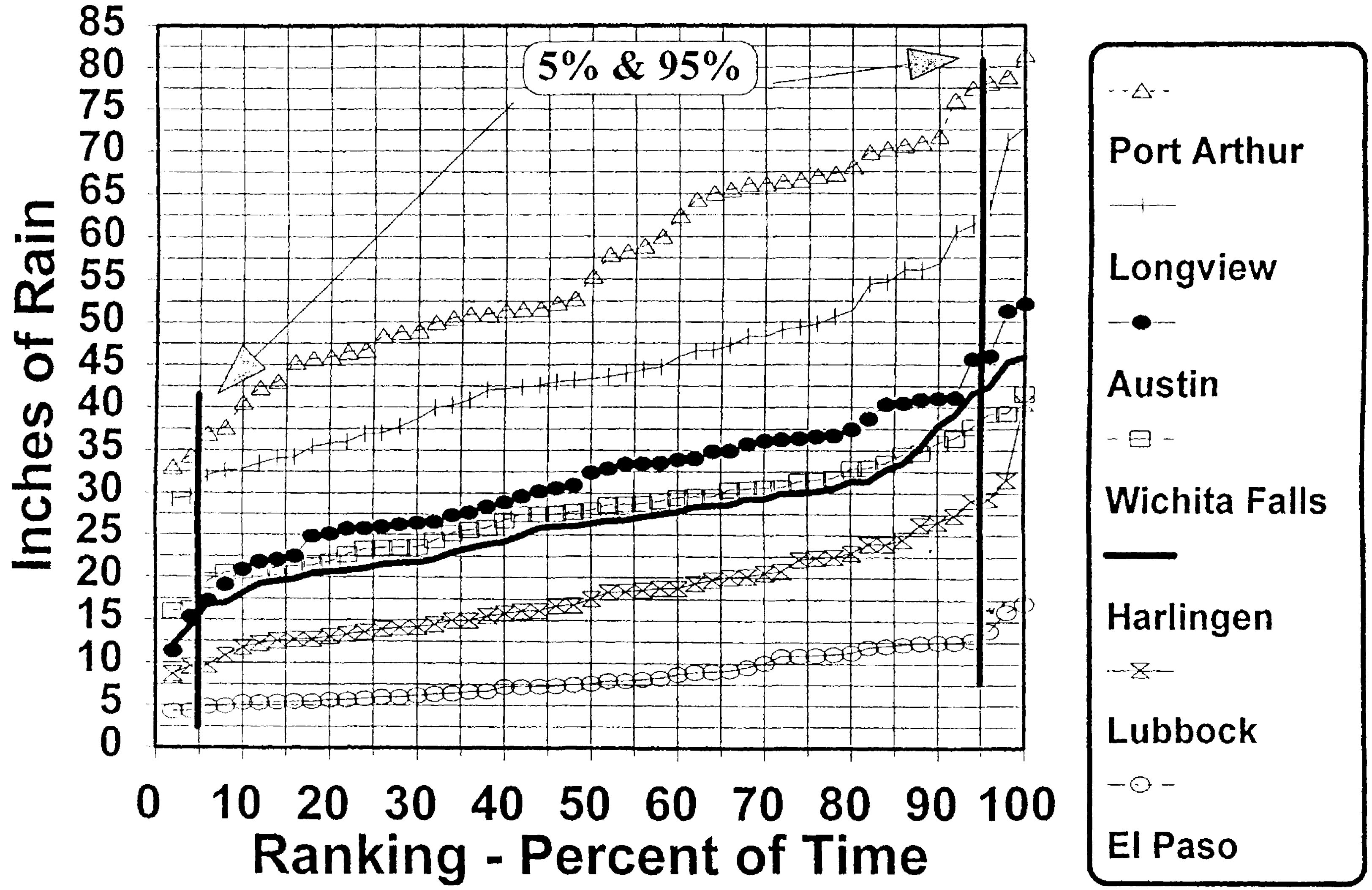
1. Calculate Roof Catchment Area (see page 7)
2. Multiply the collection area in square feet by 0.6 gallons per square foot per inch of rain times the collection factor times the average annual rainfall and half of the average annual rainfall.

For example, if you have 2,500 square feet of collection area and live in Austin, where the average annual rainfall is 32 inches a year and the collection efficiency factor is 80%, the average amount of rain you can collect is:

2,500 X 0.6 X 0.8 X 32 = 38,400 gallons per year

3. Dividing this by 365 days a year, the supply would be 105 gallons per day.
4. Using the rule-of-thumb that half of the average rainfall will provide a close estimate of the low expected rainfall for the area, in an extremely severe drought year, approximately 19,700 gallons could be collected. This would result in a supply of only 53 gallons a day.

Annual Precipitation in Rank Order For Seven Selected Texas Cities



than that value. Examination of the data also shows that the 50% values are lower than the average values. This is because the arithmetic average is skewed by a few abnormally high rainfall events such as those occurring during hurricane. While the median represents the rainfall that, when all historic rainfall values for that month are ranked from lowest to highest, is in the middle.

The way to use these data on a monthly basis is that for any given month, you can expect to get at least the median rainfall half of the time, the 25% rainfall 75% of the time, and the 10% rainfall 90% of the time. The sum of the twelve monthly median values is lower than the annual average as explained above. In Texas, the sum of the medial values provides a rainfall that can be relied on for 65% of the time or more. For example, the total for Austin is 25 inches which occurs 80% of the time in any given year and the 25% monthly value annual total is 12 inches which occurs over 95% of the time.

This information can also be used to develop monthly balances of demand and storage as shown on the following page using Austin data. In this example, the median (50%) and 25% monthly rainfall were used. The purpose is to determine how much storage capacity is needed and the level of demand that can be sustained.

Different storage volumes, roof sizes (if this is an option), and monthly demands are tried. In the example case, the roof size is 3,000 square feet, the collection efficiency is 80%, and the storage volume is 10,000 gallons. It is assumed that the year begins with 3,000 in storage; monthly demands of 2,000 gallons, 3,000 gallons, and 4,000 gallons are used. The calculation is done by following the steps below.

MONTHLY BALANCE CALCULATIONS

1. Determine January rainfall for both the 50% and 25% levels. For example, at the 50% rainfall level of 1.23 inches for January it is:

   3,000 X 0.8 X 1.23 X 0.623 = 1,839 gallons collected

2. Add the volume already in storage (3,000 gallons) to the gallons collected and subtract the monthly demand. For the 2,000 gallons a month demand example and 50% rainfall level, this is:

   1,839 + 3,000 - 2,000 = 2,839 gallons in storage at the end of the month

   This is repeated, but note that if the storage is zero or less at the end of the month, use zero for the next month; if the amount in storage at the end of the month is greater than the capacity of the cistern (10,000 gallons in this example) use the storage capacity for the end of the month storage. The end result is that for the 10,000 gallon storage capacity an anverge use of 3,000 gallons/month, but not 4,000 gallons/month, could be supported.

   Many professionals use 50 to 100 years of actual monthly rainfall data in a program which performs the same series of calculations as described above to determine the optimum system size.

EXAMPLE MONTHLY WATER BALANCE CALCULATIONS

Month	Monthly Use (gal/mo)	50% rain (inches)	Rainfall Collected (gallons)	End of Mo. Storage (gallons)	25% rain (inches)	Rainfall Collected (gallons)	End of Mo. Storage (gallons)
				3,000			3,000
1	2,000	1.23	1,839	2,839	0.60	897	1,897
2	2,000	2.28	3,409	4,248	1.13	1,690	1,587
3	2,000	1.66	2,482	4,730	0.81	1,211	798
4	2,000	2.18	3,260	5,990	1.38	2,063	861
5	2,000	3.89	5,816	9,806	1.60	2,392	1,254
6	2,000	2.63	3,932	10,000	1.51	2,258	1,511
7	2,000	1.01	1,645	9,645	0.44	658	169
8	2,000	1.19	1,779	9,424	0.60	897	0
9	2,000	3.15	4,710	10,000	1.50	2,243	243
10	2,000	2.78	4,157	10,000	0.87	1,301	0
11	2,000	1.71	2,557	10,000	0.74	1,106	0
12	2,000	1.24	1,854	9,854	0.74	1,106	0
	24,000	25.04	37,440		11.92	17,823	
1	3,000	1.23	1,839	1,839	0.60	897	897
2	3,000	2.28	3,409	2,248	1.13	1,690	0
3	3,000	1.66	2,482	1,730	0.81	1,211	0
4	3,000	2.18	3,260	1,990	1.38	2,063	0
5	3,000	3.89	5,816	4,806	1.60	2,392	0
6	3,000	2.63	3,932	5,738	1.51	2,258	0
7	3,000	1.01	1,645	4,383	0.44	658	0
8	3,000	1.19	1,779	3,162	0.60	897	0
9	3,000	3.15	4,710	4,872	1.50	2,243	0
10	3,000	2.78	4,157	6,029	0.87	1,301	0
11	3,000	1.71	2,557	5,586	0.74	1,106	0
12	3,000	1.24	1,854	4,440	0.74	1,106	0
	36,000	25.04	37,440		11.92	17,823	
1	4,000	1.23	1,839	839	0.60	897	0
2	4,000	2.28	3,409	248	1.13	1,690	0
3	4,000	1.66	2,482	0	0.81	1,211	0
4	4,000	2.18	3,260	0	1.38	2,063	0
5	4,000	3.89	5,816	1,816	1.60	2,392	0
6	4,000	2.63	3,932	1,749	1.51	2,258	0
7	4,000	1.01	1,645	0	0.44	658	0
8	4,000	1.19	1,779	0	0.60	897	0
9	4,000	3.15	4,710	710	1.50	2,243	0
10	4,000	2.78	4,157	867	0.87	1,301	0
11	4,000	1.71	2,557	0	0.74	1,106	0
12	4,000	1.24	1,854	0	0.74	1,106	0
	48,000	25.04	37,440		11.92	17,823	

RAINFALL DATA FOR SELECTED COMMUNITIES ACROSS TEXAS

This chart contains monthly rainfall data from 40 weather stations across Texas. The statistics are based on 50 years of recorded rainfall, from 1940 through 1990. For each station, six monthly precipitation values are given:

- **MIN.** The minimum recorded occurrence is the lowest recorded rainfall in 50 years.
- **10%** The 10% occurrence level indicates that 90% of the time monthly rainfall is higher.
- **25%** The 25% occurrence level indicates that 75% of the time monthly rainfall is higher.
- **50%** The 50% (median) occurrence level describes monthly rainfall for half the time.
- **AVE.** The average monthly (mean) occurrence level factors in precipitation extremes and is higher than the 50% (median) data.
- **MAX.** The maximum recorded occurrence is the highest recorded monthly rainfall in 50 years.

Refer to the map below to see if there is a data set for your town. If you live between weather stations, average the monthly precipitation values for the closest town to the north and to the south, since precipitation patterns in Texas run from the north to south/southwest. (See map of Average Annual Precipitation in Texas, page 19.)

MONTH	MIN.	10%	25%	50%	AVE.	MAX.
Abernathy						
January	0.00	0.00	0.09	0.35	0.57	3.75
February	0.00	0.01	0.12	0.45	0.67	2.28
March	0.00	0.01	0.17	0.44	0.72	3.13
April	0.00	0.13	0.37	0.88	1.11	3.96
May	0.31	0.68	0.98	1.81	2.47	6.32
June	0.32	0.52	1.56	2.84	3.03	8.36
July	0.00	0.46	1.20	2.38	2.44	9.68
August	0.10	0.45	0.83	1.96	2.34	8.54
September	0.05	0.34	0.74	1.81	2.27	6.43
October	0.00	0.00	0.28	1.00	1.67	7.41
November	0.00	0.00	0.05	0.37	0.61	2.08
December	0.00	0.01	0.09	0.31	0.57	2.22
Abilene						
January	0.00	0.00	0.10	0.79	0.98	4.29
February	0.02	0.10	0.35	1.02	1.08	3.57
March	0.02	0.13	0.41	0.79	1.08	5.08
April	0.00	0.44	0.97	1.87	2.10	6.76
May	0.14	0.70	1.44	2.98	3.36	13.11
June	0.00	0.35	1.46	2.19	2.80	9.55
July	0.00	0.23	0.86	1.71	2.16	7.11
August	0.00	0.34	0.74	1.60	2.31	8.18
September	0.00	0.50	1.23	2.31	2.79	10.97
October	0.00	0.35	1.01	2.08	2.51	10.64
November	0.00	0.00	0.33	0.76	1.23	4.55
December	0.00	0.01	0.18	0.74	1.05	6.22

MONTH	MIN.	10%	25%	50%	AVE.	MAX.
Ackerly						
January	0.00	0.00	0.00	0.37	0.56	2.17
February	0.00	0.00	0.09	0.44	0.63	3.20
March	0.00	0.00	0.00	0.48	0.75	3.91
April	0.00	0.00	0.23	0.74	1.14	7.15
May	0.00	0.53	1.10	2.04	2.58	12.61
June	0.00	0.00	0.87	2.05	2.13	7.22
July	0.00	0.10	0.59	1.79	2.25	8.30
August	0.00	0.10	0.60	1.21	1.78	5.53
September	0.00	0.00	0.99	1.99	2.60	10.53
October	0.00	0.00	0.49	1.10	1.67	6.49
November	0.00	0.00	0.00	0.20	0.59	2.89
December	0.00	0.00	0.01	0.46	0.65	3.84
Albany						
January	0.00	0.00	0.11	0.87	1.27	8.06
February	0.15	0.32	0.60	1.01	1.54	6.51
March	0.06	0.15	0.51	0.99	1.42	4.31
April	0.00	0.58	1.11	2.16	2.58	10.12
May	0.24	1.22	2.20	3.58	3.94	10.46
June	0.06	0.32	1.18	2.26	2.87	9.42
July	0.00	0.12	0.66	1.79	2.26	11.52
August	0.11	0.36	0.71	1.41	1.99	6.53
September	0.00	0.22	1.62	2.69	3.35	13.40
October	0.00	0.23	0.89	2.24	2.74	1.01
November	0.00	0.00	0.36	0.81	1.43	6.07
December	0.01	0.07	0.32	1.12	1.42	8.62

Alpine

MONTH	MIN.	10%	25%	50%	AVE.	MAX.
January	0.00	0.01	0.13	0.45	0.54	1.82
February	0.00	0.00	0.03	0.24	0.47	3.04
March	0.00	0.00	0.03	0.18	0.35	1.66
April	0.00	0.01	0.07	0.25	0.51	3.60
May	0.00	0.18	0.43	1.06	1.19	3.41
June	0.00	0.41	0.89	1.76	2.04	6.93
July	0.05	0.60	1.39	2.66	2.93	9.30
August	0.05	0.84	1.52	2.27	2.64	8.15
September	0.01	0.49	1.00	2.21	2.61	11.08
October	0.00	0.11	0.28	0.98	1.28	4.39
November	0.00	0.00	0.00	0.37	0.47	3.19
December	0.00	0.00	0.09	0.28	0.52	2.56

Amarillo

MONTH	MIN.	10%	25%	50%	AVE.	MAX.
January	0.00	0.00	0.11	0.42	0.53	2.30
February	0.00	0.03	0.20	0.48	0.55	1.76
March	0.00	0.02	0.26	0.59	0.88	3.93
April	0.00	0.19	0.40	0.85	1.03	2.75
May	0.01	0.74	1.40	2.47	2.69	9.76
June	0.00	1.00	1.70	3.15	3.44	10.62
July	0.11	0.79	1.46	2.50	2.77	7.50
August	0.26	1.20	1.68	2.87	2.99	7.45
September	0.02	0.31	0.68	1.59	1.84	4.95
October	0.00	0.12	0.45	0.99	1.34	4.78
November	0.00	0.00	0.14	0.39	0.60	2.23
December	0.00	0.02	0.15	0.27	0.52	4.46

Anahuac

MONTH	MIN.	10%	25%	50%	AVE.	MAX.
January	0.63	1.15	2.12	4.33	4.09	10.02
February	0.00	0.90	1.77	2.81	3.36	10.93
March	0.05	0.59	1.20	2.03	2.90	8.34
April	0.09	0.86	2.02	2.97	3.84	12.53
May	0.62	1.11	1.89	3.79	4.53	10.00
June	0.26	0.77	1.82	3.55	5.16	20.25
July	0.39	1.69	2.82	4.43	4.59	13.32
August	0.30	1.78	2.57	3.08	4.68	17.15
September	0.05	0.76	2.32	5.45	5.51	16.44
October	0.00	0.23	1.33	3.19	4.05	19.02
November	0.50	1.21	2.10	3.44	4.10	10.74
December	0.63	1.56	2.13	3.39	4.33	13.46

Austin

MONTH	MIN.	10%	25%	50%	AVE.	MAX.
January	0.02	0.35	0.60	1.23	1.79	9.14
February	0.23	0.59	1.13	2.28	2.40	6.48
March	0.00	0.25	0.81	1.66	1.84	5.97
April	0.03	0.53	1.38	2.18	2.89	9.85
May	0.77	1.17	1.60	3.89	4.40	9.90
June	0.00	0.66	1.51	2.63	3.41	14.87
July	0.00	0.11	0.44	1.10	1.75	10.50
August	0.00	0.25	0.60	1.19	2.03	8.84
September	0.09	0.80	1.50	3.15	3.22	7.41
October	0.00	0.56	0.87	2.78	3.50	12.25
November	0.00	0.32	0.74	1.71	2.05	7.28
December	0.00	0.32	0.74	1.24	2.18	14.05

Bakersfield

MONTH	MIN.	10%	25%	50%	AVE.	MAX.
January	0.00	0.00	0.02	0.31	0.61	4.24
February	0.00	0.00	0.10	0.40	0.62	4.37
March	0.00	0.00	0.02	0.22	0.42	1.83
April	0.00	0.00	0.11	0.54	0.82	3.58
May	0.00	0.43	0.89	1.30	1.76	4.56
June	0.00	0.00	0.18	1.20	1.40	6.00
July	0.00	0.03	0.14	0.81	1.21	6.23
August	0.00	0.03	0.40	1.17	1.46	4.73
September	0.05	0.22	0.60	1.64	2.49	23.41
October	0.00	0.12	0.32	1.38	1.83	13.30
November	0.00	0.00	0.00	0.35	0.57	2.61
December	0.00	0.00	0.00	0.23	0.54	2.92

Brady

MONTH	MIN.	10%	25%	50%	AVE.	MAX.
January	0.00	0.02	0.17	0.71	1.13	6.36
February	0.09	0.34	0.70	1.33	1.57	5.19
March	0.00	0.11	0.39	0.81	1.19	3.44
April	0.26	0.52	1.08	1.88	2.13	6.45
May	0.11	1.36	1.90	3.31	3.69	7.88
June	0.00	0.42	0.81	1.89	2.60	8.24
July	0.00	0.02	0.17	1.15	1.96	13.99
August	0.07	0.28	0.63	1.34	2.08	11.12
September	0.00	0.57	1.41	2.55	3.19	10.41
October	0.01	0.18	0.64	1.78	2.47	7.68
November	0.00	0.12	0.40	1.10	1.28	3.77
December	0.00	0.05	0.14	0.76	1.29	8.16

Brownsville

MONTH	MIN.	10%	25%	50%	AVE.	MAX.
January	0.00	0.13	0.36	1.07	1.37	4.74
February	0.00	0.05	0.35	1.00	1.43	10.21
March	0.00	0.01	0.11	0.33	0.60	3.44
April	0.00	0.00	0.23	0.88	1.65	10.33
May	0.00	0.25	1.14	1.95	2.50	9.05
June	0.00	0.06	1.34	2.20	2.80	8.45
July	0.00	0.10	0.31	1.06	1.63	9.35
August	0.00	0.12	0.88	2.10	2.52	9.47
September	0.05	1.43	2.79	4.71	5.35	20.09
October	0.33	0.63	1.26	2.79	3.17	17.03
November	0.00	0.09	0.51	0.86	1.48	7.63
December	0.00	0.02	0.14	0.71	1.09	3.91

Cameron

MONTH	MIN.	10%	25%	50%	AVE.	MAX.
January	0.00	0.55	0.96	1.73	2.28	8.94
February	0.44	0.85	1.63	2.84	2.78	7.38
March	0.07	0.48	0.96	1.74	2.20	7.29
April	0.01	1.31	1.62	2.53	3.54	11.58
May	0.57	0.88	2.96	4.12	4.36	9.74
June	0.00	0.46	1.13	2.54	3.01	8.61
July	0.00	0.00	0.20	1.01	1.50	9.23
August	0.00	0.08	0.36	1.21	1.66	5.71
September	0.01	0.72	1.17	3.28	3.54	12.49
October	0.00	0.58	1.32	2.40	3.54	11.49
November	0.00	0.58	1.18	2.51	2.73	7.6
December	0.18	0.51	1.16	2.06	2.64	11.64

Childress

MONTH	MIN.	10%	25%	50%	AVE.	MAX.
January	0.00	0.00	0.12	0.32	0.60	3.43
February	0.00	0.05	0.28	0.62	0.85	2.89
March	0.00	0.11	0.38	0.84	1.11	4.47
April	0.00	0.11	0.58	1.26	1.69	7.29
May	0.07	1.17	1.86	2.70	3.33	8.11
June	0.10	0.59	1.40	2.66	3.00	7.50
July	0.09	0.25	0.72	1.88	2.06	6.73
August	0.07	0.27	0.74	1.57	1.88	5.74
September	0.05	0.18	0.56	1.89	2.25	6.68
October	0.00	0.05	0.49	1.37	2.02	9.88
November	0.00	0.01	0.15	0.73	0.89	4.24
December	0.00	0.01	0.20	0.59	0.79	3.86

College Station

MONTH	MIN.	10%	25%	50%	AVE.	MAX.
January	0.21	0.54	1.24	2.23	2.87	15.53
February	0.10	0.87	1.52	2.68	2.89	9.72
March	0.26	0.61	1.30	1.96	2.43	6.03
April	0.04	0.94	1.71	3.32	3.73	12.44
May	0.21	1.63	2.20	4.50	4.73	11.30
June	0.07	0.53	1.47	2.75	3.78	12.56
July	0.00	0.09	0.74	1.93	2.19	7.05
August	0.00	0.19	0.60	1.83	2.29	10.61
September	0.31	0.66	2.12	4.08	4.37	12.06
October	0.00	0.36	1.79	3.16	3.74	12.84
November	0.17	0.84	1.70	2.87	3.12	8.30
December	0.23	0.93	1.67	2.56	2.93	8.57

Corpus Christi

MONTH	MIN.	10%	25%	50%	AVE.	MAX.
January	0.01	0.13	0.35	1.20	1.61	10.71
February	0.00	0.20	0.92	1.39	1.91	8.06
March	0.00	0.05	0.15	0.66	1.12	4.76
April	0.00	0.05	0.35	1.52	2.06	8.01
May	0.00	0.57	1.25	2.70	3.17	9.34
June	0.02	0.28	0.73	2.41	3.20	13.31
July	0.00	0.01	0.30	1.10	1.93	11.86
August	0.10	0.45	0.80	2.45	3.09	14.74
September	0.46	0.88	2.00	4.19	5.36	20.27
October	0.00	0.17	0.86	2.55	3.20	10.97
November	0.00	0.10	0.41	1.11	1.51	5.17
December	0.00	0.08	0.41	0.88	1.54	9.68

Cotulla

MONTH	MIN.	10%	25%	50%	AVE.	MAX.
January	0.00	0.05	0.17	0.62	0.99	5.44
February	0.00	0.05	0.37	1.08	1.31	3.81
March	0.00	0.02	0.13	0.60	0.83	5.83
April	0.00	0.30	1.01	1.66	2.10	9.35
May	0.05	0.27	0.85	2.11	2.70	7.60
June	0.00	0.35	1.16	2.08	2.67	11.53
July	0.00	0.00	0.14	0.70	1.27	6.12
August	0.00	0.10	0.40	1.19	2.00	13.17
September	0.02	0.46	0.95	2.10	2.77	9.52
October	0.00	0.10	0.80	2.08	2.99	12.86
November	0.00	0.00	0.25	0.86	1.14	3.73
December	0.00	0.00	0.19	0.79	1.15	4.10

Dalhart

MONTH	MIN.	10%	25%	50%	AVE.	MAX.
January	0.00	0.00	0.05	0.34	0.43	1.69
February	0.00	0.00	0.05	0.31	0.42	1.73
March	0.00	0.00	0.15	0.56	0.83	2.92
April	0.00	0.10	0.36	0.62	1.08	3.53
May	0.19	0.81	1.67	2.77	2.73	6.38
June	0.00	0.38	1.01	2.01	2.29	6.94
July	0.23	0.73	1.51	2.46	3.10	8.85
August	0.01	0.42	1.40	2.51	2.72	9.66
September	0.01	0.18	0.48	1.19	1.56	8.33
October	0.00	0.06	0.16	0.59	1.09	5.94
November	0.00	0.00	0.05	0.27	0.57	3.19
December	0.00	0.00	0.12	0.26	0.42	1.91

Dallas

MONTH	MIN.	10%	25%	50%	AVE.	MAX.
January	0.00	0.29	0.85	1.81	1.91	8.36
February	0.24	0.79	1.20	2.17	2.33	5.65
March	0.12	0.49	1.23	2.40	2.88	9.05
April	0.02	0.89	1.94	3.62	3.99	15.37
May	0.52	1.53	3.03	4.31	5.11	13.66
June	0.28	0.65	1.49	2.98	3.43	10.83
July	0.00	0.18	0.58	1.63	2.17	8.49
August	0.01	0.12	0.62	1.71	2.07	5.92
September	0.00	0.71	1.50	2.58	3.08	10.64
October	0.00	0.41	1.06	2.96	3.97	16.00
November	0.14	0.40	1.01	1.89	2.29	7.50
December	0.03	0.28	0.86	1.54	2.22	9.20

Dekalb

MONTH	MIN.	10%	25%	50%	AVE.	MAX.
January	0.20	0.94	1.60	3.20	3.35	10.36
February	0.61	1.31	2.55	3.74	3.74	7.46
March	0.58	1.23	2.36	4.13	4.28	11.02
April	0.51	1.10	2.35	3.44	4.56	14.11
May	0.12	1.78	2.29	4.23	5.41	16.39
June	0.07	0.77	1.24	2.83	3.75	9.55
July	0.12	1.24	2.62	3.91	4.21	8.79
August	0.05	0.53	1.12	2.28	2.76	10.62
September	0.07	0.45	1.57	3.54	3.79	12.94
October	0.14	0.55	1.43	3.29	4.32	13.90
November	0.47	0.87	1.71	3.69	4.46	12.05
December	0.12	0.69	1.97	3.90	4.33	12.57

Eagle Pass

MONTH	MIN.	10%	25%	50%	AVE.	MAX.
January	0.00	0.02	0.13	0.49	0.78	3.33
February	0.00	0.09	0.27	0.59	1.05	6.23
March	0.00	0.02	0.13	0.34	0.65	3.09
April	0.00	0.06	0.31	1.41	1.87	11.65
May	0.00	0.43	1.32	2.90	3.12	7.09
June	0.00	0.01	0.61	1.84	2.64	14.61
July	0.00	0.00	0.23	1.12	1.99	13.15
August	0.00	0.14	0.31	1.12	2.08	8.70
September	0.07	0.26	1.11	2.46	2.92	11.74
October	0.00	0.04	0.34	1.61	2.21	9.43
November	0.00	0.00	0.08	0.62	0.79	3.98
December	0.00	0.01	0.15	0.39	0.77	3.86

MONTH	MIN.	10%	25%	50%	AVE.	MAX.
El Paso						
January	0.00	0.01	0.14	0.30	0.42	1.75
February	0.00	0.00	0.05	0.36	0.40	1.61
March	0.00	0.00	0.02	0.18	0.29	2.24
April	0.00	0.00	0.00	0.07	0.20	1.39
May	0.00	0.00	0.02	0.14	0.33	4.08
June	0.00	0.00	0.00	0.25	0.62	3.12
July	0.03	0.18	0.71	1.14	1.55	5.47
August	0.00	0.25	0.48	1.08	1.46	5.50
September	0.00	0.01	0.15	0.91	1.36	6.58
October	0.00	0.00	0.17	0.52	0.70	3.08
November	0.00	0.00	0.03	0.18	0.33	1.60
December	0.00	0.00	0.07	0.36	0.59	3.23
Falfurrias						
January	0.05	0.14	0.30	0.84	1.26	9.76
February	0.00	0.07	0.61	1.12	1.62	6.17
March	0.00	0.01	0.11	0.57	0.71	2.71
April	0.00	0.08	0.33	1.01	1.35	5.36
May	0.09	0.81	1.41	2.56	2.96	12.31
June	0.00	0.13	0.79	2.77	3.21	12.95
July	0.00	0.06	0.24	1.02	1.59	11.51
August	0.01	0.10	0.53	1.46	2.39	12.83
September	0.39	1.05	1.63	3.42	4.63	32.76
October	0.00	0.27	0.63	1.81	2.64	7.16
November	0.00	0.06	0.23	0.76	1.06	5.17
December	0.00	0.06	0.25	0.83	1.18	4.90
Galveston						
January	0.16	1.15	1.52	3.14	3.32	10.69
February	0.07	0.46	1.14	2.00	2.54	8.27
March	0.03	0.22	0.77	1.47	2.15	9.39
April	0.00	0.33	0.78	1.89	2.50	10.35
May	0.00	0.44	1.30	2.69	3.34	10.92
June	0.21	0.74	1.58	3.36	3.92	14.74
July	0.00	0.34	1.21	2.67	3.59	17.38
August	0.14	0.60	1.76	3.20	4.14	15.20
September	0.27	1.20	2.84	4.44	5.34	15.36
October	0.00	0.21	1.13	2.25	2.75	9.02
November	0.45	0.68	1.35	2.39	3.05	10.74
December	0.48	1.28	1.95	2.67	3.32	8.94
Gonzales						
January	0.00	0.37	0.84	1.56	2.08	7.78
February	0.13	0.37	1.33	2.08	2.36	8.64
March	0.01	0.20	0.77	1.39	1.76	4.84
April	0.16	0.68	1.10	2.75	3.38	10.43
May	0.26	1.44	2.22	3.45	4.53	15.15
June	0.00	0.90	1.59	2.53	3.90	20.18
July	0.00	0.15	0.39	1.19	1.53	5.29
August	0.12	0.35	0.65	1.38	2.09	17.01
September	0.16	0.85	1.82	3.05	3.73	18.79
October	0.00	0.50	0.96	2.31	3.18	13.08
November	0.01	0.50	0.97	1.81	2.37	7.16
December	0.00	0.38	0.77	1.43	2.13	9.57

MONTH	MIN.	10%	25%	50%	AVE.	MAX.
Harlingen						
January	0.00	0.17	0.30	0.96	1.46	5.07
February	0.00	0.14	0.40	1.18	1.66	9.45
March	0.00	0.03	0.19	0.60	0.92	3.91
April	0.00	0.07	0.34	0.92	1.98	17.13
May	0.01	0.41	1.08	2.06	2.84	11.90
June	0.00	0.14	0.93	2.30	2.69	7.46
July	0.00	0.18	0.41	0.89	1.65	8.59
August	0.00	0.30	0.94	2.01	2.69	11.21
September	0.08	1.14	2.23	4.38	5.06	17.57
October	0.00	0.46	1.03	2.17	2.59	10.63
November	0.01	0.23	0.42	1.09	1.45	4.26
December	0.00	0.06	0.23	0.84	1.21	4.25
Houston						
January	0.15	1.11	2.13	3.44	3.70	9.49
February	0.09	0.65	1.90	3.23	3.48	11.20
March	0.03	0.71	1.16	2.00	2.71	11.38
April	0.04	0.89	1.37	2.76	3.49	10.41
May	0.46	1.16	2.46	3.81	4.84	14.76
June	0.17	1.52	2.16	4.25	5.85	17.28
July	0.05	0.82	2.02	3.43	4.29	17.22
August	0.35	1.07	2.07	3.17	4.23	15.97
September	0.14	0.63	1.87	4.53	4.85	15.30
October	0.00	0.62	1.64	3.09	4.76	22.20
November	0.16	1.09	1.50	2.99	4.02	10.15
December	0.47	1.11	1.59	3.17	3.55	9.69
Hunt						
January	0.00	0.17	0.30	1.01	1.31	6.88
February	0.00	0.35	0.91	1.50	1.82	6.14
March	0.00	0.10	0.40	1.10	1.48	4.70
April	0.07	0.52	1.11	1.74	2.32	9.25
May	0.48	1.18	2.09	3.16	3.81	10.10
June	0.00	0.50	1.44	2.41	2.80	10.47
July	0.00	0.18	0.50	2.00	2.34	10.35
August	0.00	0.00	0.63	1.57	2.66	20.01
September	0.20	0.80	1.43	3.08	3.40	12.26
October	0.00	0.10	0.75	2.39	3.12	9.00
November	0.00	0.00	0.36	1.19	1.52	4.84
December	0.00	0.00	0.24	0.83	1.45	10.11
Karnack						
January	0.05	0.91	1.92	3.22	3.74	12.58
February	0.54	1.86	2.69	3.61	4.09	8.99
March	0.00	1.18	2.45	3.92	3.98	9.36
April	0.00	1.57	2.54	3.59	4.40	13.97
May	0.00	2.10	2.75	4.65	5.02 1	4.05
June	0.00	1.10	1.64	3.66	4.46	14.47
July	0.00	0.46	1.47	3.08	3.17	9.17
August	0.11	0.47	0.87	1.99	2.52	7.45
September	0.23	0.65	1.35	2.43	3.57	11.87
October	0.00	0.52	1.25	2.98	3.80	12.65
November	0.18	1.29	2.91	4.66	4.69	11.11
December	0.00	1.82	2.61	3.66	4.32	10.39

MONTH	MIN.	10%	25%	50%	AVE.	MAX.
Longview						
January	0.12	0.82	1.80	3.76	3.68	8.40
February	0.51	1.86	2.87	3.62	3.90	7.83
March	0.48	1.62	2.26	3.68	3.84	11.61
April	0.20	1.24	1.50	4.20	4.49	15.25
May	0.42	1.46	2.40	4.68	5.18	12.46
June	0.38	0.99	2.09	3.76	4.36	14.35
July	0.00	0.28	1.02	2.07	3.14	12.36
August	0.10	0.43	1.03	2.06	2.43	9.96
September	0.07	0.77	1.94	3.61	3.93	11.13
October	0.00	0.72	1.60	2.64	3.75	14.03
November	0.23	0.97	2.55	4.16	4.31	9.30
December	0.45	1.36	2.04	3.71	4.17	12.69
Lubbock						
January	0.00	0.00	0.05	0.31	0.50	3.98
February	0.00	0.02	0.14	0.36	0.61	2.46
March	0.00	0.02	0.15	0.54	0.75	3.12
April	0.02	0.10	0.33	0.85	1.05	3.44
May	0.06	0.66	1.34	2.41	2.62	7.77
June	0.00	0.49	1.37	2.25	2.84	7.91
July	0.00	0.23	0.75	2.03	2.20	7.14
August	0.03	0.29	0.68	1.75	2.06	8.77
September	0.00	0.14	0.63	1.74	2.22	6.82
October	0.00	0.01	0.47	0.95	1.80	10.77
November	0.00	0.00	0.02	0.31	0.59	2.67
December	0.00	0.01	0.07	0.32	0.51	2.19
Lufkin						
January	0.22	1.08	1.97	2.53	3.73	13.09
February	0.89	1.40	1.74	2.87	3.38	9.87
March	0.19	0.99	1.70	3.19	3.18	7.19
April	0.28	0.70	2.36	3.45	3.83	8.77
May	0.59	1.36	3.37	4.52	5.00	12.07
June	0.33	1.15	1.45	3.21	3.70	13.93
July	0.00	0.58	1.51	2.29	2.67	6.94
August	0.13	0.68	1.14	1.90	2.59	8.46
September	0.09	0.74	2.02	2.43	3.44	11.19
October	0.00	0.46	1.26	2.68	3.60	15.45
November	0.76	1.10	2.06	3.17	3.79	12.86
December	0.58	1.67	2.17	3.69	4.04	10.01
Midland						
January	0.00	0.00	0.07	0.37	0.54	3.57
February	0.00	0.07	0.17	0.35	0.60	2.52
March	0.00	0.00	0.02	0.20	0.46	2.83
April	0.00	0.00	0.09	0.60	0.75	2.40
May	0.06	0.33	0.91	1.84	2.11	7.58
June	0.00	0.33	0.71	1.39	1.53	3.94
July	0.00	0.05	0.32	1.12	1.86	8.47
August	0.12	0.22	0.62	1.21	1.65	4.36
September	0.07	0.15	0.68	1.56	2.12	9.64
October	0.00	0.11	0.39	1.04	1.62	7.38
November	0.00	0.00	0.01	0.25	0.56	2.30
December	0.00	0.01	0.15	0.25	0.52	3.22

MONTH	MIN.	10%	25%	50%	AVE.	MAX.
Palacios						
January	0.23	0.50	1.25	2.62	2.82	10.19
February	0.15	0.61	1.10	2.77	2.85	9.36
March	0.12	0.31	0.66	1.40	2.18	9.22
April	0.00	0.36	1.10	2.33	2.71	9.21
May	0.02	0.68	1.50	3.29	4.41	13.15
June	0.00	0.49	1.47	3.03	4.38	15.49
July	0.08	0.25	0.89	2.31	3.56	12.79
August	0.06	0.39	0.94	2.77	3.52	13.59
September	0.43	0.81	2.22	4.26	5.64	23.66
October	0.00	0.50	1.14	2.72	4.53	24.21
November	0.07	0.49	1.10	2.47	3.03	9.13
December	0.28	0.76	1.12	2.34	3.11	9.02
Port Arthur						
January	0.54	1.60	2.07	4.67	4.82	14.79
February	0.14	0.70	2.01	3.92	3.97	13.07
March	0.05	0.58	1.27	2.61	3.20	10.16
April	0.24	0.88	1.85	3.13	3.93	15.28
May	0.08	0.60	2.71	4.60	5.29	13.08
June	0.74	1.12	1.94	3.91	5.43	18.82
July	0.60	2.02	3.29	4.62	5.37	18.59
August	0.89	1.65	2.49	3.93	5.08	17.17
September	0.50	1.03	2.40	4.10	5.62	21.92
October	0.00	0.07	1.66	3.09	4.24	15.05
November	0.14	1.38	2.60	3.89	4.35	10.81
December	1.27	2.01	2.87	4.03	5.01	17.93
San Angelo						
January	0.00	0.00	0.06	0.55	0.82	3.61
February	0.00	0.12	0.34	0.62	0.98	4.44
March	0.00	0.03	0.22	0.46	0.82	4.96
April	0.05	0.27	0.71	1.06	1.62	5.09
May	0.23	0.52	1.45	2.43	2.85	11.18
June	0.05	0.15	0.65	2.11	2.17	5.98
July	0.00	0.15	0.30	0.78	1.23	7.09
August	0.00	0.15	0.45	1.34	1.63	8.07
September	0.00	0.25	1.14	2.66	2.97	10.93
October	0.00	0.07	0.42	1.88	2.28	8.63
November	0.00	0.00	0.21	0.55	0.87	3.53
December	0.00	0.00	0.05	0.31	0.77	3.91
San Antonio						
January	0.02	0.24	0.56	1.12	1.64	8.40
February	0.01	0.39	0.85	1.73	1.92	6.34
March	0.00	0.11	0.53	1.16	1.59	6.06
April	0.08	0.47	1.22	2.03	2.61	9.25
May	0.16	0.93	1.73	3.05	4.08	12.77
June	0.00	1.00	1.58	2.68	3.59	11.89
July	0.00	0.02	0.22	1.25	1.93	8.22
August	0.00	0.13	0.62	1.96	2.44	11.09
September	0.47	0.74	1.05	2.23	3.15	13.03
October	0.00	0.44	1.09	2.71	3.19	9.74
November	0.00	0.12	0.69	1.88	2.17	5.99
December	0.02	0.15	0.37	1.00	1.65	13.86

Waco

MONTH	MIN.	10%	25%	50%	AVE.	MAX.
January	0.02	0.42	0.74	1.34	1.70	5.79
February	0.17	0.48	1.31	1.92	2.21	6.25
March	0.02	0.58	0.82	2.18	2.25	5.53
April	0.10	1.16	1.57	2.74	3.23	13.26
May	0.61	1.47	2.17	3.92	4.62	14.89
June	0.26	0.44	0.94	2.14	2.86	12.02
July	0.00	0.07	0.25	0.74	1.81	8.53
August	0.00	0.16	0.53	0.90	1.61	8.83
September	0.00	0.31	0.73	2.53	3.07	7.24
October	0.00	0.86	1.25	2.40	3.20	10.43
November	0.12	0.29	0.81	2.08	2.26	6.19
December	0.03	0.40	0.50	1.71	2.00	8.34

Weatherford

MONTH	MIN.	10%	25%	50%	AVE.	MAX.
January	0.00	0.13	0.34	1.45	1.68	6.20
February	0.04	0.56	0.95	1.69	2.15	5.41
March	0.23	0.66	1.04	1.82	2.27	7.14
April	0.30	1.22	1.70	2.61	3.34	11.65
May	0.49	1.87	2.80	4.45	4.79	16.31
June	0.00	0.91	1.48	2.91	3.39	9.45
July	0.00	0.16	0.83	1.90	2.15	11.07
August	0.02	0.23	0.97	1.66	2.09	8.46
September	0.00	0.27	1.31	2.74	3.16	8.61
October	0.00	0.51	0.97	1.98	3.54	14.88
November	0.00	0.28	0.86	1.57	1.84	5.51
December	0.00	0.24	0.49	1.40	1.80	10.98

Wichita Falls

MONTH	MIN.	10%	25%	50%	AVE.	MAX.
January	0.00	0.12	0.23	1.02	1.04	4.41
February	0.00	0.20	0.61	1.05	1.34	4.47
March	0.00	0.42	1.07	1.70	1.86	5.29
April	0.30	0.62	1.53	2.37	2.78	8.44
May	0.00	1.01	2.23	4.05	4.48	13.07
June	0.22	0.87	1.65	2.86	3.39	8.55
July	0.02	0.20	0.70	1.44	1.98	11.74
August	0.03	0.18	0.55	1.82	2.12	7.55
September	0.00	0.04	1.41	2.28	3.25	10.16
October	0.00	0.34	0.99	2.07	2.74	7.81
November	0.00	0.02	0.28	0.86	1.36	5.66
December	0.01	0.10	0.39	0.85	1.41	6.86

Wink

MONTH	MIN.	10%	25%	50%	AVE.	MAX.
January	0.00	0.00	0.05	0.12	0.43	3.04
February	0.00	0.00	0.04	0.25	0.42	1.63
March	0.00	0.00	0.00	0.10	0.35	2.96
April	0.00	0.00	0.10	0.36	0.72	4.74
May	0.05	0.25	0.42	0.85	1.20	8.61
June	0.00	0.04	0.31	1.18	1.45	4.84
July	0.00	0.25	0.59	1.34	1.84	5.83
August	0.00	0.14	0.37	1.13	1.27	3.71
September	0.00	0.08	0.49	1.19	1.76	9.04
October	0.00	0.00	0.18	0.93	1.38	5.59
November	0.00	0.00	0.00	0.15	0.46	2.34
December	0.00	0.00	0.05	0.14	0.40	3.04

VII. COST CONSIDERATIONS

A rainwater harvesting system designed as an integrated component of a new construction project is generally more cost-effective than retrofitting a system onto an existing building. This is because many of the shared costs (roof and gutters) can be designed to optimize system performance, and the investment can be amortized over time. As described above, a system can be designed as a full-service or supplemental water source, each having specific costs and paybacks. While costs for the same system are equivalent regardless of whether there is access to a municipal water supply, *payback* (the amount of time it takes to recoup the investment relative to dollars saved) varies depending on other available water supply options. For example, based on current water rates, payback on a system where the only option is drilling a well is better than if municipal water supply is available, since the cost of drilling a well and associated annual maintenance and treatment costs are often higher than annual costs of a municipal water supply. Other variables which affect system economics include choice of tank and filtration. In general, maximizing storage capacity and minimizing water use through conservation and reuse are important rules to keep in mind.

For buildings outside a municipal water service area, rainwater harvesting systems designed to fulfill all water requirements can be as costly, and frequently more expensive, than the cost of drilling a conventional well. However, there is evidence that with careful planning and design, the cost of a rainwater system can be less than the cost of a well in many cases – especially if the well water must be softened and treated to remove dissolved minerals, and the rainwater system is owner-built, which is a viable option for people with available time and basic skills. Factoring in the full costs of drilling and operating a well are necessary to understand comparative costs. For example, costs of drilling a well vary depending on soil type and water availability, and range from about $6.00 to $15.00 per linear foot of depth. In addition, wells require a pump and possibly a water softener and filter, depending on water quality. Monthly costs including operations, maintenance, appliance replacement, are estimated to be as much as $120. In addition, reliance on well water has the potential uncertainties of long term water supply and water quality. And, if salt is added to well water, a related environmental cost is the resulting negative impact on soil quality, which can make the soil sterile.

Around the state, city-supplied water is relatively inexpensive, though does not always reflect the "full" cost of water including costs of treatment and pumping. For new construction, many cities require a tap to be installed before a Certificate of Occupancy will be issued. The tap fee is generally in the range of $1,500 to $2,900, depending on rates for particular cities. Because of these factors, the return of a full-service rainwater harvesting system where city water is available is rarely less than 30 years and can be as high as 90 years, assuming about present values for municipal water and approximate construction costs of $1.00 per gallon of collection capacity for a rainwater harvesting system.

Although difficult to quantify, an important consideration for some people when comparing options is the value of water *quality*, which varies tremendously depending on source. Some rainwater harvesters in Texas believe rainwater to be the highest quality water available, and therefore worth the added expense to harvest.

Understanding water quality relative to available water sources may be an important consideration for you in determining what water source to rely on.

Hardness and high mineral content in some parts of Texas make municipal and private well water less desirable because of deposits that build-up on pipes and appliances, poor taste, and possible negative health effects. Therefore, the value of the rainwater due to its high quality may offset the added expense if the alternative is high mineral content city-water, especially if additional costs of bottled water for cooking and drinking, a water softener, and increased soap use are factored in. In parts of the state where city-supplied water is satisfactory, a rainwater system as a supplemental water source may be most practical. For example, a system sized just for drinking and cooking, or just for garden irrigation, can be significantly smaller than a full-service system, but provide the benefits that have particular value to the user.

Conventional financing for stand alone rainwater harvesting systems has been provided for just a few new homes in Texas. While this has not become standard practice, such precedents will help to educate the financial community of the viability of rainwater harvesting. However, until this practice is better understood, appraisers may underestimate the value of a rainwater system, and insurance underwriters may require a back-up water source such as an on-demand supply contract with a local water hauler.

The term "stand alone system" refers to rainwater harvesting systems that do not have municipal or well water back-up.

VIII. CODE AND SAFETY ISSUES

The Texas Natural Resource Conservation Commission (TNRCC) regulates municipal and well water, not rainwater. The Texas Department of Health (TDH) regulates mosquito hazards and greywater. Check with local authorities since no agency authorizes or inspects private rainwater collection systems. The Texas Plumbing Code does not allow double trenching wastewater and potable water lines. In Austin, for example, an airgap wider than the municipal line must exist between the public water and rainwater to keep the rainwater from entering the supply outlet.

The State of Ohio Department of Health and the State of Virginia Bureau of Sewage and Water Services regulate rainwater systems. Since the State of Texas does not presently inspect or enforce any guidelines regarding captured rainfall, you may want to consider some specifications from these other states when designing your system.

- A cistern may not be located closer than 50 feet from a source of contamination, such as a septic tank.
- A cistern must be located on a grade lower than the roof washer to ensure that it can fill completely.
- A rainwater system must include installation of an overflow pipe which empties into a non-flooding area.
- Inlets to cisterns must be designed to dissipate pressure of influent stream and minimize the stirring of any settled solids.
- An above-ground roof washer or filtering device shall be provided on all cisterns.
- The water intake for a pump in a cistern shall be attached to a flotation device and be located a minimum of 4 inches below the surface of the water.
- Overflow from rainwater systems cannot flow into wastewater systems.
- Cisterns shall be accessible for cleaning.
- All openings into the cistern shall be screened.
- Cisterns cannot be relied upon to provide potable water without adequate treatment consisting of roofwashing and continuous disinfection.

CASE Studies

The following case studies are organized by material (masonry, cast in place concrete, ferrocement, fiberglass, polyethylene, steel, and composite systems utilizing more than one material) and capacity (from smallest to largest). With the exception of a few installations identified by a proper name, these systems are found on buildings throughout the state, with a majority in central Texas.

MASONRY AND CONCRETE

MASONRY

County:	Gillespie
Number of People in Household:	2
Roofing Material:	Galvanized Steel
Gutter and Downspout Material:	Galvanized Steel
Preliminary Filters:	Inlet Screen
Above or Below Ground Storage:	Below
Cistern Materials:	Masonry
Site Built or Shop Fabricated:	Site Built
Number of Cisterns:	1
Storage Capacity:	1,200 Gallons
Installation Date:	1889
Cost:	Unknown
Potable or Non Potable	Potable only Water Supply
Treatment:	Coal at top of cistern to filter incoming rain
Integrated with Greywater System:	No
Additional Comments:	In last 47 years of continuous use, only one repair of replastering a crack.

CAST IN PLACE CONCRETE

County:	Travis
Number of People in Household:	3
Roofing Material:	Galvanized Steel
Gutter and Downspout Material:	Seamless Aluminum
Preliminary Filters:	Screen Basket
Above or Below Ground Storage:	Below
Cistern Materials:	Concrete
Site Built or Shop Fabricated:	Poured in Place
Number of Cisterns:	1
Storage Capacity:	25,000 Gallons
Installation Date:	1992
Cost:	$18,000
Potable or Non Potable Water Supply:	Both
Treatment:	15 Micron Sediment Filter
Integrated with Greywater System:	House is plumbed for black and greywater reuse but recovery system is not in place

CAST IN PLACE CONCRETE

County:	Travis
Number of People in Household:	3
Roofing Material:	Galvanized Steel
Gutter and Downspout Material:	Aluminum
Preliminary Filters:	Leaf Screens and Roof Washer
Above or Below Ground Storage:	Above
Cistern Material:	Concrete
Site Built or Shop Fabricated:	Site Built
Number of Cisterns:	1 Rain Cistern, 1 Greywater Tank
Storage Capacity:	25,000 Gallons Rain, 2,500 Gallons Greywater
Installation Date:	1994
Cost:	$30,000
Potable or Non Potable Water Supply:	Both
Treatment:	5 Micron Sediment Filter, Carbon Cartridge, Ultraviolet Light and Reverse Osmosis
Integrated with Greywater System:	Yes

GUNNITE

County:	Travis
Number of People in Household:	3
Roofing Material:	Galvalume
Gutter and Downspout Material:	Aluminum
Preliminary Filters:	Inlet Screens and Roof Washer
Above or Below Ground Storage:	Below
Cistern Material:	Gunnite
Site Built or Shop Fabricated:	Site Built
Number of Cisterns:	1
Storage Capacity:	25,000 Gallons
Installation Date:	1995
Cost:	$7,000
Potable or Non Potable Water Supply:	Potable
Treatment:	Sediment Filter and Ultraviolet Light
Integrated with Greywater System:	No
Additional Comments:	Cistern built like a swimming pool with domed concrete cover.

FERROCEMENT

County:	Hidalgo
Number in Household:	6
Roofing Material:	Mineralized Asphalt
Preliminary Filters:	Manual Roofwashing Prior to Rainfall
Above or Below Ground Storage:	Above
Cistern Material:	Ferrocement
Site Built or Shop Fabricated:	Site Built
Number of Cisterns:	1
Storage Capacity:	600 Gallons
Installation Date:	1992
Cost:	$100
Potable or Non Potable Water Supply:	Potable (Cooking and Drinking only)
Filters:	None
Integrated with Greywater System:	Yes. Also rainwater diversion system that irrigates 19-tree orchard with 24,000 gallons per year
Additional Comments:	While the asphalt roofing is not recommended for potable water supply, no significant levels of any contaminant have been detected. The only objection to the mineralized asphalt roofing is its texture which makes cleaning the catchment area prior to a rain event more difficult than it would be on a smoother surface such as metal.

CASE Studies

FERROCEMENT

Location:	Travis
Number of People in Household:	3
Roofing Material:	Metal
Gutter and Downspout Material:	Seamless Metal
Preliminary Filters:	Screen over Downspouts
Above or Below Ground Storage:	Above
Cistern Material:	Ferrocement
Site Built or Shop Fabricated:	Site Built
Number of Cisterns:	1
Storage Capacity:	20,000 Gallons
Installation Date:	1995
Cost:	$6,790 for Cistern Only
Potable or Non Potable Water Supply:	Both
Treatment:	20 and 5 Micron Sediment Filters and Ultraviolet Light
Integrated with Greywater System:	No

FERROCEMENT

Location:	Travis
Number of People in Household:	3
Roofing Material:	Galvanized Sheet Metal
Gutter and Downspout Material:	Seamless Aluminum
Preliminary Filters:	Roof Washer
Above or Below Ground Storage:	Above
Cistern Materials:	Ferrocement
Site Built or Shop Fabricated:	Site Built
Number of Cisterns:	1
Storage Capacity:	20,000 Gallons
Installation Date:	1995
Cost:	$9,000
Potable or Non Potable Water Supply:	Both
Treatment:	None
Integrated with Greywater System:	No

FERROCEMENT

County:	Williamson
Number of People in Household:	5
Roofing Material:	Galvalume
Gutter and Downspout Material:	Aluminum/PVC
Preliminary Filters:	Manual Wash Box
Above or Below Ground Storage:	Above Ground
Cistern Material:	Ferrocement
Site Built or Shop Fabricated:	Site Built
Number of Cisterns:	1
Storage Capacity:	25,000 Gallons
Installation Date:	1995
Cost:	$8,000
Potable or Non Potable Water Supply:	Potable
Treatment:	Ultraviolet Light and 400 micron Cartridge Filter
Integrated with Greywater System:	No
Additional Comments:	Daily per capita water use for family of 5 averages 150 gallons per day but can be reduced to 120 gallons per day.

FERROCEMENT

County:	Travis
Number of People in Household:	6
Roofing Material:	Tin
Gutter and Downspout Material:	Tin
Preliminary FIlters:	Screen at Cistern Inlet
Above or Below Ground Storage:	Above and Below
Cistern Material:	Reinforced Concrete
Site Built or Shop Fabricated:	Site Built
Number of Cisterns:	1
Storage Capacity:	26,000 Gallons
Installation Date:	1994
Cost:	$20,000
Potable or Non Potable Water Supply:	Both
Treatment:	Ultraviolet Light
Integrated with Greywater System:	Yes. Both black and greywater pass through a sand filter then are reused in a drip irrigation system around the house. FERROcement

FERROCEMENT

County:	Hays
Number of People in Household:	3
Roofing Material:	Metal
Gutter and Downspout Material:	Seamless Metal
Preliminary Filters:	20 and 5 Micron Sediment Filters
Above or Below Ground Storage:	Partially Below Ground
Cistern Material:	Reinforced Concrete
Site Built or Shop Fabricated:	Site Built
Number of Cisterns:	1
Storage Capacity:	28,000 Gallons
Installation Date:	1995
Cost:	$9,400
Potable or Non Potable Water Supply:	Both
Treatment:	Ultraviolet Light
Integrated with Greywater System:	No
Additional Comments:	Unusual 32 feet long by 15 feet wide by 5 feet high rectangular shape.

FERROCEMENT

County:	Travis
Number of People in Household:	3
Roofing Material:	Cement Shingles
Gutter and Downspout Material:	Aluminum
Preliminary Filters:	Leaf Screens
Above or Below Ground Storage:	Below Ground 6 Feet, Above Ground 3 Feet
Cistern Material:	Ferrocement
Site Built or Shop Fabricated:	Site Built
Number of Cisterns:	1
Storage Capacity:	33,000 Gallons
Installation Date:	1995
Cost:	$6,800
Potable or Non Potable Water Supply:	Potable
Treatment:	5 Micron Sediment Filter
Integrated with Greywater System:	No
Additional Comments:	Unusual 35 foot long kidney shaped tank covered with earth and terraced with limestone

PLASTIC

FIBERGLASS

County:	Bexar
Number of People in Household:	1
Roofing Material:	Asbestos Shingles
Gutter and Downspout Material:	Aluminum
Preliminary Filters:	Leaf Screens
Above or Below Ground Storage:	Above
Cistern Materials:	Fiberglass
Site Built or Shop Fabricated:	Prefabricated
Number of Cisterns:	2
Storage Capacity:	1,000 (2 @ 500 Gallons)
Installation Date:	1993
Cost:	$5,000
Potable or Non Potable Water Supply:	Non Potable
Treatment:	None
Integrated with Greywater System:	No

FIBERGLASS

County:	Travis
Number of People in Household:	3
Roofing Material:	Concrete Tile
Gutter and Downspout Material:	Aluminum
Preliminary Filters:	Leaf Screens
Above or Below Ground Storage:	Above
Cistern Material:	Fiberglass
Site Built or Shop Fabricated:	Shop Built
Number of Cisterns:	1
Storage Capacity:	5000 Gallons
Installation Date:	1993
Cost:	$4,200
Potable or Non Potable Water Supply:	Potable
Treatment:	5 Micron Sediment Filter, Carbon Cartridge Filter, and Ultraviolet Light
Integrated with Greywater System:	No

FIBERGLASS

County:	Hays
Number of People in Household:	2
Roofing Material:	Galvalume
Gutter and Downspout Material:	Aluminum
Preliminary Filters:	Leaf Screens
Above or Below Ground Storage:	Above
Cistern Material:	Fiberglass
Site Built or Shop Fabricated:	Shop Fabricated
Number of Cisterns:	1
Storage Capacity:	5,000 Gallons
Installation Date:	1995
Cost:	$9,000
Potable or Non Potable Water Supply:	Potable
Treatment:	Ultraviolet Light and Cartridge Filter
Integrated with Greywater System:	No

FIBERGLASS

County:	Travis
Number of People in Household:	2
Roofing Material:	Metal
Gutter and Downspout Material:	Aluminum
Preliminary Filters:	Leaf Screens
Above or Below Ground Storage:	Above
Cistern Material:	Fiberglass
Site Built or Shop Fabricated:	Shop Fabricated
Number of Cisterns:	1
Storage Capacity:	8,500 Gallons
Installation Date:	1995
Cost:	$8,500
Potable or Non Potable Water Supply:	Potable
Treatment:	Ultraviolet Light and Cartridge
Integrated with Greywater System:	No
Additional Comments:	Retrofit system with water well as back-up supply.

FIBERGLASS

County:	Hays
Number of People in Household:	2
Roofing Material:	Metal with Baked Enamel Finish
Gutter and Downspout Material:	Aluminum
Preliminary Filters:	Leaf Screens
Above or Below Ground Storage:	Above
Cistern Material:	Fiberglass
Site Built or Shop Fabricated:	Shop Fabricated
Number of Cisterns:	3
Storage Capacity:	13,000 Gallons Total
Installation Date:	1995
Cost:	$5,500
Potable or Non Potable Water Supply:	Potable
Treatment:	30, 5, and 1 micron Filters, Chlorine, Reverse Osmosis for Kitchen Tap
Integrated with Greywater System:	No
Additional Comments:	Rainwater system less expensive than well.

FIBERGLASS

County:	Bastrop
Number of People in Household:	6
Roofing Material:	Galvalume
Gutter and Downspout Material:	Seamless Aluminum
Preliminary Filters:	Leaf Screens, 20 Gallon Roof Washer
Above or Below Ground Storage:	Above
Cistern Material:	Fiberglass
Site Built or Shop Fabricated:	Shop Fabricated
Number of Cisterns:	2
Storage Capacity:	16,000 Gallons (10,000 Gallon and 6,000 Gallon Tanks)
Installation Date:	1994
Cost:	$12,500
Potable or Non Potable Water Supply:	Potable
Treatment:	Prefilter, Sediment Filter, Ultraviolet Light, and Carbon Filter
Integrated with Greywater System:	No
Additional Comments:	Owner built house with system designed during construction. Freestanding garage also collects rainwater in smaller of two tanks. To reduce water consumption, the house contains two composting toilets, one that uses low water and another that uses no water.

FIBERGLASS

County:	Travis
Number of People in Household:	3
Roofing Material:	Galvanized Metal
Gutter and Downspout Material:	Aluminum
Preliminary Filters:	Screens, Roofwasher
Above or Below Ground Storage:	Above
Cistern Material:	Fiberglass
Site Built or Shop Fabricated:	Shop Fabricated
Number of Cisterns:	2
Storage Capacity:	20,000 Gallons, 2 @ 10,000 Gallons
Installation Date:	1994 first tank, 1996 second tank
Cost:	$6,390 first tank + $4,032 second tank (includes tank, pad, and plumbing) = $10,422 total
Potable or Non Potable Water Supply:	Potable
Treatment:	Ultraviolet Light, Sediment Cartridge Filter, and Carbon Filter
Integrated with Greywater System:	Yes, greywater from sinks, shower, and washing machine is reused.
Additional Coments:	Pole barn planned to be added over tanks.

FIBERGLASS

County:	Hays
Number of People in Household:	3
Roofing Material:	Galvalume
Gutter and Downspout Material:	PVC
Preliminary Filters	Leaf Screen
Above or Below Ground Storage:	Above
Cistern Materials:	Fiberglass
Site Built or Shop Fabricated:	Prefabricated
Number of Cisterns:	1
Storage Capacity:	20,000 Gallons
Installation Date:	1995
Cost:	$12,000 (Includes 3,200 square foot water barn)
Potable or Non Potable Water Supply:	Both
Treatment:	Ozonation
Integrated with Greywater System:	No

FIBERGLASS

County:	Travis
Number of People in Household:	2
Roofing Material:	Concrete Tile
Gutter and Downspout Material:	Aluminum
Preliminary Filters:	Leaf Screens, Buffer Tank Screens, Sand Prefilter
Above or Below Ground Storage:	Buffer Tanks Below, Storage Tanks Above
Cistern Material:	Buffer Tanks are Concrete, Storage Tanks are Fiberglass
Site Built or Shop Fabricated:	Shop Fabricated
Number of Cisterns:	4 Buffer Tanks, 3 Storage Tanks
Storage Capacity:	25,000 Gallon Storage Tanks, 4,000 Gallon Buffer Tanks
Installation Date:	1996
Cost:	$30,000
Potable or Non Potable Water Supply:	Potable
Treatment:	Sediment and Acti-vated Carbon Filters, Ultra-violet Light, and Reverse Osmosis (Kitchen only)
Integrated with Greywater System:	No

FIBERGLASS

County:	Hays
Number of People in Household:	3
Roofing Material:	Metal
Gutter and Downspout Material:	PVC, Copper
Preliminary Filters:	Leaf Screens, Roofwasher
Above or Below Ground Storage:	Above
Cistern Material:	Fiberglass
Site Built or Shop Fabricated:	Shop Fabricated
Number of Cisterns:	3
Storage Capacity:	25,000 Gallons
Installation Date:	1994
Cost:	$18,000
Potable or Non Potable Water Supply:	Potable
Treatment:	Ultraviolet Light and Cartridge
Integrated with Greywater System:	No

POLYETHYLENE

County:	Brewster
Number of People in Household:	2
Roofing Material:	Metal
Gutter and Downspout Material:	Metal
Preliminary Filters:	Continuous Leaf Screen, 30 Micron Sediment Filter before Pump
Above or Below Ground Storage:	Above
Cistern Material:	Polyethylene
Site Built or Shop Fabricated:	Shop Fabricated
Number of Cisterns:	4
Storage Capacity:	10,000 Gallons
Installation Date:	1995
Cost:	$3,500
Potable or Non Potable Water Supply:	Non Potable
Treatment:	5 Micron Sediment Filter
Integrated with Greywater System:	No
Additional Comments:	House is totally reliant on solar energy which powers a 24 volt pump with a pressure tank.

METAL

STEEL

County:	Travis
Number of People in Household:	2
Roofing Material:	Metal
Gutter and Downspout Material:	Metal
Preliminary Filters:	None
Above or Below Ground Storage:	Above
Cistern Material:	Galvanized Steel Horse Trough
Site Built or Shop Fabricated:	Prefabricated Trough with Custom Wood Cover
Number of Cisterns:	1
Storage Capacity:	230 Gallons
Installation Date:	1993
Cost:	$200
Potable or Non Potable Water Supply:	Non Potable, for garden irrigation only
Treatment:	None
Integrated with Greywater System:	No

STEEL

County:	Travis
Number of People in Household:	2
Roofing Material:	Asphalt Composition Shingles
Gutter and Downspout Material:	Aluminum
Preliminary Filters:	Screens at tank inlet pipes
Above or Below Ground Storage:	Above
Cistern Material:	Steel Drums (55 gallons each)
Site Built or Shop Fabricated:	Prefabricated Drums, Site Built Installation
Number of Cisterns:	2 Collection Systems comprised of 3 drums each, 6 drums total
Storage Capacity:	330 Gallons (2 @ 165 Gallons)
Installation Date:	1995
Cost:	$400 including gutters
Potable or Non Potable Water Supply:	Non Potable, for garden irrigation only
Treatment:	None
Integrated with Greywater System:	No
Additional Comments:	The tanks are stacked horizontally on wood supports.

STEEL

Project:	Park Place Gardens
County:	Travis
Roofing Material:	Asphalt Shingles
Gutter and Downspout Material:	Aluminum
Preliminary Filters:	Screen Basket
Above or Below Ground Storage:	Above
Cistern Material:	Galvanized Steel
Site Built or Shop Fabricated:	Shop Built
Number of Cisterns:	1
Storage Capacity:	650 Gallons
Installation Date:	?
Cost:	Not Available
Potable or Non Potable Water Supply:	Non Potable
Treatment:	None
Integrated with Greywater System:	No

STEEL

County:	Travis
Number of People in Household:	2
Roofing Material:	Galvalume
Gutter and Downspout Material:	Aluminum
Preliminary Filters:	Screen along Gutter and at Downspout
Above or Below Ground Storage:	Above
Cistern Materials:	Galvanized Steel
Site Built or Shop Fabricated:	Shop Built
Number of Cisterns:	1
Storage Capacity:	850 Gallons
Installation Date:	1995
Cost:	$1,350 (including foundation and rock base)
Potable or Non Potable Water Supply:	Non Potable
Treatment:	None
Integrated with Greywater System:	No
Additional Comments:	Gravity feed system for garden use only. Overflow drains to pond.

STEEL

County:	Houston
Number of People in Household:	4
Roofing Material:	Galvalume
Gutter and Downspout Material:	Metal
Preliminary Filters:	Screen at Downspout
Above or Below Ground Storage:	Above
Cistern Materials:	Steel with Swimming Pool Liner
Site Built or Shop Fabricated:	Site Built
Number of Cisterns:	2
Storage Capacity:	6,000 Gallons (2 @ 3,000 Gallons)
Installation Date:	1995
Cost:	$2,000
Potable or Non Potable Water Supply:	Both
Treatment:	Carbon and Ultraviolet Light
Integrated with Greywater System:	No

STEEL

Project:	Advanced Green Builder House, Center for Maximum Potential Building Systems
County:	Travis
Collection Surface:	Roof
Roofing Material:	Galvalume
Gutter and Downspout Material:	Galvanized Steel and ABS Pipe
Preliminary Filters:	Roof Washer
Above or Below Ground Storage:	Above Ground
Cistern Material:	Galvanized Steel
Number of Cisterns:	7
Site Built or Shop Fabricated:	Shop Fabricated
Storage Capacity:	13,970 Gallons
Number of People in Household:	Designed for Family of Four
Installation Date:	1996
Cost:	$12,000 (tanks only)
Potable or Non Potable Water Supply:	Both
Treatment:	Undecided Between Ultraviolet Light or Reverse Osmosis
Integrated with Greywater System:	Yes

COMPOSITE SYSTEMS

COMPOSITE

Project:	Cross Timbers Permaculture Institute at Fossil Rim Wildlife Center
County:	Sommervell
Number of People in Household:	3
Roofing Material:	Galvanized Sheet Metal
Gutter and Downspout Material:	Seamless Aluminum and PVC
Preliminary Filters:	8 Gallon Diversion Catchment, "P" Trap
Above or Below Ground Storage:	Above
Cistern Materials:	Ferrocement and Metal
Site Built or Shop Fabricated:	Site Built and Prefabricated
Number of Cisterns:	3
Storage Capacity:	13,300 Gallons
Installation Date:	1995
Cost:	$500 each for the ferrocement tanks
Potable or Non Potable Water Supply:	Potable
Treatment:	None
Integrated with Greywater System:	No.

COMPOSITE

County:	Travis
Number of People in Household:	4
Roofing Material:	Galvanized Sheet Metal
Gutter and Downspout Material:	Seamless Aluminum
Preliminary Filters:	Roof Washer, 5 Micron Sediment Filter
Above or Below Ground Storage:	Above
Cistern Materials:	Fiberglass, Rigid and Sheet Polyethylene, Galvanized Steel, and Plaster
Site Built or Shop Fabricated:	Site Built and Prefabricated
Number of Cisterns:	13
Storage Capacity:	35,700 Gallons
Installation Date:	Ongoing Since 1983
Cost:	Not Available
Potable or Non Potable Water Supply:	Both
Treatment:	Ultraviolet Light
Integrated with Greywater System:	Laundry water in summer months only.
Additonal Comments:	Swimming pool filled with 35,000 gallons of rainwater.

COMPOSITE

County:	Hays
Number of People in Household:	2
Roofing Material:	Galvanized Metal
Gutter and Downspout Material:	Aluminum
Preliminary Filters:	Roof Washer
Above or Below Ground Storage:	Above
Cistern Materials:	Concrete, Steel and Fiberglass
Site Built or Shop Fabricated:	Both
Number of Cisterns:	4
Storage Capacity:	40,000 Gallons
Installation Date:	Since 1993
Cost:	$25,00 (includes water barn)
Potable or Non Potable Water Supply:	Both
Treatment:	Reverse Osmosis
Integrated with Greywater System:	Yes

COMPOSITE

Project:	National Wildflower Research Center
County:	Travis
Collection Surfaces:	Central Courtyard and Roofs
Roofing Materials:	Galvanized Steel
Preliminary Filters:	10 Gallon Roofwasher
Above or Below Ground Storage:	Central Collection Below Ground Pumped to All Others Above Ground
Cistern Materials:	Concrete (Precast and Poured in Place) Galvanized Steel, Fiberglass
Site Built or Shop Fabricated:	Both
Number of Cisterns:	Central Collection (poured in place). Entry (stone clad precast concrete). Childrens's Discovery (galvanized metal). Tower, Irrigation (2 fiberglass)
Storage Capacity:	70,000 Gallons (underground)
Installation Date:	1995
Cost:	$250,000
Potable or Non Potable Water Supply:	Non Potable
Filters:	None
Integrated with Greywater System:	No
Additional Comments :	Gravity fed system from roofs and courtyard to underground tank which pumps harvested rain to above ground tanks. Rainwater is also used for an entry pond and central fountain.

IN PROCESS

Project:	Franklin High School, El Paso Independent School District (in process)
County:	El Paso
Collection Surface:	Roof and Courtyards
Roofing Material:	Galvalume
Gutter and Downspout Material:	Galvalume
Preliminary Filters:	No
Above or Below Ground Storage:	Below
Cistern Material:	Undetermined
Site Built or Shop Fabricated:	Undetermined
Number of Cisterns:	Undetermined
Storage Capacity:	300,000 gallon potential
Installation Date:	1995 for Gutters, Downspouts and Supply Lines Cistern Installation in Future
Potable or Non Potable Water Supply:	Non Potable
Integrated with Greywater System:	Separate Provisions for Future

Additional Comments: This system is not yet in operation. Downspouts and area drains in courtyards lead to planned central storage tank. Construction budget did not provide funds for cistern in this phase. Campus is planned to include xeriscape landscaping and greywater reuse as future budget allows.

APPENDIX

GLOSSARY

air gap: a vertical space between a water or drain line and the flood level of a receptacle used to prevent backflow or siphonage from the receptacle in the event of negative pressure or vacuum.

aquifer: an underground waterway that is replenished by precipitation.

backflow: flow of water in a pipe or water line in a direction opposite to normal flow.

backflow preventer: a device or system installed in a water line to stop backflow from a nonpotable source.

blackwater: as defined in Texas, the wastewater from toilets and kitchen sinks.

buffer: to shift pH to a specific value.

building footprint: the area of a building on the ground.

cistern: an above or below ground tank used to store water, generally made of galvanized metal, fiberglass, ferrocement or concrete.

disinfection: a process in which pathogenic (disease producing) bacteria are killed by use of chlorine or physical processes.

diverter: a mechanism designed to divert the first flush rainwater from entering the cistern.

erosion: the loss of topsoil that occurs as a result of run-off.

filtration: the process of separating particles of 2 microns or larger in diameter from water by means of a porous substance such as a permeable fabric or layers of inert material housed in a media filter or removable cartridge filter.

first flush: generally the first 10 gallons of rainwater per 1,000 square feet of roof surface that is diverted due to potential for contamination.

flow rate: the quantity of water which passes a given point in a specified unit of time, expressed in gallons per minute.

forcebreaker: an extension of the fill pipe to a point 1" above the bottom of the cistern, which dissipates the pressure of incoming rainwater and thus minimizes the stirring of settled solids.

greywater: as defined in Texas, the wastewater from residential appliances or fixtures except toilets and kitchen sinks.

groundwater: water found below ground that has seeped there through spaces in soil and geologic formations.

hardness: a characteristic of groundwater due to the presenc of dissolved calcium and magnesium which is responsible fo most scale formation in pipes and water heaters.

hydrologic cycle: the continual exchange of water from th atmosphere to the land and oceans and back again.

leaf screen: a mesh installed over gutters and entry points t downspouts to prevent leaves and other debris from cloggin the flow of rainwater.

micron: a linear measure equal to one millionth of a meter or .00003937 inch.

nonpotable water: water intended for non-human con sumption purposes, such as irrigation, toilet flushing, an dishwashing.

pH: a logarithmic scale of values of 0 to 14 that measu hydrogen ion concentration in water which deter whether the water is neutral (pH 7), acidic(pH 0-7) or bas (pH 7-14).

pathogen: an organism which may cause disease.

potable water: water which is suitable and safe for huma consumption.

pressure tank: a component of a plumbing system tha provides the constant level of water pressure necessary for th proper operation of plumbing fixtures and appliances.

rainwater harvesting: the principle of collecting and usin precipitation from a catchment surface.

roof washer: a device used to divert the first flush rainwate from entering a cistern.

run-off farming: the agricultural application of harveste rainwater involving a system of terraces that directs th rainwater from higher to lower elevations.

sedimentation: the process in which solid suspended par ticles settle out (sink to the bottom) of water, frequently afte the particles have coagulated.

total dissolved solids: a measure of the mineral content o water supplies.

xeriscape: a landscape practice which specifies regiona adapted, drought-resistant plants and other water-conse techniques.

ABBREVIATIONS

FDA	Food & Drug Administration
mg/L	milligrams/Liter
psi	pounds per square inch
PVC	Polyvinylchloride
TDH	Texas Department of Health
TDS	Total dissolved solids
THMs	Trihalomethanes
TNRCC	Texas Natural Resource Conservation Commission
TWDB	Texas Water Development Board

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"Up on the Roof," *Rodale's New Shelter*, April 1980, pp. 36-37.

VIDEOS

Rainwater Collection Systems, distributed by Gardening Naturally Productions, sponsored in part by Red Ewald, Inc., Karnes City, TX 78118, produced by Morris Media Associates, Austin, TX, 1992

ORGANIZATIONS

American Rainwater Catchment Systems Association, P.O. Box 685283, Austin, TX 78768-5283

American Water Works Association, 6666 West Quincy Avenue, Denver, CO, 80235

Center for Maximum Potential Building Systems, 8604 F.M. 969, Austin, Texas 78724. (512) 928-4786.

Water Quality Association, 4151 Naperville Road, Lisle, IL 60532

COMPUTER PROGRAMS

Raincatch, developed by Commonwealth Scientific and Industrial Research Organization, Division of Tropical Crops and Pastures, Townsfille, Australia: enables a given roof and tank to be quickly tested over the entire period of historical rainfall records by computer, and can find the most economic means of achieving a desired reliability, or the greatest reliability for a given cost, from any starting point, with or without rationing. Program initially developed for an Australian project in Africa, but can be applied anywhere that rainfall, consumption, and cost data are available.

Rainwater System Simulator (RainSim) is a spreadsheet program developed by Rain Harvest, Inc. (now Sustainable Homesteads), that simulates the performance of a rainwater collection system. For every month of the simulation, it subtracts the water that is used and adds in any rainwater that was collected. The amount of water remaining in the cistern at the end of the month is output to a graph. The program uses historical rainfall records from the National Weather Service records for the years 1955-1984 recorded in Austin, Texas. A total of 100 years' rainfall data may be added to the program.

The following values are manipulated for simulation:

- the size of the collection area in square feet
- the number of gallons that will be used each month
- the total size of storage capacity in gallons
- the amount of water in storage at the beginning of the simulation, in gallons
- the amount, if any, of water that will be put into storage if it is empty.

A companion program, *RainCalc,* calculates water production and peak flow rate based on the collection area and peak design rainfall rates to be expected in this area once every 10 years. *RainCalc* is used to properly design the collection plumbing system to catch all rainfall flowing off the roof without losing any to system back-up.

RESOURCES- a list of Rainwater design, construction and equipment firms is available upon request. If you want your firm listed; send information to **Conservation, Texas Water Development Board, P.O. Box 13231, Austin, Texas 78711-3231**

ATTACHMENT 2

City of Austin, Sustainable Building Sourcebook, City of Austin Environmental and Conservation Services Department, Austin Texas; Section 6, Harvested Rainwater

HARVESTED RAINWATER

CSI Numbers	07630 Gutters & Downspouts 15201 Water Supply 15220 Pumping and Piping System 15240 Water Tanks & Resevoirs 15251 Filtration Equipment 15401 Plumbing 15422 Roof Drains
Rainwater harvesting systems are required by law in new construction in Bermuda and the US Virgin Islands. California offers a tax credit for rainwater harvesting systems and financial incentives are offered in cities in Germany and Japan. Austin is presently piloting rainwater catchment rebate programs.	

DEFINITION:

In this section, *Harvested Rainwater* is rainwater that is captured from the roofs of buildings on residential property. Harvested rainwater can be used for indoor needs at a residence, irrigation, or both, in whole or in part.

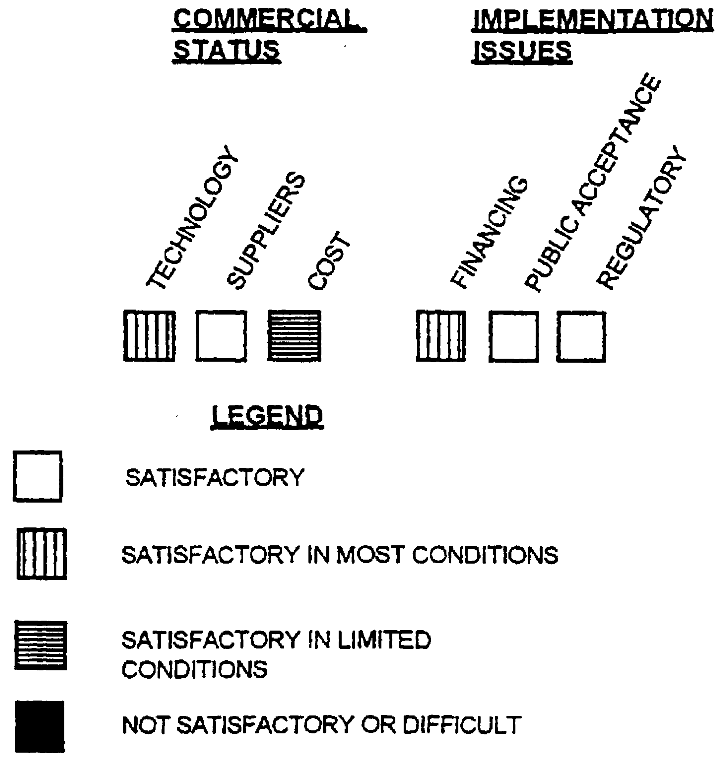
CONSIDERATIONS:

The Austin area receives an average of 32 inches of rain per year. A 2000 square foot area can capture 36,000 gallons of water, which would match up 100 gallons per day in water demand. This is a significant amount of water toward the needs of a water-conserving home.

The quality of rainwater can vary with proximity to highly polluting sources. However, in general, the quality is quite good. The softness of rainwater is valued for its cleaning abilities and benign effects on water-using equipment. As an irrigation source, its acidity is helpful in the high PH soils of our region and, as one would expect, is the best water for plants.

Rainwater harvesting systems designed to fill <u>all</u> the water needs of a home can exceed the expense of putting in a well. Operating costs for a rainwater system can be less. Rainwater collection systems designed to supplement the water needs of a home already on the city system for irrigation purposes can be costly. The primary expense is in the storage tank (cistern). In our area, the cistern size for irrigation can be large due to the high temperatures and extended dry periods in the summer. If the system is not counted upon as the only source of irrigating water, building as large a cistern as one can afford is often the measuring gauge for cistern size.

HARVESTED RAINWATER



COMMERCIAL STATUS

TECHNOLOGY: Fairly well-developed; new products are being developed. Rainwater harvesting is an old tradition practiced in all parts of the world including Texas.

SUPPLIERS: Suitable roof and gutter materials are common products in our region. Specialized products such as roof washers (pre-filters) are also available in our region. Storage tanks (cisterns) are available regionally and statewide. System designers and installers are present locally.

COST: Rainwater harvesting systems are costly compared to a city hookup. Compared to a well, they are equal or, likely, greater in cost.

IMPLEMENTATION ISSUES

FINANCING: Appraisers may not properly value a rainwater harvesting system and underwriters may not accept this system as the sole source of household water. If the owner provides a backup water source, such as an on-demand supply contract with a water hauler, lenders would be more favorably inclined to accept such systems. It has become more common for new homes with rainwater systems to receive conventional financing.

HARVESTED RAINWATER

IMPLEMENTATION ISSUES (cont'd)

PUBLIC ACCEPTANCE: In the Austin region, there are a small but increasing number of rainwater harvesting systems. A small segment of the population desires rainwater catchment systems for indoor water use. A larger portion of the population feels there is an advantage of using captured rainwater for irrigation. Rainwater harvesting presentations draw large crowds.

REGULATORY: At present, there is no Texas regulation for rainwater for indoor or outdoor household use unless the system is backed up by publicly supplied waterlines. If a backup system is used, to avoid any cross-connection, an airgap must exist between the public water and rainwater. (An example is a city water line feeding into a rainwater cistern.) This airgap must exceed two diameters of the city line in width. The Health Department will require that the rainwater system does not contribute to mosquito breeding by having an uncovered cistern.

HARVESTED RAINWATER

GUIDELINES

1.0 Capacity

The capacity of a rainwater harvesting system depends on the amount of rainfall, size of collection area, storage capacity, and the household's level of demand for water.

Table 1.0 on page W 6.5 indicates the gallons of water produced annually for different size roof areas and rainfall amounts.

To determine the square footage of catchment area of a house, use only the house's footprint. (The actual area of roof material will be greater due to the roof slope. However, the amount of rainfall on the roof is not affected by the slope.) In Table 1.0, note that Austin's average rainfall is 32 inches.

For outdoor uses of rainwater, the types of plants, amount of exposure to direct summer sun, soil conditions, presence or lack of mulch, and size of the area will determine how much irrigation water is needed. Large landscapes with large water demands are not readily accommodated by rainwater catchment systems.

Storage capacity for indoor uses of rainwater can typically be more readily gauged; although this is not a precise science due to the vagaries of rainfall and personal habits.

A conserving household may use 25- 40 gallons of water per person per day. Multiply the number of persons in the household by the average use (40 gallons per person is a generous amount, 25 gallons is quite conservative. See the Water Budget section if more precise amounts are needed.) The longest drought in 50 years lasted 75 days in our area. Multiply the total of the number of persons times daily use times 100. This gives a safety factor of 25 days over the worst-case scenario of the last 50 years. The total is the amount of storage capacity required.

Example: 3 people use 40 gallons per day each. 3 (persons) x 40 (gallons per day per person) x 100 (days) = 12,000 gallons of storage required.

2.0 Rainwater for Irrigation

Since the largest need for irrigation water in our area occurs during the time of lowest rainfall and highest temperature, a rainwater system designed to meet this need will have to capture water prior to the summer.

The size of the storage system may be prohibitive for using rainfall for the sole source of irrigation water in large or water-intensive landscapes. A low water demanding landscape is required.

GUIDELINES (cont'd)

Table 1.0.
Annual Rainfall Yield in Gallons for Various Roof Sizes and Rainfall Amounts

ROOF SIZE IN SQUARE FEET	RAINFALL IN INCHES 20	24	28	32	36	40	44	48	52
1000	11236	13483	15730	17978	20225	22472	24719	26966	29214
1100	12360	14832	17303	19775	22247	24719	27191	29663	32135
1200	13483	16180	18876	21573	24270	26966	29663	32360	35056
1300	14607	17528	20450	23371	26292	29214	32135	35056	37978
1400	15730	18876	22023	25169	28315	31461	34607	37753	40899
1500	16854	20225	23596	26966	30337	33708	37079	40450	43820
1600	17978	21573	25169	28764	32360	35955	39551	43146	46742
1700	19101	22921	26742	30562	34382	38202	42023	45843	49663
1800	20225	24270	28315	32360	36405	40450	44495	48540	52584
1900	21348	25618	29888	34157	38427	42697	46966	51236	55506
2000	22472	26966	31461	35955	40450	44944	49438	53933	58427
2100	23596	28315	33034	37753	42472	47191	51910	56629	61349
2200	24719	29663	34607	39551	44495	49438	54382	59326	64270
2300	25843	31011	36180	41348	46517	51686	56854	62023	67191
2400	26966	32360	37753	43146	48540	53933	59326	64719	70113
2500	28090	33708	39326	44944	50562	56180	61798	67416	73034

The average rainfall per month per month follows:

Month	Average Rainfall
January	1.60
February	2.49
March	1.68
April	3.11
May	4.19
June	3.06
July	1.89
August	2.24
September	3.60
October	3.38
November	2.20
December	2.06

GUIDELINES (cont'd)

The average rainfall will not indicate the actual amount that will fall in any particular year.

Table 2.0 on page W 6.7 shows the amount of gallons of rainwater that can be captured from rain for various roof areas in smaller increments than Table 1.0 (these are termed rainfall "events") and the gallons of water it takes to irrigate various landscape areas to equal a certain amount of rainfall.

Table 2.0 and the average rainfall amounts are useful in calculating the storage size and roof area associated with various irrigation requirements.

2.1 *Example of Irrigation Requirement Estimation*

The landscape to be irrigated for this example consists of 2,500 square feet. It is determined through consultation with landscape specialists that the plants should receive a minimum of one inch of rain per week to be healthy from June through September. The roof area for collection in this example will be 1,500 square feet.

1. Table 2.0 shows that 2,500 square feet of landscape area requires a little over 1400 gallons of water to equal one inch of rain. *(Find 2,500 in the landscape/roof size column and follow across to the one inch rainfall column.)*

2. In 16 weeks (June - September), the water requirement is 22,400 gallons. *(16 weeks x 1400 gallons per week)*

3. Choose if you wish to assume average rainfall or a lesser amount will fall during this period. For this example, we will estimate that only half of the average summer rainfall will occur. *(June through September rainfall totals 10.79 inches. We will assume therefore only 5.25 inches will fall.)*

4. Select the amount of gallons from Table 2.0 that this amount of rainfall will equal. The five inch column for 2500 feet of area equals 7,023 gallons. The 0.25 inch column for 2,500 feet gives 351 gallons. *(The total is 7, 374 gallons. This is the amount of natural rainfall the landscape will receive.)*

5. Subtract the natural rainfall (7,374) from the required amount (22,400) for the net need of the landscape. This amount equals 15,026 gallons. This is the amount of water that will need to be collected for irrigating the landscape when rainfall is half the average amount.

6. The roof area during this period will similarly receive 5.25 inches of rain which can be collected for irrigation purposes. Locate the 5 inch column and the 0.25 inch column totals for 1,500 square feet of roof/landscape area. *(The 5 inch total is 4,214 gallons and the 0.25 inch column gives 211 gallons for a total of 4,425 gallons.)*

GUIDELINES (cont'd)

Table 2.0

LAND-SCAPE/ ROOF SIZE SQUARE FEET	RAINFALL IN INCHES								
	0.25	0.50	0.75	1.00	2.00	3.00	4.00	5.00	6.00
1000	140	281	421	562	1124	1685	2247	2809	3371
1100	154	309	463	618	1236	1854	2472	3090	3708
1200	169	337	506	674	1348	2022	2697	3371	4045
1300	183	365	548	730	1461	2191	2921	3652	4382
1400	197	393	590	787	1573	2360	3146	3933	4719
1500	211	421	632	843	1685	2528	3371	4214	5056
1600	225	449	674	899	1798	2697	3596	4494	5393
1700	239	478	716	955	1910	2865	3820	4775	5730
1800	253	506	758	1011	2022	3034	4045	5056	6067
1900	267	534	801	1067	2135	3202	4270	5337	6405
2000	281	562	843	1124	2247	3371	4494	5618	6742
2100	295	590	885	1180	2360	3539	4719	5899	7079
2200	309	618	927	1236	2472	3708	4944	6180	7416
2300	323	646	969	1292	2584	3876	5169	6461	7753
2400	337	674	1011	1348	2697	4045	5393	6742	8090
2500	351	702	1053	1405	2809	4214	5618	7023	8427

7. Subtract the amount the roof will collect in step #6 (4,425 gallons) from the required amount in step #5 (15,026 gallons). *(15,026 minus 4,425 equals 10,600 gallons. This is the amount of rainwater that must be in storage prior to June for use as irrigating water for the landscape if rainfall is one half the average amount.)*

By knowing the average amounts of rainfall that can fall in the period preceding the summer irrigation period, the time needed to collect that amount of water can be estimated. *(Use the 1,500 square foot row on Table 2.0 and add each month's average rainfall until you reach the required amount.)*

Some parts of the landscape may require water throughout the entire year in various amounts. Total the requirement for each month in the same manner as in the example above and follow the same procedure. When calculating water requirements for an entire year, it is best to use the average monthly rainfall figures rather than a conservative amount as in the above example.

HARVESTED RAINWATER

GUIDELINES (cont'd)

3.0 Subsystem Components

A rainwater harvesting system consists of the following subsystems: catchment area (roof), conveyance system (guttering, downspouts, and piping), filtration, storage (cistern), and distribution.

3.1 Catchment Subsystem

Rainwater harvesting can be done with any roofing material if it is for non-drinking use only. For potable use of rainwater, the best roof materials are metal, clay, and cementitious although all roof material types have been used(except asbestos). Asbestos roof materials used in older homes should not be part of a system to provide drinking water. Asphalt shingles can contribute grit to the system and need a pre-filter for the water before it enters the cistern. Lead materials in any form should not be used in the system (i.e. lead flashing).

3.2 Conveyance Subsystem

Gutters are used to convey water from the roof to pipes to the cistern.

If a straight run of gutter exceeds 60 feet, use an expansion joint.

Keep the front of the gutter one half inch lower than the back.

Provide a gutter slope of 1/16 inch per foot minimum.

Provide gutter hangars at 3 feet O.C.(on center).

Gutter should be a minimum of 26 gauge galvanized steel or 0.025 inch aluminum.

Downspouts should provide 1 square inch of downspout opening for every 100 square feet of roof area.

The maximum run of gutter for one downspout is 50 feet.

The conveyance piping from the gutter system to the cistern or filter should be Schedule 40 PVC or comparable in a 4 inch diameter. Do not exceed 45 degree angle bends in horizontal pipe runs and provide 1/4 inch slope per foot minimum. Use one or two-way cleanouts in any horizontal pipe run exceeding 100 feet.

3.3 Storage Subsystem

The storage tank (cistern) must be sized properly to ensure that the rainwater potential is optimized. See the previous section regarding capacity for sizing information.

GUIDELINES (cont'd)

Cisterns can be located above or below ground.

The best materials for cisterns include concrete, steel, ferro-cement, and fiberglass.

When ordering a cistern, specify whether the cistern will be placed above or below ground and if the cistern will be used to store potable water. (Fiberglass cisterns are constructed differently to meet the various criteria.)

If using a manufactured tank designed to hold drinking water, the tank should conform to the published specifications of the American Waterworks Association. (See Resources.)

3.3.1 *Cistern characteristics*

A cistern should be durable and watertight.

A smooth clean interior surface is needed.

Joints must be sealed with non-toxic waterproof material.

Manholes or risers should have a minimum opening of 24 inches and should extend at least 8 inches above grade with buried cisterns.

Fittings and couplings that extend through the cistern wall should be cast-in-place.

Dissipate the pressure from the incoming water to minimize the stirring of any settled solids in the bottom of the cistern. This can be accomplished in a concrete cistern by placing concrete blocks (cavities facing upward) surrounding the base of the inlet pipe. The blocks can be 8"x 8"x16" blocks with the pipe exiting one inch above the bottom of the cistern. Baffles to accomplish the same result can be made as part of fiberglass cisterns. This is not a concern for cisterns that always have a large reserve.

The use of two or more cisterns permits servicing one of the units without losing the operation of the system.

Have a fill pipe on the cistern for adding purchased water as a backup.

Have a cover to prevent mosquito breeding and algae growth from contact with sunlight.

GUIDELINES (cont'd)

CAPACITIES OF VARIOUS SIZED CISTERNS

	DIAMETER OF ROUND TYPE						
DEPTH	6	8	10	12	14	16	18
6	1266	2256	3522	5076	6906	9018	11412
8	1688	3008	4696	6768	9208	12024	15216
10	2110	3760	5870	8460	11510	15030	19020
12	2532	4512	7044	8532	13812	18036	22824
14	2954	5264	8218	11844	16114	21042	26628

	LENGTH OF SIDES SQUARE TYPE						
DEPTH	6	8	10	12	14	16	18
6	1614	2874	4488	6462	8796	11490	14534
8	2152	3832	5984	8616	11728	15320	19378
10	2690	4790	7480	10770	14660	19150	24222
12	3228	5748	8976	12924	17592	22980	29068
14	3766	6706	10472	15078	20524	26810	33912

3.4 Filtering Subsystem

The rainwater may become contaminated by dirt, debris, and other materials from the roof surface. The best strategy is to filter and screen out the contaminants before they enter the cistern.

A leaf screen over the gutter and at the top of the downspout is helpful.

A primary strategy is to reject the first wash of water over the roof. The first rainfall will clean away any contaminants and is achieved by using a "roof washer."

The main function of the roof washer is to isolate and reject the first water that has fallen on the roof after rain has begun and then direct the rest of the water to the cistern. Ten gallons of rainfall per thousand square feet of roof area is considered an acceptable amount for washing. Roof washers are commercially available and afford reliability, durability, and minimal maintenance to this function.

Roof washing is not needed for water used for irrigation purposes. However, prefiltering to keep out debris will reduce sediment buildup. A sand filter can also be used.

3.5 Distribution

Removing the water from the cistern can be achieved through gravity, if the cistern is sufficiently high enough, or by pumping.

GUIDELINES (cont'd)

Most cases will require pumping the water into a pressure vessel similar to the method used to withdraw and pressurize water from a well (except a smaller pump can be used to pump from a cistern).

A screened 1.25 inch foot valve inside the tank connected to an 1.25 inch outlet from the cistern approximately one foot above the bottom (to avoid any settled particles) will help maintain the prime on the pump. A float switch should be used to turn off the pump if the water level is too low.

Another alternative is the use of a floating filter inside the cistern connected to a flexible water line. This approach withdraws the water from approximately one foot below the surface which is considered to be the most clear water in any body of water.

The water that will be used for potable purposes can pass through an inline purification system or point of use water purification system. Other uses for the water do not need additional purification. (Water purification options are not discussed in the Sourcebook.)

HARVESTED RAINWATER

RESOURCES

PROFESSIONAL ASSISTANCE:

See "Systems" suppliers below

COMPONENTS/MATERIALS/ SYSTEMS:

Bowerbird Construction
P. O. Box 698
Dripping Springs, TX 78620
(512) 419-4555
rainwater systems

Agua Dulce
P.O.Box 165
San Marcos, TX
(512) 392-7747
rainwater systems

Sustainable Homesteads
2701 S. Rainbow Ranch Rd.
Wimberley, TX 78676
(512) 832-0737
systems, consultation

Rain Man Waterworks
P. O. Box 972
Dripping Springs, TX 78620
(512) 858-7020
design & installation, systems

Austin Pump & Supply
3803 Todd Lane
Austin, Texas 78744
(512) 442-2348
polyethylene tanks

Farm & Ranch Service Supply Co.
P. O. Box 10165
San Antonio, TX 78210
(800) 292-0007
concrete tanks, roof washers, floating filters, more

Water Works of Texas
2206 Matterhorn Lane
Austin, TX 78704
(512) 326-4636, rainfall@swbell.net
rainwater systems

Rainwater Collection Over Texas
201 Thurman Rd.
San Marcos, TX 78666
(800) 222-3164 (512) 353-4949
rainwater systems, conservation products

Tank Town
1212 Quail Ridge
Dripping Springs, TX 78620
(512) 894-0861
rainwater systems

Rainman Irrigation
2210 South First Street Suite C
Austin, TX 78704
512-327-7246
systems, components, tanks, consultation

Travis Cty. Rural Water Delivery Program
(512) 473-9114
water to "prime" rainwater systems after 90 days drought in Travis County, TX

RESOURCES (cont'd)

COMPONENTS/MATERIALS/ SYSTEMS: (cont'd)

The Ecos Catalog
152 Commonwealth Ave.
Concord, MA 01742-2842
(800) 462-3341
small rainwater systems & components

GENERAL ASSISTANCE

American Rainwater Catchment Systems Assoc.
c/o Kate Houser, sec.
Water Works of Texas
2206 Matterhorn Ln.
Austin, Texas 78704
(512) 326-4636

Center for Maximum Potential Building Systems
8604 FM 969
Austin, TX 78724
(512) 928-4786, www2.cmpbs.org
Consulting and design

National Small Flows Clearinghouse
West Virginia University
NRCCE
P. O. Box 6064
Morgantown, WV 26506-6064
(800) 624-8301
Information, "Small Flows" newsletter

More Information:

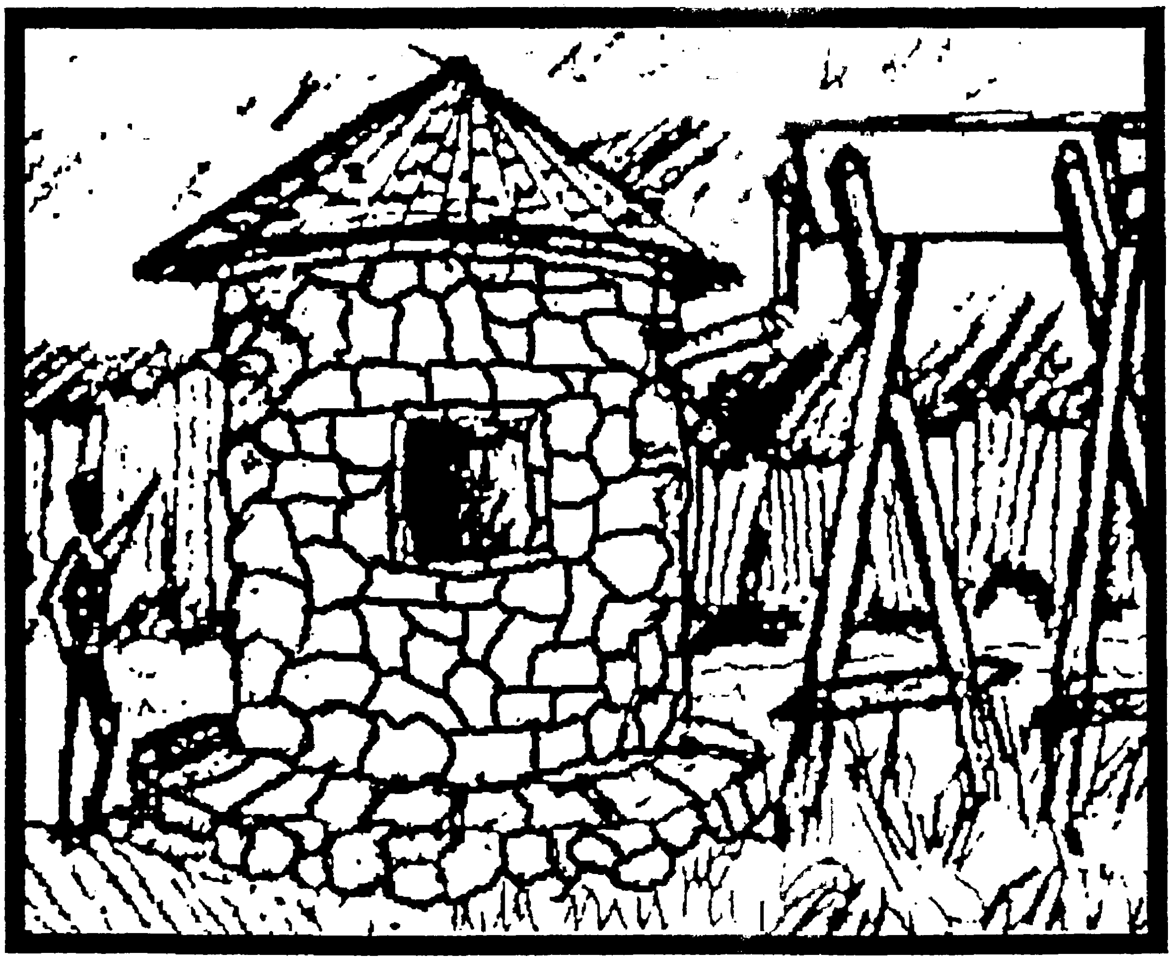
Texas Guide to Rainwater Harvesting
Texas Water Development Board
Conservation Division
P.O.Box 13231
Austin, TX 78711
Patsy Waters, (512) 463-7955
Free, easy to understand introduction to rainwater harvesting
Also available from Green Building Program, (512) 499-3029

Rainwater Collection for the Mechanically Challenged, Suzy Banks and Richard Heinichen, 1997, 50 pgs., Dripping Springs, TX.
Available at Book People, Gardenville and Eco-Wise in Austin, Texas. Nationally available from RealGoods.

Rainwater Collection Systems
(video and 45 page instructional book)
available from Iris Communications (800) 346-0104, www.oikos.com, $30

RAINWATER HARVESTING DEMONSTRATION

INCENTIVE PROGRAM



WATER CONSERVATION DIVISION
P.O. BOX 1088
AUSTIN, TX 78767

FOR MORE
INFORMATION
CALL 499-3514

RAINWATER HARVESTING DEMONSTRATION INCENTIVE PROGRAM

General Purpose

The City of Austin Water Conservation Division is implementing an incentive program to encourage the use of rainwater as a supplement to municipal water. We would like to develop several demonstration sites that can be examined by the public, on municipal, public or non-profit related sites, which can educate our citizens about rainwater harvesting. Incentives are for a maximum of $5,000, depending on specifics of the proposal. Various methods of harvesting and storage will be selected. Proposed rainwater projects can not to be used for potable water systems nor can they be connected to the potable water supply system. All applicable building codes must be followed. Ideally, these projects should be scheduled for completion by September 30, 1998 or earlier.

Program Specifics

Each proposal will be evaluated on its own merits. More consideration will be given to proposed projects with matching funds than projects funded entirely by the incentive. You may request the booklet "Texas Guide to Rainwater Harvesting" from the Texas Water Development Board to calculate appropriate storage requirements. Copies of this publication are also available at the Water Conservation office, 625 East 10th Street, Suite 615. The charge is $2.50.

The application form includes a simplified method that will be used to calculate the optimum tank size for each site. The assumptions used in this model are based upon the desire to reduce peak-day water use during typical dry summer months.

Tanks should be designed to provide a minimum estimated 20-year life span. Non-ultraviolet resistant tanks must be enclosed.

Application Procedure

For your project to be considered, please submit the following along with the attached official application form:

- Drawing - Sketch of the proposed system including all design calculations.
- Site Plan - Layout of buildings, streets, and public access.
- Maintenance Plan - Provide a detailed plan on how maintenance will be done, including scheduled bacteria control measures if spray irrigation is to be used.
- Operation Guide - Explain how your system will reduce dependence upon City water during peak-water-use days of mid-summer.
- Educational Provisions - Outline proposed provisions to encourage public interaction with your new system. Up to 10% of the incentive may be for permanent signage and/or brochures.
- Authorization Notice - Include a signed letter from responsible authority within the organization authorizing the incentive request and agreeing to the project installation.
- Non-profit Certification - Include a copy of the organization's most recent letter of exemption from the Internal Revenue Service.

Send your proposal to: **Dick Peterson—Water Conservation**
City of Austin—PECSD
625 East 10th Street
Austin, TX 78701

Selection Process

Proposals will be evaluated on suitability, accessibility, esthetics, design and potential water savings. You will be contacted after the proposed projects have been evaluated and ranked. Incentives will not be issued until project is finished according to the approved application packet.

Postmark deadline for entries for this portion of the program is March 14, 1998.
You may continue to submit after closing date for a later evaluation period. Funds are limited, so submissions before March 14, have the best opportunity for incentives.
For information, contact Dick Peterson, 499-3514.

1/30/98

Choosing a Contractor

We have developed the Rainwater Harvesting Demonstration Incentive Program to encourage a network of educational sites around Austin. If you are interested in becoming part of the program, you may not do all the work alone. You may need a contractor.

How Do You Find a Good Contractor?

Ask anyone who has a rainwater harvesting system if they are satisfied with their contractor. Word of mouth is an excellent information source. Was the work completed as promised? Were there any warranty problems? And the best question—would you use the same contractor again? If you do not know anyone with a system to ask, check the yellow pages under cisterns, or call some of the contacts on the reverse of this page. Regardless of how you find a contractor, ask *them* for a list of customers to contact about their credentials and service. Do your research. Time spent verifying references is time well spent.

How Much Will a System Cost?

There are many variables in rainwater harvesting systems. Capacity, available water, landscape size, site location, existing gutters, and distribution systems all contribute to the cost, so no price can be established for the *average* system. The main point here is to solicit bids—at least three bids—before you decide on a contractor. Remember, the lowest price is not necessarily the best price. Study your site and investigate system requirements on your own. Research pays dividends in the future performance of your system.

What About Deposits or Prepayments?

Most contractors will not require prepayment, but they may require a deposit before construction begins. For large sums of money, your contract should specify payment methods. The contractor may draw from the agreed total as the project progresses. The actual contract agreement is between the contractor and the owner of the system. Check with your attorney about contractual obligations.

What If I Have Problems?

Reputable contractors will offer a guarantee period for their work. Manufacturers of component parts will have varying warranty periods. Be sure to get all guarantees and warrantees in writing. Check with the Better Business Bureau before signing the contract.

Am I Ready To Sign?

After all the research has been done and the references have been checked, are you ready to sign the contract? Be sure you have verification from the City that your project has been selected for the incentive program. Funding the project is between you and your contractor. Remember, the incentive is paid only if you have completed your project according to agreement with the City of Austin. We will inspect the project before any incentive is authorized.

RAINWATER HARVESTING CONTACTS AND SUPPLIERS

American Rainwater Catchment Systems Association
P O Box 685283—Austin, TX 78768-5283
information and rainwater publication sources

Austin Pump & Supply
3803 Todd Lane—Austin, TX
(512) 442-2348 *polyethylene tanks, pumps*

Barrel City USA
8401 South 1st—Austin, TX 78748
(512) 282-1328 *Recycled 55-gallon drums*

Barley & Pfeiffer Architects - Peter Pfeiffer
1800 West 6th Street—Austin, TX 78703
(512) 476-8580
system design, design/build, consulting

Stephen Bell Landscape & Irrigation
P O Box 16159—Austin, TX 78716
(512) 899-8888
Design, installation, systems, consultation

Bowerbird Construction
P O Box 698—Dripping Springs, TX 78620
(512) 419-4555 *ferocement tanks, systems*

Bracken Designers—Ashley Bracken
916 Remschel Ave.—Kerrville, TX 78028
(830) 257-7400 *consultation and design*

John Dorn Tank Building, Inc.
P O Box 1833—Vidor, TX 77662
(409) 769-5129 *bolted, galvanized tanks*

Red Ewald, Inc
P O Box 519—Karnes City, TX 78118
(800) 242-3524 *fiberglass reinforced tanks*

Farm & Ranch Service Supply Company
P O Box 10165—San Antonio, TX 78210
(800) 292-0007
concrete tanks, roof washers, floating filters

L & F Manufacturing
P O Box 578, Highway 290 East
Giddings, TX 78942
(800) 237-5791 *fiberglass tanks*

Landmark Structures, Inc.
1103 East Price #102—Keller, TX 76248
(817) 379-6816 *elevated steel tanks*

Midessa Membranes
Midessa Industrial Vinyl Company
Rt. 4, 5203 W. 42nd—Odessa, TX 79764
(915) 333-3055 *PVC bladders*

Preload, Inc.
5710 LBJ Freeway, Suite 140
Dallas, TX 75240
(800) 645-3195 *concrete tanks*

Rainman Waterworks—Charles Gibson
P O Box 972—Dripping Springs, TX 78620
(512) 858-7020 *design, installation, systems*

Rainsoft
11500 Metric Blvd. Ste. 290—Austin, TX 78758
(512) 837-2488, 459-3131 *water treatment systems*

Rainwater Collection Over Texas—Tx. Lic. # 6047
3000 Dry Hole Drive—Kyle, TX 78640
(800) 222-3614 *rainwater systems, service, supplies, consultation and design*

Tank Town—Richard Heinichen, Mayor
1212 Quail Ridge—Dripping Springs, TX 78620
(512) 894-0861 *tanks, complete systems, how-to book*

Texas Water Development Board
P O Box 13231—Austin, TX 78711
(512) 463-7955 *Texas Guide to Rainwater Harvesting*

Triple S Feed
2111 Highway 290 West—Dripping Springs, TX 78620
(512) 894-0344 *polyethylene tanks*

Water Filtration Company
1205 Gilman—Marietta, OH 45750
(800) 733-695 (614) 373-6953
roof washers, floating filters, more

Water Works of Texas—Jess Reich
2206 Matterhorn Lane—Austin, TX 78704
(512) 326-4636 *rainwater systems*

These suppliers and designers are just some of the contacts we have encountered in researching our Rainwater Harvesting Demonstration Incentive Progr... They are not necessarily all the contacts you should consider. Also, we have no way of knowing the reliability of their services or products. As with all purchases of this type, references should be verified and products evaluated. If you know of any other suppliers that should be added to future lists, contact Dick Peterson at 499-3514.

1/30/98

APPLICATION
RAINWATER HARVESTING DEMONSTRATION INCENTIVE PROGRAM

Name of organization ____

Mailing address ______________________________________ Zip ___________

Contact person _______________________ Phone _____________ Fax ________

Location of proposed project ____

City of Austin Water Utility account number ________________________________

Estimated construction start date _______________ Completion date ______________

To determine the optimum tank capacity, we assume you can collect 80% of the average rainfall that typically falls during the months of June, July, August and September. This gives us an estimate of 5,000 gallons of water collected per 1,000 sq. ft. of collection area. Use the floor square footage under the roof directing water into your cistern.

Square footage of rainwater collection area $\frac{\_\_\_\_\_\_\_\_\_\_}{1{,}000}$ X 5,000 = _______ gallons

Second, assume that the typical St. Augustine lawn requires 1 inch of water per week or about 560 gallons per 1,000 sq. ft. using conventional spray irrigation. During the 16 week peak-water-use period, the landscape would require approximately 9,000 gallons of water per 1000 sq. ft. with 5000 of that provided by average rainfall.*

Square footage of landscape to be watered $\frac{\_\_\_\_\_\_\_\_\_\_}{1{,}000}$ X 4,000 = _________ gallons.

Optimum tank capacity, for the Demonstration Incentive Program, is the lesser of these two figures; however, alternative calculations may be submitted for consideration.

Dominant type of planting for the irrigated area (St. Augustinegrass, Buffalograss, or plants and shrubs, etc.)

____

Distribution method (gravity, pump, or drip irrigation, etc.) ______________________

____

____

____

Estimated project cost $_________ Amount to be provided by organization $_________

Use this form for a brief summary (description, purpose and objective) of the proposed project.

*Less water may be required if alternative irrigation technology is used or if Xeriscape principles are employed.

ATTACHMENT 3

City of Austin, Sustainable Building Sourcebook, City of Austin Environmental and Conservation Services Department, Austin Texas 1998; Section 5, Greywater Irrigation

GREYWATER IRRIGATION

CSI Numbers	15300 Waste Water Disposal 15361 Septic Tanks 15362 Drainage Field

DEFINITION:

Greywater is defined as the wastewater produced from baths and showers, clothes washers, and lavatories. The wastewater generated by toilets, kitchen sinks, and dishwashers is called *blackwater*. The primary method of greywater irrigation that will be discussed is through sub-surface distribution. This is the method that is readily approved in Austin when conditions are suitable.

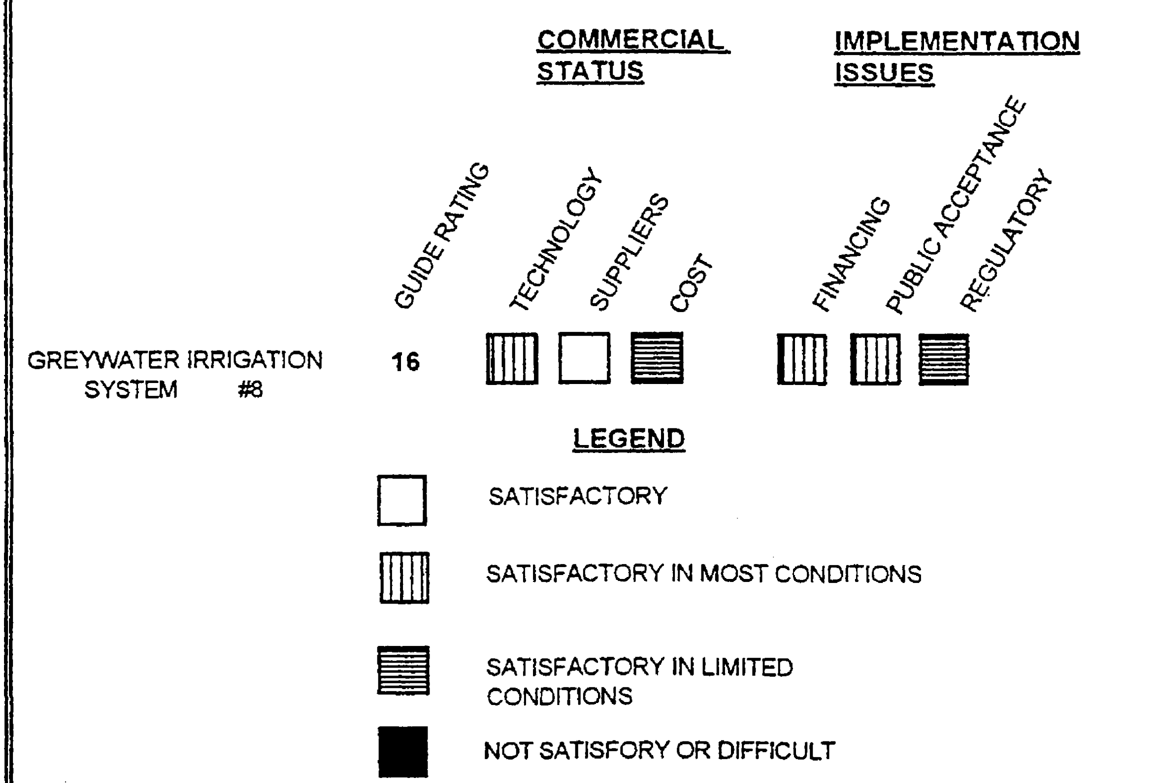
CONSIDERATIONS:

The use of greywater for irrigation requires separate blackwater and greywater waste lines in the house. This is not a difficult task in new construction but can be problematic in existing buildings.

In certain parts of Austin, difficult conditions such as steep slopes, poor soil percolation qualities, close proximity to lakes, or other problems may require the services of a licensed Professional Engineer. However, in areas without unusual conditions, a sub-surface greywater system can be approved.

Sub-surface distribution systems are required by the local Health Department for greywater. Sub-surface systems are not as effective as above-ground spray systems for turf areas but are highly conserving and effective for providing root zone irrigation of plant beds, shrubbery, and trees. The best applications for greywater will be in conjunction with low water demanding landscapes (Xeriscapes).
Regulation of site wastewater disposal systems is provided by the Austin-Travis County Health Department and LCRA (where appropriate) under rules established by the State Legislature, the Texas Water Commission, and the City of Austin. The rules that govern greywater systems are currently based on modifications of septic system guidelines. Some variances are permitted for greywater since less volume is created than in a septic system. Low pressure dosing systems allow for uphill and smaller drainfields. Above-ground greywater spray systems are not permitted in Travis County.

GREYWATER IRRIGATION



COMMERCIAL STATUS

TECHNOLOGY: Greywater systems have been used informally for a long time. Greywater systems are modifications of septic system technology and, thereby, use components standard to septic systems. The primary modification is the location of the drainfield in the root zone of plants making the greywater most useful as irrigation. *An important feature of a greywater system is the isolation of blackwater to a separate system, leaving the greywater available for reuse - most often irrigation.* Additional research by some companies is focusing on greywater treatment processes prior to its release for irrigation or other uses.

SUPPLIERS: Septic system components are readily available. Consultation for greywater system engineering is similarly available in our area.

COST: A sub-surface greywater irrigation system is similar to the cost of a downsized septic system for a home. Greywater irrigation systems cost more than conventional spray and drip irrigation systems to install due to the tank used in greywater systems (a filter and special emitters are also needed for greywater drip irrigation systems). When a sewer line is available, the added cost of a greywater system is significant.

GREYWATER IRRIGATION

IMPLEMENTATION ISSUES

FINANCING: Available.

PUBLIC ACCEPTANCE: Greywater systems are a popular alternative water system in Austin. Public presentations regarding greywater systems have been well attended over the past several years. Illegal greywater use has been noted to be occurring currently in Austin, primarily from clothes washers.

REGULATORY: A greywater system must be approved by the Austin-Travis County Health Department. There are presently new state regulations affecting greywater and septic systems. Please consult the Austin-Travis County Health Department on the practical implementations of the new regulations. Current regulations deal with sub-surface greywater systems similarly to septic systems, with the following differences:

A smaller area on a lot can be used for a greywater system.

The lot size can be less.

Ordinances

Ordinance #880310-H & I establishes regulations of individual septic tank systems and septic tank system use in subdivisions. These regulations are found in Chapter 12-4 of the 1992 Code of the City of Austin and govern the construction, inspection, and approval of all septic systems, greywater systems, and composting toilets within the jurisdiction of the City of Austin.

A section to this ordinance allows the Austin - Travis County Health Department to approve "Innovative Systems". Innovative Systems are defined as those systems not specifically described in any technical reference found in Chapter 12 of the 1992 Code of the City of Austin, or issued by the Texas Water Commission, or in the LCRA's *Supplemental Standards to the Texas Department of Health Construction Standards for Private Sewage Facilities.*

The Innovative Systems section to ordinance #880310-H & I does not grant categorical approval to non sub-surface greywater irrigation systems. The regulation allows a case by case review of innovative approaches. The possibility of system failure causing a public health threat, liability and maintenance issues, and potential negative environmental effects are central concerns in considering approval of innovative systems. Currently, the Health Department will not approve above-surface greywater irrigation systems.

The Health Department has a "cookbook" of acceptable septic system and greywater designs. Standard designs may be allowed in accordance with lot size and conditions such as slope. Any system outside of the "cookbook" typically requires submission by a registered Professional Engineer.

GREYWATER IRRIGATION

IMPLEMENTATION ISSUES (cont'd)

Approval Process

The following is the step by step process to gain a license to operate a greywater irrigation system (sub-surface only):

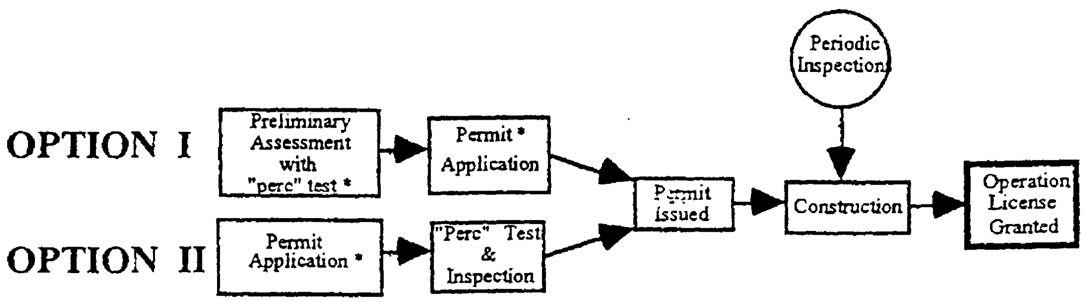
1. Apply for a permit from the Health Department. The permit fee is $200 for a non-engineered system and $300 for an engineered system and is paid with the application.

2. The Health Department will conduct a percolation test and a preliminary site inspection. This can be done prior to applying for a permit if you are not certain if a greywater system can be used in that location. The cost for this earlier evaluation is $50.

3. A permit to construct the system is issued and periodic inspections by the Health Department will occur during the installation.

4. A license is granted to operate the system providing the installation is done properly.

Figure 1
Approval Process Schematic



* Fee Payment

GREYWATER IRRIGATION

GUIDELINES

It is important to recognize the definition of blackwater (See diagram, next page), and that blackwater can be generated by what would usually be considered greywater sources. For example, homes with babies or ill individuals can generate wastewater classifiable as blackwater out of clothes washers.

Wastewater systems that incorporate greywater irrigation should permit flexibility in response to occupant's wastewater patterns, seasonal variations in demand for irrigation, and weather. This system would entail a separate sewer or septic connected blackwater system that is linked to the greywater system for overflow and other backup purposes. However, the fact that blackwater can occasionally be generated by greywater sources is less of a concern in sub-surface systems than in above-ground systems.

1.0 Factors Affecting Approval of Greywater Systems

Size of lot and topography *(As a general rule of thumb, lot sizes well under one half an acre will need professional engineering. Steeper slopes - beyond 15% - may need more design and engineering work as well.)*

Subsoil texture *(sandy and loamy soils are best)*

Subsoil structure *(again, sandy and loamy soils are best)*

Soil depth

Restrictive horizon factors *(none within 36 inches of the ground surface)*

Soil drainage - internal characteristics and external factors such as flooding

Soil permeability

Flooding characteristics

2.0 Types of Systems

There is a range of options in sub-surface systems that can respond to the different factors listed above. The following are not the only options, as qualified engineers can design systems specific to unique circumstances. The systems mentioned herein, again, do not assure automatic approval by virtue of being listed. *Case-by-case, site-specific approval is always needed.*

It is important to note that all these systems should have vegetative cover specified on the plan to cover the drainfield area. All plans should specify erosion control procedures to prevent loss of top soil during the vegetation establishment period.

GUIDELINES (cont'd)

Innovative or experimental systems will require property owners to submit a letter stating they know the system is experimental. In the event of property sale, the new owner must be informed about the experimental nature of the system. Each plan must have an Operation and Maintenance Manual, one to attach to the permit submittal and one for the owner.

2.2 *Evapotranspiration (ET) System*

This system combines the process of evaporation and transpiration to utilize and dispose of wastewater. *(Transpiration is the process whereby plants take in water through the roots, and convert it to vapor which is given off through the leaves.)* A typical evapotranspiration system consists of a septic tank for pre-treatment (removal of solids) followed by distribution into a shallow sand bed covered with vegetation.

The greywater (wastewater from baths, showers, laundry and lavatory sinks) flows from the house through the septic tank and into the evapotranspiration bed. The greywater is distributed through perforated pipes. Once in the sand, greywater is taken into the plant root system. Underneath the bed is either a plastic lining or very impermeable soil which prevents the grey water from seeping into the ground. Blackwater (wastewater from toilets and kitchen sinks) flows into a sewer line or an alternative treatment.

There are special variations on this approach such as rock/plant systems that offer distinct advantages where the greywater movement and use needs to be highly controlled. These alternative systems can be used as a pre-filtering device. These filters can be thought of as constructed wetlands, that use living beds of marsh plants combined with gravel to break down wastewater pollutants that become food for the plants. Canna lilies, iris, ginger lily, elephant ears, and cattails have been used with these types of systems. Trenches are lined with PVC liner and filled with 1 to 1 1/2 inches of river gravel and topped with 6 inches of pea gravel. Plants are planted directly in the gravel, so no soil is used. An average two bedroom house requires about 210 square feet of trench, or a 3 foot x 70 foot trench. Maintenance involves cutting away dead leaves and plant stems seasonally.

2.3 *Shallow Trench*

In this system, greywater flows from the house through pre-treatment and is piped into shallow trenches (pipe placed 8 inches deep). These pipes are placed close enough to the surface to feed the plant roots.

The distinction between a conventional septic tank system and a shallow trench subsurface landscape irrigation system occurs in the absorption field design.

Conventional septic tank systems are designed for disposal only; therefore, the distribution pipes are usually placed too deep for efficient irrigation and the

GUIDELINES (cont'd)

spacing of the trenches is sometimes too wide. Consequently, irrigation gaps may occur which will need additional watering to prevent a lawn from having a striped effect. Mulched plant beds would pose less of a problem as the wicking effect of the mulch will even out the water concentration.

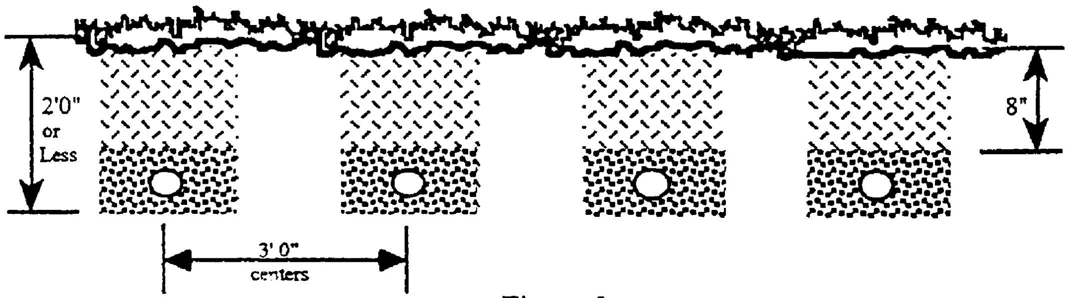


Figure 2
Shallow Trench Section View

The shallow trench greywater system can provide irrigation via shallow placement of distribution pipes and the optimum spacing of trenches.

2.4 *Shallow Mound*

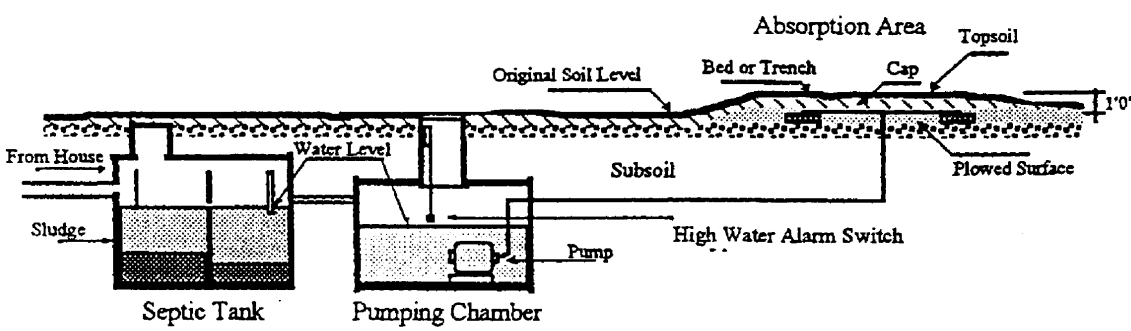


Figure 3
Shallow mound Section View

The shallow mound uses an elevated absorption field for disposal of wastewater. For irrigation, a shallow layer of sand fill and top soil is placed over existing soil. This technique is usually done when existing soil is unsuitable for wastewater disposal. Pipes are placed near the root zone to provide irrigation.

The greywater flows from the house through pre-treatment and into the shallow mound. Blackwater flows into a sewer line or an alternative disposal mechanism.

GUIDELINES (cont'd)

The Shallow Mound system will require pumping of the greywater to function properly.

2.5 *Pressure Effluent Dosing and Drip Irrigation*

Low pressure effluent dosing is an option to gravity distribution. Although more maintenance is required, this type of greywater system is the most common. It can overcome many site limitations such as shallow soils, high ground water, excessive slopes, and uphill drainfields. Low pressure dosing uses a pump to distribute greywater through perforated pipes in the absorption bed. This modification is applicable to ET, shallow trench, shallow mound, and sub-surface drip irrigation systems. The greywater flows from the house through pre-treatment and is pumped into absorption alternatives.

Low pressure dosing is used for houses of no larger than 2700 square feet or with four bedrooms. Water saving fixtures (See section on Indoor Water Conservation) are required in conjunction with this system.

With the addition of a pump to a greywater system, distribution is more uniform than gravity flow, and greywater dosage into the bed can be controlled. Also, there is less soil clogging (which lengthens the life of the system) with properly designed and installed pressure dosing. Pump tank size is site specific; pump tanks must be a minimum of 500 gallon capacity and large enough to avoid overflow in the event of pump failure.

Trench locations and lengths are determined by the contours and the site slope. Trenches are narrow and 18-24 inches deep, and must be cut with a trenching machine or a rock saw. Trench cutting must be done to exact specifications (level within 2 inches) and may not be backfilled in order to achieve the desired level.

Trenches are covered with 6 inches of gravel before the distribution pipe is installed. Geotextile filter fabric must cover the gravel layer. The trenches are finally backfilled with sandy loam, and covered with a 6 inch mound of sandy loam so that rainwater will be diverted away from the area.

An initial distribution test must be done *before* the trenches are backfilled, including a head distribution check and leak check. This test must be repeated with a Health Department inspector present. The final landscape inspection will require adequate cover by the mound, good surface drainage, and a cover of seeded or sodded grass.

A drip system will require a filter in addition to the settling tank (septic tank) to prevent clogging the emitters. Specific application rates will be required depending on slope and soil types. Required separation distances of 50 feet for sharp slopes and breaks in slope can be reduced 10 feet.

GUIDELINES (cont'd)

Drip irrigation system emitters should be the pressure compensating type that will prevent soil from clogging the emitters. Greywater in the drip system is released at the emitters just below the surface in strategic locations in the landscape.

3.0 System Capacity

The amount of greywater available for irrigation is obviously directly proportional to the amount of water used by a household. Water conserving fixtures and appliances produce a lower amount of wastewater as do smaller households. In a highly conserving home, 30 gallons per person per day of greywater is likely to be produced. This amount can vary according to individual usage patterns.

If greywater is the primary source of irrigating water, a low water use landscape should be used. Year-round outputs of greywater through sub-surface systems make greywater irrigation ideal for maintaining evergreen trees and shrubs. The irrigation benefits of greywater should be integrated with the landscape design.

The availability of greywater for irrigation on a square foot basis will vary according to the greywater system's area requirements. The system's area requirement is determined by the site's soil and slope characteristics discussed earlier. It is best to assume that some additional water from other sources than greywater will probably be needed on a seasonal basis.

GREYWATER IRRIGATION

RESOURCES

PROFESSIONAL ASSISTANCE:

Robert Morriss Inc.
P.O.Box 1688
Cedar Park, TX 78630
(512) 267-0688
septic engineer experienced in alternative systems

See "Engineers-Professional" in the Yellow Pages

COMPONENTS/MATERIALS/ SYSTEMS:

See "Septic Tanks" in Yellow Pages

Complete systems:

Clivus Multrum, Inc.
15 Union St.
Lawrence, MA 01840-1801
(800) 962-8447, (928) 725-5591
Compost/greywater system

Aerobic Wastewater Systems
P. O. Box 163263
Austin, TX 78716-3263
(512) 263-2219
Aerobic system **call**

The Ecos Catalog
152 Commonwealth Ave.
Concord, MA 01742-2842
(800) 462-3341
compost/greywater systems

Drip-Tech WW Systems
PO Box 5814
Austin, TX 78763
(512) 329-0066
Drip wastewater irrigation systems

Jade Mountain
P.O. Box 4616
Boulder, CO 80306-9846
(800) 442-1972, www.jademountain.com
greywater systems

GENERAL ASSISTANCE:

Austin-Travis County Health Department
15 Waller St.
Austin, TX 78702
(512) 469-2022

City of Austin Water Conservation Program
P.O. Box 1088
Austin, TX 78767
(512) 499-2199

National Small Flows Clearinghouse
P.O.Box 6064
Morgantown, WV 26506-6064
(800) 624-8301
Information, "Small Flows" newsletter

Texas On-Site Insights, free newsletter re: on-site wastewater disposal
write to: Texas Water Resources Institute
Texas A & M University
301 Scoates Hall
College Station, Texas 77843
(409) 845-1851 or 845-8571
http://towtrc.tamu.edu

RESOURCES (cont'd)

GENERAL ASSISTANCE (cont'd):

More Information:

Chapter 12-4 of the 1992 Code of the City of Austin

"Greywater Task Force Report," City of Austin Resource Management Department, 1985.

Brittain, Richard G., DeCook, K. James, Foster, Kennith E., Water Harvesting and Reuse: Designing an Urban Residential Demonstration, Office of Arid Lands Studies, College of Agriculture, University of Arizona, Tuscon, Arizona, November, 1984.

"How to Use Greywater: Guidelines to the Approved Use of Greywater in Santa Barbara County," The County of Santa Barbara Greywater Technical Advisory Committee, March, 1990.

Carlisle, B.L. and Batte, Charles, Guide to Soil Evaluation and Suitability for On-Site Sewage Disposal Systems for Travis, Williamson, and Hays Counties, Texas, Texas A & M, U. S. Soil Conservation Service and City of Austin, February, 1984.

"Grey Water," City of Austin Resource Management Department, 1985.

Brittain, Richard G., DeCook, K. James, Foster, Kennith E., etal, "Summary Reports on Phase I and Phase III, Casa Del Agua: A Community Water Conservation Demonstration and Evaluation Project", University of Arizona, Tuscon, Arizona, July, 1986 and October, 1989.

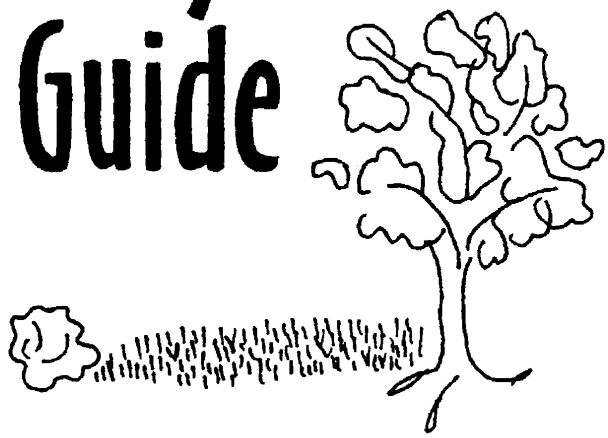
Reed, Sherwood C., E. Joe Middlebrooks, Ronald W. Crites. Natural Systems for Waste Management and Treatment, 2nd edition. McGraw-Hill: New York, 1994.

ATTACHMENT 4

Graywater Guide. California, December 1994

Using Graywater in Your Home Landscape

Graywater Guide



Pete Wilson
Governor
State of California

Douglas P. Wheeler
Secretary for Resources
The Resources Agency

David N. Kennedy
Director
Department of Water Resources

December 199

Using Graywater in Your Home Landscape

Graywater Guide

Pete Wilson
Governor
State of California

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Secretary for Resources
The Resources Agency

David N. Kennedy
Director
Department of Water Resources

December 199[illegible]

Graywater is untreated household waste water which has not come into contact with toilet waste.

Includes: used water from bathtubs, showers, bathroom wash basins, and water from clothes washing machines and laundry tubs.

Does not include: waste water from kitchen sinks, dishwashers, or laundry water from soiled diapers.

(from California Graywater Standards)

Thanks to the Urban Water Research Association of Australia for their contribution of four illustrations from their publication, *Domestic Greywater Reuse: Overseas Practice and its Applicability to Australia.*

Foreword

California's Graywater Standards are now part of the State Plumbing Code, making it legal to use graywater everywhere in California. These standards were developed and adopted in response to Assembly Bill 3518, the Graywater Systems for Single Family Residences Act of 1992.

This Guide was prepared to help homeowners and landscape and plumbing contractors understand the Graywater Standards and to help them design, install and maintain graywater systems.

Carlos Madrid
Chief, Division of Local Assistance

Table Of Contents

This report was written by:

Marsha Prillwitz.....Water Conservation Office
Larry Farwell.....Water Conservation Office

With the assistance of:

Ed Craddock.....Division of Planning
Carole Rains.....Publications and Editorial Services

Write to: California Department of Water Resources, P.O. Box 942836, Sacramento, 94236-0001 or call Marsha Prillwitz at (916) 327-1620.

Why Use Graywater?

Are you tired of watching your bathing and laundry water go down the drain when it could be put to good use on your landscape? Now it is safe and legal to reuse that "graywater" and this guide shows you how.

In addition to conserving water and probably reducing your water and sewer bills, you will also be "drought-proofing" your landscape by using graywater. Since more than half of your indoor water can be reused as graywater, during shortages, when outdoor watering may be restricted, you will have a constant source of water. With landscapes valued at between 5 percent and 10 percent of the value of a home, this back-up supply of water may be an important economic insurance policy for you. Furthermore, the nutrients in graywater may be beneficial to your plants.

The seven steps to follow to put graywater to use in your landscape are:

1. Investigate the permit process
2. Prepare a plan
3. Design the graywater system
4. Submit the plan for review and approval
5. Install the system
6. Arrange for system inspection and approval
7. Use, monitor and maintain the system

If you decide not to do some of the steps yourself, you can hire a landscape contractor to install the irrigation system or a plumbing contractor to install the plumbing. They will follow this same process.

To better illustrate how to install a residential graywater system, this guide features the Brown family. In examples throughout the text, this family of four follows the seven steps.

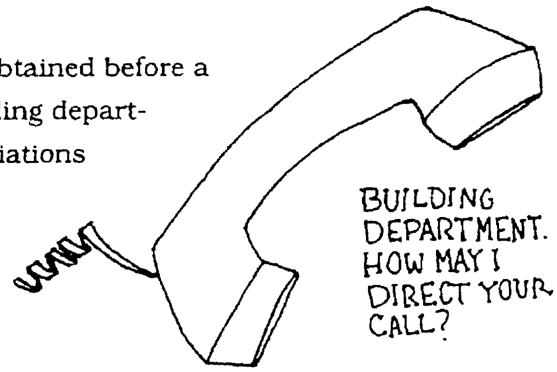
The Seven Steps

The following seven steps will help you plan, design, install, and maintain your graywater system.

1. Investigate the Permit Process

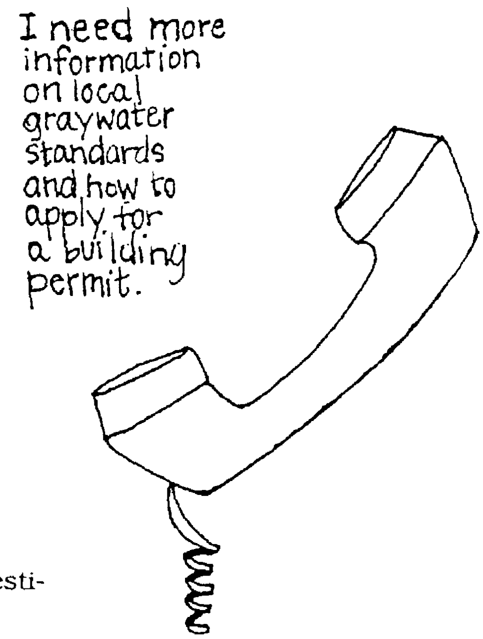
Information in this guide is based on the California Graywater Standards. In the appendix, you will find a copy of Title 24, Part 5, of the California Administrative Code, GRAYWATER SYSTEMS FOR SINGLE FAMILY DWELLINGS, commonly called the California Graywater Standards (Appendix J). These are the official rules for using graywater in California.

The Standards require that a building permit be obtained before a graywater system is installed. Check with your local building department for information on their permit process and any variations made to the Graywater Standards before you proceed.



2. Prepare the Plan

Is a graywater system for you? By first learning approximately how much graywater your family will produce and how much landscape you can irrigate with it, you will be better able to decide. Determining whether your soil is suitable for a graywater system is another primary consideration. Once you have decided that a graywater system is in your future, the next step is to draw a plan and design your system.



Estimate the Amount of Graywater Your Family Will Produce

The number of plumbing fixtures which you connect to the graywater system will determine how much graywater is available for irrigation use. See the section entitled "Plumbing System: Pipes and Valves" page 8 for more information about accessing plumbing fixtures.

The Graywater Standards use the following procedure to estimate your daily graywater flow:

(1) Calculate the number of occupants of your home as follows:

First Bedroom	2 occupants
Each additional bedroom	1 occupant

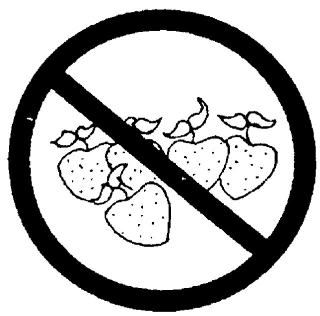
(2) Estimated daily graywater flows for each occupant are:

Showers, bathtubs and wash basins (total)	25 Gal./Day/Occupant
Clothes washer	15 Gal./Day/Occupant

(3) Multiply the number of occupants by the estimated graywater flow.

Example: The Brown family has a three bedroom house so the system must be designed for a minimum of four people. If all fixtures are connected, then each occupant is assumed to produce 40 gallons of graywater per day, resulting in a total of 160 gallons each day.

The reason graywater flow is based upon the number of bedrooms rather than the actual number of people is that the number of bedrooms will remain constant, while the number of people may vary over time.


Estimate the Amount of Landscape You Can Irrigate

Graywater is distributed subsurface and will efficiently maintain lawns, fruit trees, flowers, shrubs and groundcovers. It can be used to irrigate all plants at your home except vegetable gardens.

You do not need to do the following calculation as part of the permit process, but it will help you determine just how much landscape your graywater will irrigate and how many plumbing fixtures you may want to hook up to the system. On page 6, you will find specific information about determining the minimum required irrigated area.

You can estimate either the square footage of the landscape or the number of plants which can be irrigated. Generally, estimating the square footage is more useful for lawn areas and subsurface drip irrigation systems while estimating the number of plants would be more useful for trees and shrubs irrigated by a mini-leachfield system.

Use this formula to estimate the square footage of the landscape to be irrigated:

$$LA = \frac{GW}{ET \times PF \times 0.62}$$

where:

LA = landscaped area (square feet)

GW = estimated graywater produced (gallons per week)

ET = evapotranspiration* (inches per week)

PF = plant factor

0.62 = conversion factor (from inches of ET to gallons per week)

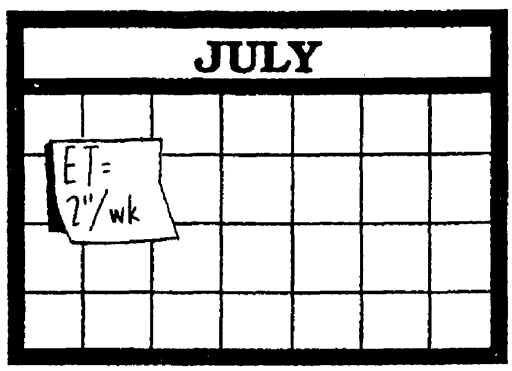
*Evapotranspiration is the amount of water lost through evaporation (E) from the soil and transpiration (T) from the plant. (This formula does not account for irrigation efficiency. If your irrigation system does not distribute water evenly, extra water will need to be applied.)

Example: If the Brown family living in Sacramento produces 160 gallons of graywater per day, how much lawn can be irrigated with that graywater? (160 x 7 days = 1120 gallons per week)

$$LA = \frac{1120}{2 \times .8 \times 0.62}$$

LA = 1129 square feet

Since Sacramento has an ET of 2 inches per week in July (the peak irrigation month in most areas of California), the Brown family can irrigate 1129 square feet of lawn with the available graywater.



If the landscape includes less water thirsty plants, more than twice as much square footage can be irrigated. For specific information about evapotranspiration and estimating landscape water needs, see University of California Leaflet 21493, *Estimating Water Requirements of Landscape Plantings*, and *U.C. Water Use Classification of Landscape Species*. These publications can be obtained through your county cooperative extension office. Also, in the appendix, you will find a list of evapotranspiration rates for the month of July for selected sites in California.

An alternative to considering the square footage of the landscape is to estimate the number of plants that can be irrigated with this 1120 gallons of graywater per week. Here is a look-up chart to help you determine approximately how much water an individual tree or shrub will need for one week during July:

Climate	Relative Water Need of Plant (Plant Factor)	Gallons Per Week 200 SQ FT CANOPY	100 SQ FT CANOPY	50 SQ FT CANOPY
Coastal (ET=1in/wk)	low water using (0.3)	38	19	10
	medium water using (0.5)	62	31	16
	high water using (0.8)	100	50	25
Inland (ET=2in/wk)	low water using (0.3)	76	38	19
	medium water using (0.5)	124	62	31
	high water using (0.8)	200	100	50
Desert (ET=3in/wk)	low water using (0.3)	114	57	28
	medium water using (0.5)	186	93	47
	high water using (0.8)	300	150	75

[The gallons per week calculation for this chart was determined with the following formula: Gallons per week = ET x plant factor x area x .62 (conversion factor.)(This formula does not account for irrigation efficiency. If your irrigation system does not distribute water evenly, extra water will need to be applied.)]

Example: The 1120 gallons of graywater per week produced by the Brown family in Sacramento could irrigate:

8 young fruit trees:	8 x 50 = 400 gallons		(high water using, 50 foot canopy)
8 medium-sized shade trees:	8 x 62 = 496		(medium water using, 100 foot canopy)
7 large shrubs:	7 x 31 = 217		(medium water using, 50 foot canopy)
total:		1113 gallons per week	

The number of gallons of water per week a plant needs will vary from season to season, plant to plant, and site to site, but this will give you a general idea about the number of plants you can successfully irrigate in July with your graywater.

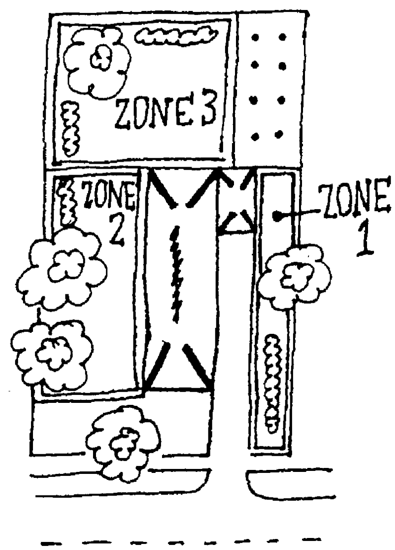
Irrigation needs of the landscape may be greater than the total available graywater. So, even if the system includes the shower, tub and clothes washer, some supplemental water would be necessary during the hot summer months. Contrarily, the amount of available graywater may be greater than the amount you can use on the landscape. In that case, you can reduce the number of plumbing fixtures connected to the graywater system.

Gather Soil and Ground Water Data

Determine the soil types and ground water level on your property. The local building department will probably provide this information or allow you to use Table J-2 of the Graywater Standards. If this information is not available, consult with the local building department about the approved soil testing method. They may require that you hire a qualified professional to conduct a percolation test, or may allow you to do it. Usually you would be required to dig test holes in close proximity to any proposed irrigation area and conduct a percolation test. The U.C. Cooperative Extension Office, the county agricultural agent or a local geologist, soil scientist or college instructor will be able to assist with soil type identification and characteristics. The United States Department of Agriculture Soil Conservation Service publishes a Soil Survey of every county which may be helpful for this purpose.

Draw a Plot Plan

A plot plan of your property should be drawn to scale and may be required to include dimensions, lot lines, direction and approximate slope of the surface. The location of retaining walls, drainage channels, water supply lines, wells, paved areas, and structures should be included. If you have a septic tank, show the location of your sewage disposal system and the required 100 percent expansion area. Provide information on the number of bedrooms and which plumbing fixtures will be connected to the proposed graywater system. Finally, indicate the landscape area that you plan to irrigate with graywater.



Determine the Size of the Irrigated Area

Above, you learned how to estimate the amount of landscape you can irrigate based on the graywater produced and the water needs of the plants. Now you need to determine the minimum size of the irrigation field required, based on soil type. With either a subsurface drip or mini-leachfield system, at least two irrigation zones are required and each must irrigate enough area to distribute all the graywater produced daily without surfacing.

For sub-surface drip irrigation systems, Table J-3 of the Graywater Standards is used to determine the number of emitters required. The emitters must be at least 14 inches apart in any direction.

Example: The Brown family produces 160 gallons of graywater per day and irrigates plants in a sandy loam soil. Based on Table J-3, the minimum number of emitters per gallons per day of graywater production is .7 x 160 = 112 emitters. With at least 14 inches between each emitter, the total irrigation area for one zone would be 112 emitters x 14 inches / 12 inches (to get square feet) = 130 square feet. The Browns would need 130 x 2 = 260 square feet for the minimum of two irrigation zones required by the Graywater Standards to safely distribute their graywater without surfacing.

As we discovered earlier, the Browns could irrigate up to 1129 square feet of lawn with 160 gallons of graywater per day. Therefore, they can design their system to irrigate over four times the minimum irrigated area in this case and still maintain a healthy landscape.

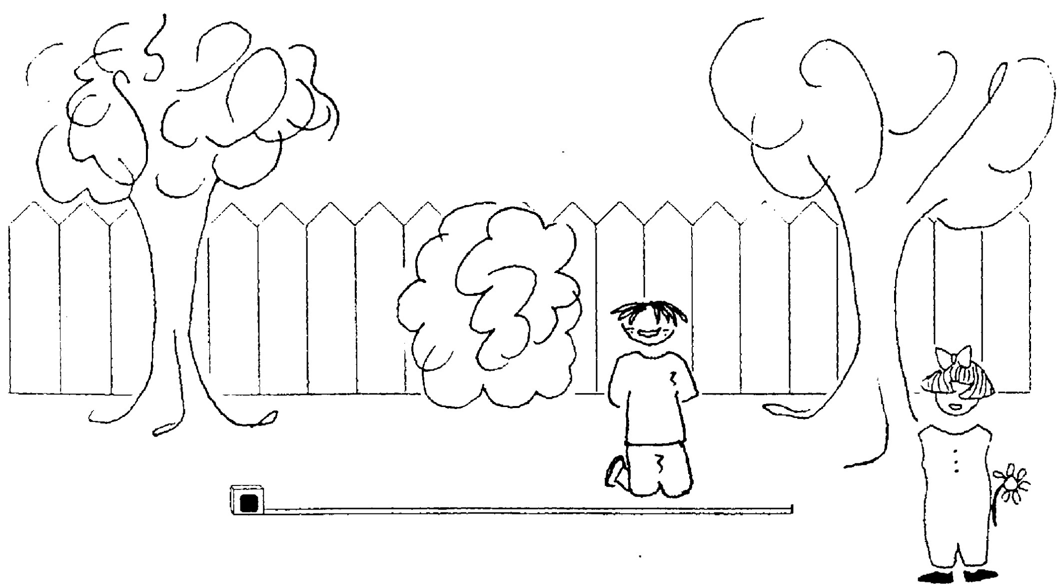
If the mini-leachfield irrigation system is used, the required square footage is determined from Table J-2 of the Graywater Standards.

Example: The Brown family produces 160 gallons of graywater per day and is irrigating a sandy loam soil. Based on Table J-2, the minimum square feet of irrigation area for a mini-leach field system would be 40 square feet per 100 gallons, (160/100=1.6)1.6 x 40 = 64 square feet. The Browns would need two irrigation zones, each 64 square feet in size, a total size of 128 square feet.

The Browns want to install a 100-foot line with a trench that is 8 inches wide to irrigate the 8 fruit trees and 7 large shrubs along the perimeter of their yard. Then, they want to install an 80 foot line with a trench that is 1 foot wide to irrigate 8 mature shade trees. To calculate the area of the mini-leachfield irrigation field, the length of the line as well as the width of the trench must be considered. Therefore, the total area of the irrigation field would be 66 square feet (100 ft. length x .66 ft. width) + 80 square feet (80 ft. length times 1 ft. width) = 146 square feet. Since 146 square feet is greater than the minimum required irrigated area for a mini-leachfield (128 square feet), and since each zone is greater than the required 64 square feet, the Browns meet the minimum irrigated area requirement.

Determine Location of the Graywater System

Once you know the size of the irrigation field, based on the soil and plant needs, you can decide where to put it. Table J-1 in the Graywater Standards establishes distances that the surge tank and irrigation field have to be from various features, such as buildings, septic tanks, and the domestic water line. In addition, your system must be designed so that no irrigation point is within five vertical feet of the highest known seasonal ground water.



3. Design the Graywater System

The next step is to determine the different components of your graywater system and prepare a description of the system itself. Included will be a determination of the irrigated area and details of the graywater system. This construction plan includes a description of the complete installation including methods and materials.

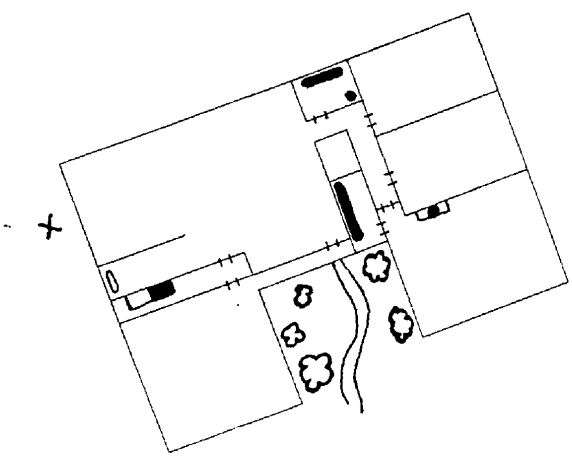
A graywater system usually consists of:

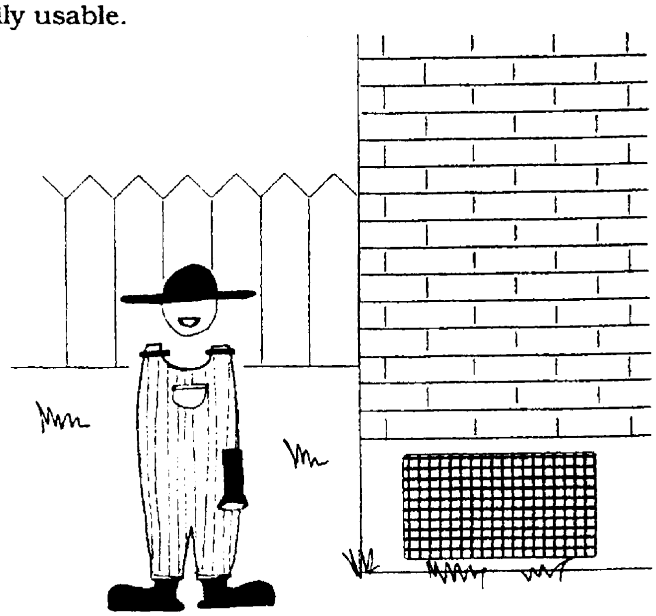
Plumbing System made up of pipes and valves to bring the graywater out of the house
Surge tank to temporarily hold large drain flows from washing machines or bathtubs
Filter to remove particles which could clog the irrigation system
Pump to move the water from the surge tank to the irrigation field
Irrigation System to move the water to the plants

It may be helpful to refer to Figure 1 in the Graywater Standards to get a sense of the overall layout of a graywater system. Then continue reading this section which describes the different parts needed to assemble your system. In your plan, all of the parts of your graywater system must be identified as to the manufacturer.

Plumbing System: Pipes and Valves

The plumbing fixtures which can be used easily in a graywater system depend on the building's foundation. If your home is built on a slab foundation, most drain pipes are buried beneath the concrete slab and the graywater from the bath and shower are unusable without expensive remodeling. However, if your washing machine is located near an outside wall or in the garage, the water is easily usable.

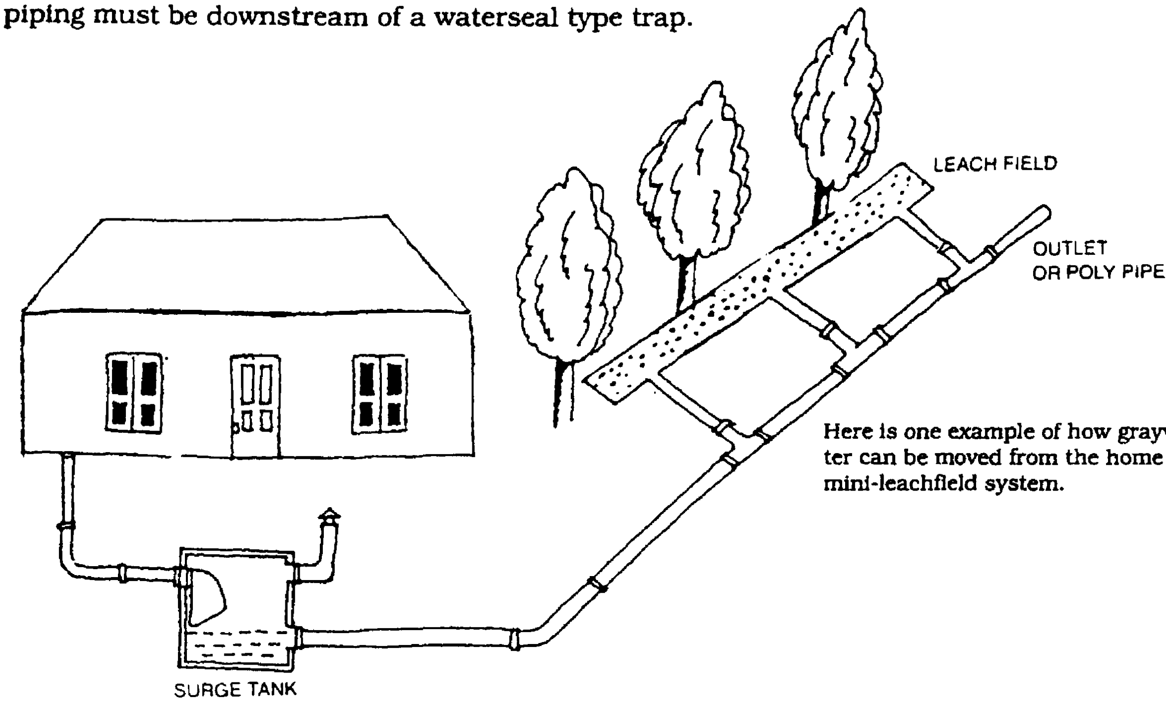




If your home is built on a raised foundation, the drain pipes are generally accessible from the crawl space. Before you enter the crawl space, draw a floor plan of your house, noting the location of the shower, bath, washing machine, and bathroom sinks. Under the house, identify which drain lines serve which fixtures and decide which ones you would like to include in your system. The more fixtures included in the graywater collection system, the more graywater you will have, but the more plumbing changes you will have to make. If you are remodeling your home, this is a great time to access the plumbing and install a graywater system.

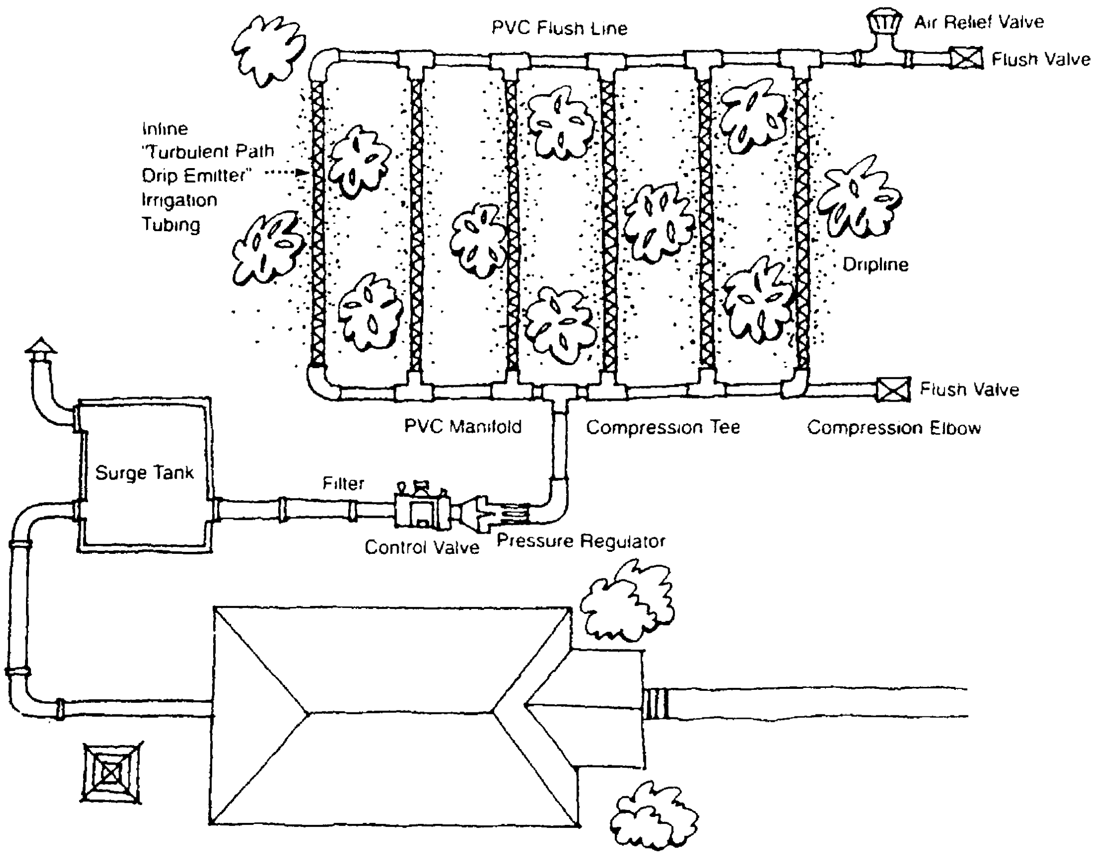
The Graywater Standards require that all graywater piping be marked "Danger-Unsafe Water." This is usually done by wrapping the pipe with purple tape, which is available at most irrigation supply stores. You can install graywater plumbing to a new house for future graywater use even though you are not quite ready to install the irrigation system. This capped off, preliminary plumbing, often referred to as "stub-out plumbing," is allowed in the Graywater Standards as long as it is properly marked.

All valves in the plumbing system must be readily accessible, and backwater valves must be installed on surge tank drain connections to sanitary drains or sewers. Finally, piping must be downstream of a waterseal type trap.



Here is one example of how graywater can be moved from the home to a mini-leachfield system.

This illustration shows a typical hook up from the home to a subsurface drip system.



Surge Tank

Where a graywater pipe exits the home's foundation, it is routed to a surge tank. The tank can be located near the house or, if the line is run underground, nearer the irrigation area. The tank must be solid, durable, watertight when filled, and protected from corrosion. The tank must be vented and have a locking gasketed lid. It must be anchored on dry, level, compacted soil or on a three-inch concrete slab. The capacity of the tank and "GRAYWATER IRRIGATION SYSTEM, DANGER- UNSAFE WATER" must be permanently marked on the tank. The tank drain and overflow gravity drain must be permanently connected to the sewer line or septic tank. The drain and overflow pipes must not be less in diameter than the inlet pipe.

Filter

For subsurface drip irrigation systems, a 140 mesh (115 micron) one inch filter with a capacity of 25 gallons per minute is required. A mesh size of 140 means that a screen has 140 openings per square inch. The size of the openings are 115 microns (a micron is equal to one-thousandth of a millimeter) each, which is equivalent in measure to a 140 mesh.

Pump

If all of the plants you wish to irrigate with graywater are below the building's drain lines, then the graywater system and irrigation lines could use gravity to distribute the water. If any of the plants you wish to irrigate with graywater are higher than the surge tank or the building's drain lines you will need a small, inexpensive pump to lift the water to the plants. A pump will increase the cost of the system slightly .

To pick the right size pump you must know:

1. the 'head' (the total lift measured in feet from the pump to the highest point in the landscape) of your system;
2. the distance from the tank to the furthest point you wish to irrigate; and
3. the maximum discharge rate of all your graywater sources.

For both distance and head, the pump's specifications must show a gallon-per-hour (gph) or gallon-per-minute (gpm) rate. Make sure that the rating is at least 10 gpm at the head you will be using. Try to get a pump that does not need water cooling so that all the water can be pumped out of the tank. Buy a pump that meets or exceeds your needs. Check the manufacturer's specifications.

Irrigation System

The Graywater Standards allow for two kinds of irrigation systems to be used for graywater: sub-surface drip irrigation or mini-leach fields.

Subsurface Drip Irrigation System

Here is a description of the various parts of a subsurface drip irrigation system:

Emitters: The minimum flow path of the emitters is 1200 microns (the holes can be no smaller than 1200 thousandths of a millimeter in size). The coefficient of manufacturing variation (Cv) can be no more than 7 percent. Cv is a method of describing how evenly the emitters apply water at the time they come from the factory. According to the American Society of Agricultural Engineers, good emitters have a Cv of 5 percent or less, average emitters are between 5 and 10 percent, and marginal emitters are between 10 and 15 percent. Emitters must be recommended for subsurface and graywater use and demonstrate resistance to root intrusion.

(To determine the emitter ratings of various products, check with your local building department or order a copy of the Irrigation Equipment Performance Report, *Drip Emitters and Micro-Sprinklers*, from the Center For Irrigation Technology, California State University, 5730 N. Chestnut Ave., Fresno, CA 93740-0018, (209) 278-2066.)

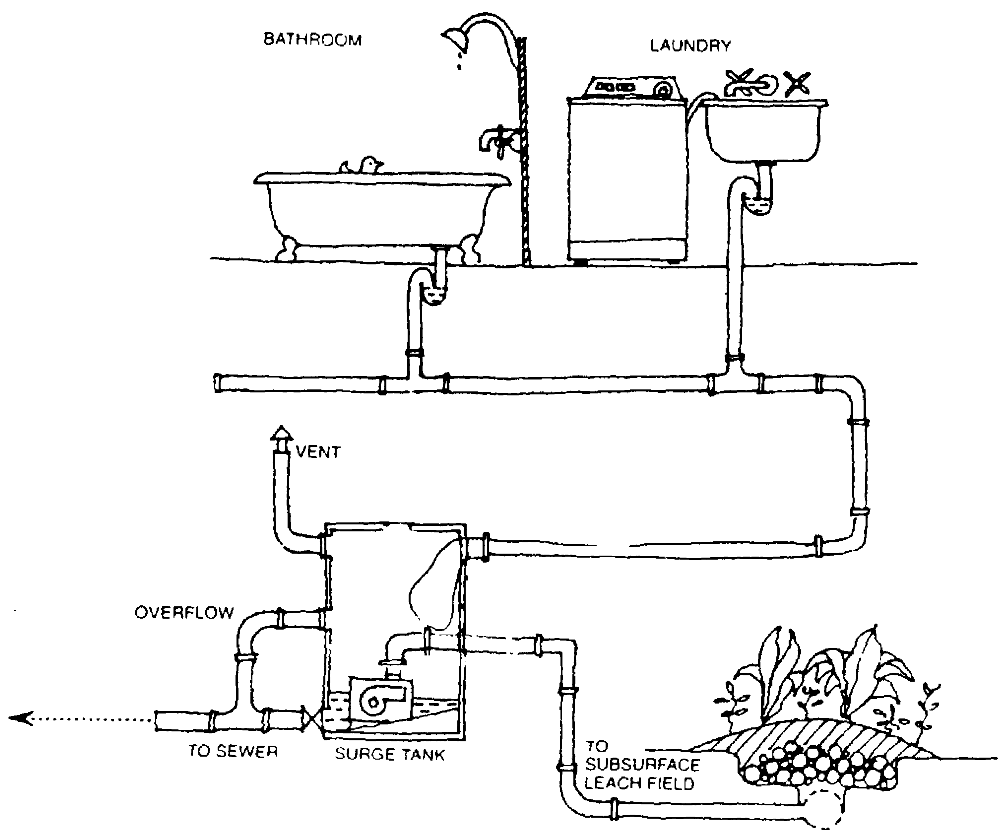
Supply lines: PVC class 200 pipe or better and schedule 40 fittings must be used for all supply lines. Joints, when properly glued, will be inspected and pressure tested at 40 psi and must remain drip tight for 5 minutes. All supply lines must be buried at least 8 inches deep.

Drip lines: Poly or flexible PVC tubing shall be used for drip lines which must be buried at least 9 inches deep.

Pressure reducing valve: Where pressure at the discharge side of the pump exceeds 20 pounds per square inch (psi) a pressure reducing valve must be used to maintain pressure no greater than 20 psi downstream from the pump and before any emission device.

Valves, switches, timers, and other controllers: These devices are used, as appropriate, to rotate the distribution of graywater between irrigation zones and to schedule the irrigations.

Automatic flush valve/vacuum breaker: These devices are required to prevent back syphonage of water and soil.

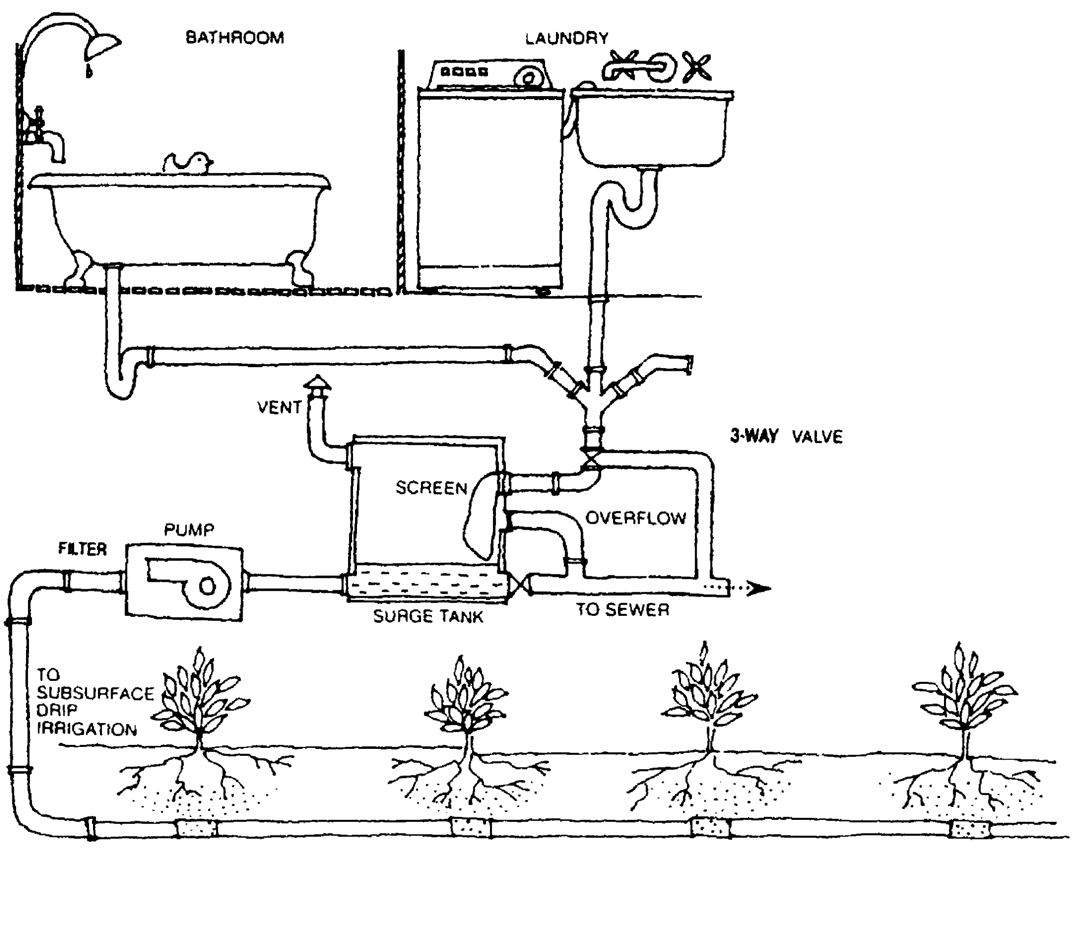


Mini-Leachfield System

The dimension specifications of the mini-leachfield are found in the Graywater Standards, Section J-11 (b) (3). Here is a description of the various parts of a mini-leachfield system:

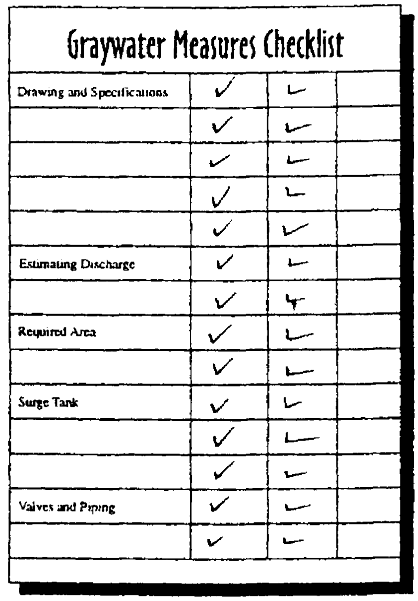
<u>Perforated pipe:</u> The pipes must be a minimum 3-inch diameter, constructed of perforated high density, polyethylene, ABS, or PVC pipe, or other approved material. The maximum length is 100 feet; minimum spacing between lines is 4 feet; and the maximum grade is 3 inches per 100 feet.

<u>Filter material:</u> A clean stone, gravel, or similar material, sized between 3/4 and 2-1/2 inches, must be used. This filter material is then covered with landscape filter fabric or similar porous material before being covered with earth. Do not backfill the trench until after it has been inspected.



4. Submit the Plan for Review and Approval

Once you have completed the application form, plot plan, construction plan, and soil and ground water determinations, submit them to the building department. Staff will review your submittal to insure that you are in compliance with the Graywater Standards. Most likely, they will have a form listing the provisions of the Graywater Standards and will check off each item as they determine it conforms with the regulations. In the Appendix you will find a sample Graywater Measures Checklist on page 31. Once your submittal is approved, you may begin installation of your graywater system. Remember that the building inspector will want to inspect your system before you cover the subsurface drip irrigation lines or backfill the mini-leachfield trenches.



5. Install the System

Purchase the Equipment

Your construction plan includes a description of the materials to be used for the graywater system. This will form the basis of your "shopping list." On the following page is a shopping list for the system the Brown Family plans to install.

In most cases, the plumbing parts, pump and tank can be purchased at your local plumbing supply store. Look in the Yellow Pages under "Plumbing Fixtures, Parts, and Supplies, Retail." The Yellow Pages also has listings for "Pumps-Dealers" and "Tanks-Fiber Glass, Plastic, Etc," or "Tanks-Metal" if your first stop does not have all the parts you need.

"Irrigation Systems and Equipment" is the heading to look under for the components of the subsurface drip irrigation system. The pipes for a mini-leachfield system can be purchased from a plumbing supply store and the gravel filter material can be found at a "Sand and Gravel" company, listed as such in the Yellow Pages.

There are some specialty sign companies that produce the warning labels such as "GRAYWATER IRRIGATION SYSTEM-DANGER-UNSAFE WATER," needed for your graywater system.

Parts and Approximate Costs for the Brown Family Graywater System*

Parts	Approximate Cost ($)	
washing machine hook-up		
connection parts	20	
three-way diverter valve	28	
pipe to sewer	4	
pipe to tank	4	
sanitary tee	3	
shower/bath hook-up		
connection parts	15	
pipe to tank	4	
bends	15	
fittings	15	
vent	13	
Total: Plumbing Parts		**$121**
55 gallon tank with lid	101	
vent	13	
inlet pipe	4	
overflow pipe	4	
drain pipe	4	
backwater valve	4	
water seal type trap	3	
emergency drain ball valve	28	
tank adapters ($20 each, one for each pipe)	60	
union	12	
Total: Tank Parts		**$233**
Total: Pump		**$150**
AND		
Subsurface Drip Irrigation System		
filter 140 mesh one-inch 25 gal/min	25	
pipe: PVC class 200	12	
fittings: schedule 40	15	
drip lines: 112 emitters	46	
valves ($25 each)	50	
automatic flush valve ($2 each)	4	
controller	50	
switches	32	
pressure reducing valve	15	
compression Ts	4	
Total: Drip Parts		**$253**
OR		
Mini-leachfield		
solid pipe	50	
perforated pipe: 180 ft.	70	
gravel, 18 in /130'/1' = 7 yds.	70	
landscape filter fabric	40	
Total: Leachfield Parts		**$230**
GRAND TOTAL: DRIP		**$757**
GRAND TOTAL: LEACHFIELD		**$734**

*Cost for permit fees, rental equipment, professional installation, and maintenance not included.

Install the Plumbing System

Modifying drain lines usually requires extensive plumbing knowledge and skills; seeking professional assistance is recommended. This guide does not provide basic plumbing instructions. If you are a do-it-yourselfer, the staff at a retail plumbing store, plumbing books at the library, or friends may be able to provide you with the plumbing information you will need for most of the plumbing work associated with a graywater system.

The drain pipes in homes built before 1970 are generally cast iron, while those built since 1970 will probably be plastic. The tools required to make the necessary plumbing changes will usually include: a hacksaw, tape measure, flashlight, hammer, pipe wrenches (metal pipes only), and screw drivers. An electric drill and a hole saw may be necessary to provide access holes through walls. If you do not have the necessary tools, most rental companies rent these tools inexpensively. Be careful not to connect any part of the graywater system piping to the existing water supply system.

In order to clearly identify graywater pipes, all graywater lines must be continuously marked along the entire length of the pipe with a warning label. Identification of graywater pipes is important to avoid the possibility of cross-connecting graywater pipes with fresh water supply lines. This is for your protection as well as for the protection of future occupants of your home who may be unaware of the exact location of the graywater plumbing and is especially important with graywater pipes that resemble standard freshwater supply pipes.

Install the Subsurface Drip Irrigation System

Once again, this guide provides a brief overview of the installation process, not basic landscape irrigation instructions. You can call the local chapter of the California Landscape Contractor's Association or their state office at (916) 448-2522 for a list of qualified referrals to install subsurface drip irrigation systems.

If you decide to do it yourself, first, gather all the parts you have determined will be needed for your system. There are special tools for digging the trenches for the drip lines, or you can do it with an ordinary shovel. After the trenches are dug, it is recommended that you install the main valve, filter, and pressure regulator first. Next, install of the main PVC lines and finally the drip lines. Once the system is fully installed, test it for leaks. Don't cover the system until it is inspected and approved.

Install the Mini-Leachfield System

To create a mini-leachfield, dig a trench along the dripline (the outer edge of the foliage) and fill it with gravel to within nine inches of the surface. Be sure to cover the gravel with a landscape filter fabric or similar material before filling the trench with soil. If soil is able to infiltrate down into the gravel, the mini-leach field will quickly clog and the water will be forced to the surface.

6. System Inspection and Approval

Once all the plumbing is connected, the tank in place, and the irrigation system in the ground (but uncovered), arrange to have a building inspector come out for the final inspection and approval. The inspector will be checking that the surge tank remains watertight as the tank is filled with water; that all the lines remain watertight during a pressure test; and that the other measures listed on the Graywater Measures Checklist in the appendix meet the Graywater Standards.

7. Using, Monitoring and Maintaining the System

Protect Health

If a member of a household is ill, graywater may carry infectious bacteria or viruses. However, in order for the graywater to make another person ill it would be necessary for that person to drink or otherwise consume the contaminated graywater. As long as a person does not drink the graywater or irrigate vegetables with graywater and then eat them unwashed, graywater is safe.

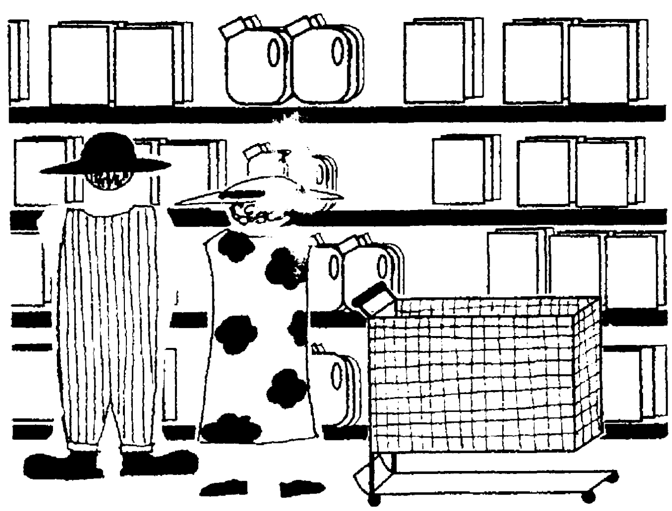
The Graywater Standards require that graywater not surface and that human contact with graywater be avoided. Graywater systems designed, installed, and maintained in accordance with the standards present minimal risk to public health. The California Department of Health Services participated actively in the development of these standards to insure the protection of public health.

When graywater is used, always follow these rules :

Don't drink or play in graywater.
Don't mix potable (drinking) water with graywater.
Don't allow anything that may be eaten to come into contact with graywater.
Don't allow graywater to pond on the surface or run off the property.

Select Garden-Friendly Soaps

The chemical and biological composition of graywater varies greatly, based on numerous factors, including the original quality of the water coming to your home, the personal habits of the family members, which plumbing fixtures are connected to the system, and the soaps used. Since the type of detergent you select is one major factor that you can control, the use of garden-friendly soaps can contribute significantly to better quality graywater.



Most hand and dish soaps and shampoos will not damage plants at low residential concentrations. Laundry detergents, on the other hand, need to be selected carefully. Sodium and boron are chemicals that can have a negative effect on landscapes. Powdered detergents and soaps include "filler" ingredients (not essential to clothes cleaning) which are usually some compound of sodium. Liquid soaps contain few fillers, thus less sodium.

A few soaps are now being formulated for use with graywater systems. Cleaners and laundry soaps you may wish to **avoid** are:

bleaches or softeners (send graywater to sewer when used)

detergents that advertise whitening, softening and enzymatic powers

detergents with ingredients which include:

- boron, borax, or chlorine, or bleach
- peroxygen or sodium perborate
- petroleum distillate or alkylbenzene
- sodium trypochlorite

Often the labeling on detergents is incomplete. The University of Arizona Office of Arid Lands Studies (with the sponsorship of Tucson Water) tested the composition of many common detergents for sodium, boron, phosphate, alkalinity, and conductivity. High alkalinity often indicates a high level of sodium. Conductivity is the measure of all dissolved salts in the water. The higher the concentration of salts and minerals, the greater the potential for adverse impacts on the soil and plants. Phosphates are good for plant growth, but the detergent form may not always be usable by the plants. The Office of Arid Lands Studies suggests that you select detergents with the lowest levels of alkalinity, conductivity, boron, and sodium. This information is included in the Appendix.

Generally, once people begin to use graywater, they think more carefully about what they put down the drain. Some cleaning products are toxic to plants, people and the environment and should not be used. Products designed to open clogged drains or clean porcelain without scrubbing **must** be sent to the sewer or replaced with alternative products or boiling water and elbow grease.

Also, home water softeners often use a solution that contains high levels of sodium chloride that may have a negative effect on soils. Avoid using softened water as graywater when possible.

Keep Soils Healthy

Sodium, potassium and calcium are alkaline chemicals. Because of the presence of these chemicals in laundry detergent, graywater use tends to raise alkalinity of the soil. Slightly alkaline soils will support many garden plants. Even most acid-soil loving plants will be happy with slightly alkaline soils that are generously amended with organic matter. The pH of an acid soil is 6.9 or lower while that of an alkaline soil is 7.1 or higher. If a simple pH test indicates that the pH reading is over 8.0, the pH should be reduced. This can be accomplished by adding agricultural sulfur or an acidifying fertilizer such as ammonium sulfate.

Problems with water infiltration may be due to a sodium build up in the soil. Soil analyzed by a soil lab is the only way to verify excess sodium. Depending upon the severity of the problem, you can usually correct it by adding agricultural gypsum and/or organic matter to the soil.

A sandy, well-drained soil will be less affected by the application of graywater than a poorly drained clay soil. Sometimes graywater may degrade the structure of a clay soil by making it stickier and less loamy. The soil's physical condition also may be affected by high sodium. To correct these problems and keep soil healthy, once again, till in organic matter.

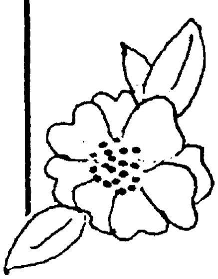
The salts that might build up from the use of graywater will only be a problem if they are not leached away periodically by heavy rains. If winter rains are light, occasionally leach the soil with fresh water.

Grow Healthy Plants

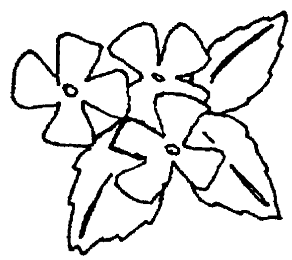
The application of too much water, of any kind, too frequently will result in saturated soils, and an invitation to plant disease. Generally, plants are healthier when the soil is allowed to dry out between irrigations.

A very small percentage of plants may be damaged by graywater, most of these are listed below. Too much sodium or chlorine could result in leaf burn, chlorosis (yellow leaves), and twig die back. Boron can be toxic to plants at levels only slightly greater than is required for good plant growth. Symptoms of boron toxicity include leaf tip and margin burn, leaf cupping, chlorosis, branch die back, premature leaf drop, and reduced growth.

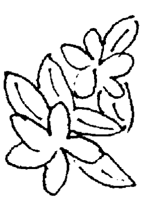
Shade loving and acid loving plants do not like graywater. Their native habitats are forested areas where acid soils predominate. Here are some plants that are not suitable for the alkaline conditions often associated with graywater irrigation:



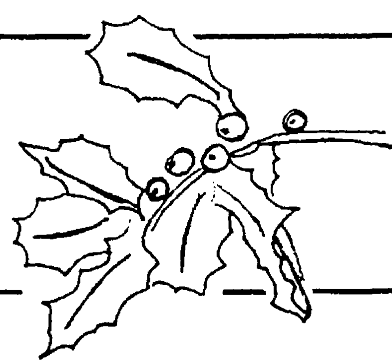
Rhododendrons	Begonias
Bleeding Hearts	Ferns
Oxalis (Wood Sorrel)	Foxgloves
Hydrangeas	Gardenias
Azaleas	Philodendrons
Violets	Camellias
Impatiens	Primroses



Other plants that are especially susceptible to high sodium, and chloride which may be present in graywater are:

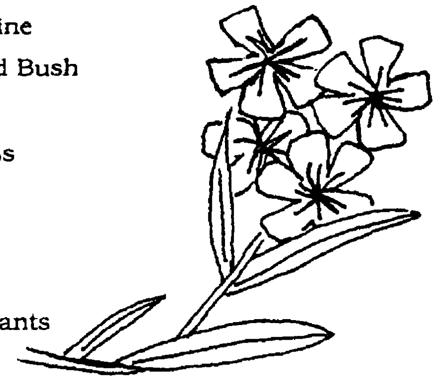


Crape Myrtle
Redwoods
Star Jasmine
Holly
Deodar Cedar



Plants that would probably do well with graywater irrigation are:

Oleander	Italian Stone Pine
Bougainvillea	Purple Hopseed Bush
Fan & Date Palms	Oaks
Rose	Arizona Cypress
Rosemary	Cottonwood
Agapanthus	Olive
Bermuda Grass	Ice Plant
Honeysuckle	many native plants
Australian Tea Tree	Juniper



Monitor and Maintain the System

If you have someone else install your graywater system, the installer will provide an operation and maintenance manual. That person will recommend such practices as checking the pump, filters, main lines, and other lines to keep your system in top condition.

It is important to check your system on a regular basis, every week or so, to see that graywater is not surfacing, that the plants and soils are healthy, and that the equipment is working properly.

The pump is an important part of the graywater system. Read the pump's instruction guide carefully. Adjust the pump's float switch to turn on as early as possible to avoid an overflowing tank. Be sure to connect the grounded, three-pronged cord supplied with the pump to an approved Ground Fault Intercept outlet. The pump runs off standard house current, so special wiring is not necessary.

A pump should not be run without a check-valve, which is installed between the pump and the first irrigation point. The check-valve allows water to pass in only one direction--toward the landscape, and not back into the tank. Without a check-valve, water draining back into the tank would activate the pump and the pump would run continuously.

The main concern people have with drip irrigation systems is the possible clogging of the emitters, preventing the flow of water to the plants. With properly selected and maintained filtration and occasional flushing of the subsurface drip irrigation system, most problems with emitter clogging can be avoided. If clogging does occur, simple chemical solutions can be used to clear the emitters.

The 3-way diverter valve (or washing machine "Y" valve) which was installed as part of the graywater system allows the graywater to be sent back to the sewer/septic line when rain has saturated the soil. Turning the graywater system off during the rainy season will help keep the soil healthy because the rain will leach away any soap buildup. The diverter valve is also employed to send water with caustic cleaners or strong bleaches to the sewer/septic line.

APPENDIX J

Graywater Systems for Single-family Dwellings

J 1 Graywater Systems (General)

(a) The provisions of this Appendix shall apply to the construction, alteration and repair of graywater systems for subsurface landscape irrigation. Installations shall be allowed only in single-family dwellings. The system shall have no connection to any potable water system and shall not result in any surfacing of the graywater. Except as otherwise provided for in this Appendix, the provisions of the Uniform Plumbing Code (U.P.C.) shall be applicable to graywater installations.

(b) The type of system shall be determined on the basis of location, soil type and ground water level and shall be designed to accept all graywater connected to the system from the residential building. The system shall discharge into subsurface irrigation fields and may include surge tank(s) and appurtenances, as required by the Administrative Authority.

(c) No graywater system, or part thereof, shall be located on any lot other than the lot which is the site of the building or structure which discharges the graywater; nor shall any graywater system or part thereof be located at any point having less than the minimum distances indicated in Table J-1.

(d) No permit for any graywater system shall be issued until a plot plan with appropriate data satisfactory to the Administrative Authority has been submitted and approved. When there is insufficient lot area or inappropriate soil conditions for adequate absorption of the graywater, as determined by the Administrative Authority, no graywater system shall be permitted. The Administrative Authority is a city or county.

(e) No permit shall be issued for a graywater system which would adversely impact a geologically sensitive area, as determined by the Administrative Authority.

(f) Private sewage disposal systems existing or to be constructed on the premises shall comply with Appendix I of this Code or applicable local ordinance. When abandoning underground tanks, Section 1119 of the U.P.C. shall apply. Also, appropriate clearances from graywater systems shall be maintained as provided in Table J-1. The capacity of the private sewage disposal system, including required future areas, shall not be decreased by the existence or proposed installation of a graywater system servicing the premises.

(g) Installers of graywater systems shall provide an operation and maintenance manual, acceptable to the Administrative Authority, to the owner of each system. Graywater systems require regular or periodic maintenance.

(h) The Administrative Authority shall provide the applicant a copy of this Appendix.

J 2 Definitions

Graywater is untreated household waste water which has not come into contact with toilet waste. Graywater includes used water from bathtubs, showers, bathroom wash basins, and water from clothes washing machines and laundry tubs. It shall not include waste water from kitchen sinks, dishwashers or laundry water from soiled diapers.

Surfacing of graywater means the ponding, running off or other release of graywater from the land surface.

J 3 Permit

It shall be unlawful for any person to construct, install or alter, or cause to be constructed, installed or altered, any graywater system in a building or on a premises without first obtaining a permit to do such work from the Administrative Authority.

J 4 Drawings and Specifications

The Administrative Authority may require any or all of the following information to be included with or in the plot plan before a permit is issued for a graywater system:

(a) Plot plan drawn to scale completely dimensioned, showing lot lines and structures, direction and approximate slope of surface, location of all present or proposed retaining walls, drainage channels, water supply lines, wells, paved areas and structures on the plot, number of bedrooms and plumbing fixtures in each structure, location of private sewage disposal system and 100 percent expansion area or building sewer connecting to public sewer, and location of the proposed graywater system.

(b) Details of construction necessary to ensure compliance with the requirements of this Appendix together with a full description of the complete installation, including installation methods, construction and materials as required by the Administrative Authority.

(c) A log of soil formations and ground water level as determined by test holes dug in close proximity to any proposed irrigation area, together with a statement of water absorption characteristics of the soil at the proposed site as determined by approved percolation tests. In lieu of

percolation tests, the Administrative Authority may allow the use of Table J-2, an infiltration rate designated by the Administrative Authority, or an infiltration rate determined by a test approved by the Administrative Authority.

J 5 Inspection and Testing

(a) Inspection

(1) All applicable provisions of this Appendix and of Section 318 of the U.P.C. shall be complied with.

(2) System components shall be properly identified as to manufacturer.

(3) Surge tanks shall be installed on dry, level, well-compacted soil if in a drywell, or on a level, 3-inch concrete slab or equivalent, if above ground.

(4) Surge tanks shall be anchored against overturning.

(5) If the irrigation design is predicated on soil tests, the irrigation field shall be installed at the same location and depth as the tested area.

(6) Installation shall conform with the equipment and installation methods identified in the approved plans.

(7) Graywater stub-out plumbing may be allowed for future connection prior to the installation of irrigation lines and landscaping. Stub-out shall be permanently marked GRAYWATER STUB-OUT, DANGER—UNSAFE WATER.

(b) Testing

(1) Surge tanks shall be filled with water to the overflow line prior to and during inspection. All seams and joints shall be left exposed and the tank shall remain watertight.

(2) A flow test shall be performed through the system to the point of graywater irrigation. All lines and components shall be watertight.

J 6 Procedure for Estimating Graywater Discharge

The Administrative Authority may utilize the graywater discharge procedure listed below, water use records, or calculations of local daily per person interior water use:

(a) The number of occupants of each dwelling unit shall be calculated as follows:

First bedroom	*2 occupants*
Each additional bedroom	*1 occupant*

(b) The estimated graywater flows for each occupant shall be calculated as follows:

Showers, bathtubs and wash basins	*25 GPD/occupant*
Laundry	*15 GPD/occupant*

(c) The total number of occupants shall be multiplied by the applicable estimated graywater discharge as provided above and the type of fixtures connected to the graywater system.

J 7 Required Area of Subsurface Irrigation

Each irrigation zone shall have a minimum effective irrigation area for the type of soil and infiltration rate to distribute all graywater produced daily, pursuant to Section J-6, without surfacing. The required irrigation area shall be based on the estimated graywater discharge, pursuant to Section J-6 of this Appendix, size of surge tank, or a method determined by the Administrative Authority. Each proposed graywater system shall include at least two irrigation zones and each irrigation zone shall be in compliance with the provisions of this Section.

If the mini-leachfield irrigation system is used, the required square footage shall be determined from Table J-2, or equivalent, for the type of soil found in the excavation. The area of the irrigation field shall be equal to the aggregate length of the perforated pipe sections within the irrigation zone times the width of the proposed mini-leachfield trench.

No irrigation point shall be within 5 vertical feet of highest known seasonal groundwater nor where graywater may contaminate the ground water or ocean water. The applicant shall supply evidence of ground water depth to the satisfaction of the Administrative Authority.

J 8 Determination of Irrigation Capacity

(a) In order to determine the absorption quantities of questionable soils other than those listed in Table J-2, the proposed site may be subjected to percolation tests acceptable to the Administrative Authority or determined by the Administrative Authority.

(b) When a percolation test is required, no mini-leachfield system or subsurface drip irrigation system shall be permitted if the test shows the absorption capacity of the soil is less than 60 minutes/inch or more rapid than five minutes/inch, unless otherwise permitted by the Administrative Authority.

(c) The irrigation field size may be computed from Table J-2, or determined by the Administrative Authority or a designee of the Administrative Authority.

J 9 Surge Tank Construction (Figures 1, 2, 3 and 4)

(a) Plans for surge tanks shall be submitted to the Administrative Authority for approval. The plans shall show the data required by the Administrative Authority and may include dimensions, structural calculations, and bracing details.

(b) Surge tanks shall be constructed of solid, durable materials, not subject to excessive corrosion or decay, and shall be watertight.

(c) Surge tanks shall be vented as required by Chapter 5 of this Code and shall have a locking, gasketed access opening, or approved equivalent, to allow for inspection and cleaning.

(d) Surge tanks shall have the rated capacity permanently marked on the unit. In addition, GRAYWATER IRRIGATION SYSTEM, DANGER—UNSAFE WATER shall be permanently marked on the surge tank.

(e) Surge tanks installed above ground shall have a drain and overflow, separate from the line connecting the tank with the irrigation fields. The drain and overflow shall have a permanent connection to a sewer or to a septic tank, and shall be protected against sewer line backflow by a backwater valve. The overflow shall not be equipped with a shut-off valve.

(f) The overflow and drain pipes shall not be less in diameter than the inlet pipe. The vent size shall be based on the total graywater fixture units, as outlined in U.P.C. Table 4-3 or local equivalent. Unions or equally effective fittings shall be provided for all piping connected to the surge tank.

(g) Surge tanks shall be structurally designed to withstand anticipated loads. Surge tank covers shall be capable of supporting an earth load of not less than 300 pounds per square foot when the tank is designed for underground installation.

(h) Surge tanks may be installed below ground in a dry well on compacted soil, or buried if the tank design is approved by the Administrative Authority. The system shall be designed so that the tank overflow will gravity drain to a sanitary sewer line or septic tank. The tank must be protected against sewer line backflow by a backwater valve.

(i) Materials

(1) Surge tanks shall meet nationally recognized standards for nonpotable water and shall be approved by the Administrative Authority.

(2) Steel surge tanks shall be protected from corrosion, both externally and internally, by an approved coating or by other acceptable means.

J 10 Valves and Piping (Figures 1, 2, 3 and 4)

Graywater piping discharging into a surge tank or having a direct connection to a sanitary drain or sewer piping shall be downstream of an approved waterseal-type trap(s). If no such trap(s) exists, an approved vented running trap shall be installed upstream of the connection to protect the building from any possible waste or sewer gases. All graywater piping shall be marked or shall have a continuous tape marked with the words DANGER—UNSAFE WATER. All valves, including the three-way valve, shall be readily accessible and shall be approved by the Administrative Authority. A backwater valve, installed pursuant to this Code, shall be provided on all surge tank drain connections to the sanitary drain or sewer piping.

J 11 Irrigation Field Construction

The Administrative Authority may permit subsurface drip irrigation, mini-leachfield or other equivalent irrigation methods which discharge graywater in a manner which ensures that the graywater does not surface. Design standards for subsurface drip irrigation systems and mini-leachfield irrigation systems follow:

(a) Standards for a subsurface drip irrigation system are:

(1) Minimum 140 mesh (115 micron) 1-inch filter with a capacity of 25 gallons per minute, or equivalent, filtration shall be used. The filter backwash and flush discharge shall be caught, contained and disposed of to the sewer system, septic tank or, with approval of the Administrative Authority, a separate mini-leachfield sized to accept all the backwash and flush discharge water. Filter backwash water and flush water shall not be used for any purpose. Sanitary procedures shall be followed when handling filter backwash and flush discharge or graywater.

(2) Emitters shall have a minimum flow path of 1,200 microns and shall have a coefficient of manufacturing variation (Cv) of no more than 7 percent. Irrigation system design shall be such that emitter flow variation shall not exceed ± 10 percent. Emitters shall be recommended by the manufacturer for subsurface use and graywater use, and shall have demonstrated resistance to root intrusion. For emitter ratings, refer to Irrigation Equipment Performance Report, Drip Emitters and Micro-Sprinklers, Center for Irrigation Technolo-

gy, California State University, 5730 N. Chestnut Avenue, Fresno, California 93740-0018.

(3) Each irrigation zone shall be designed to include no less than the number of emitters specified in Table J-3, or through a procedure designated by the Administrative Authority. Minimum spacing between emitters is 14 inches in any direction.

(4) The system design shall provide user controls, such as valves, switches, timers and other controllers, as appropriate, to rotate the distribution of graywater between irrigation zones.

(5) All drip irrigation supply lines shall be PVC Class 200 pipe or better and Schedule 40 fittings. All joints shall be properly glued, inspected and pressure tested at 40 psi, and shown to be drip tight for five minutes, before burial. All supply lines will be buried at least 8 inches deep. Drip feeder lines can be poly or flexible PVC tubing and shall be covered to a minimum depth of 9 inches.

(6) Where pressure at the discharge side of the pump exceeds 20 psi, a pressure-reducing valve able to maintain downstream pressure no greater than 20 psi shall be installed downstream from the pump and before any emission device.

(7) Each irrigation zone shall include an automatic flush valve/vacuum breaker to prevent back siphonage of water and soil.

(b) Standards for the mini-leachfield system are (Figure 5):

(1) Perforated sections shall be a minimum 3-inch diameter and shall be constructed of perforated high-density polyethylene pipe, perforated ABS pipe, perforated PVC pipe, or other approved materials, provided that sufficient openings are available for distribution of the graywater into the trench area. Material, construction and perforation of the piping shall be in compliance with the appropriate absorption field drainage piping standards and shall be approved by the Administrative Authority.

(2) Clean stone, gravel or similar filter material acceptable to the Administrative Authority, and varying in size between 3/4 inch to 2 1/2 inches shall be placed in the trench to the depth and grade required by this Section. Perforated sections shall be laid on the filter material in an approved manner. The perforated sections shall then be covered with filter material to the minimum depth required by this Section. The filter material shall then be covered with landscape filter fabric or similar porous material to prevent closure of voids with earth backfill. No earth backfill shall be placed over the filter material cover until after inspections and acceptance.

(3) Irrigation fields shall be constructed as follows:

	Minimum	Maximum
Number of drain lines per irrigation zone	1	—
Length of each perforated line	—	100 feet
Bottom width of trench	6 inches	18 inches
Total depth of trench	17 inches	18 inches
Spacing of lines, center to center	4 feet	—
Depth of earth cover of lines	9 inches	—
Depth of filter material cover of lines	2 inches	—
Depth of filter material beneath lines	3 inches	—
Grade of perforated lines	level	3 inches/100 feet

J 12 Special Provisions

(a) Other collection and distribution systems may be approved by the Administrative Authority as allowed by Section 201 of the U.P.C.

(b) Nothing contained in this Appendix shall be construed to prevent the Administrative Authority from requiring compliance with stricter requirements than those contained herein, where such stricter requirements are essential in maintaining safe and sanitary conditions or from prohibiting graywater systems.

J 13 Health and Safety

(a) Graywater may contain fecal matter as a result of bathing and/or washing of diapers and undergarments. Water containing fecal matter, if swallowed, can cause illness in a susceptible person.

(b) Graywater shall not include laundry water from soiled diapers.

(c) Graywater shall not be applied above the land surface or allowed to surface and shall not be discharged directly into or reach any storm sewer system or any water of the United States.

(d) Graywater shall be not be contacted by humans, except as required to maintain the graywater treatment and distribution system.

(e) Graywater shall not be used for vegetable gardens.

Table J-1 Location of Graywater System

Minimum Horizontal Distance From	Surge Tank (feet)	Irrigation Field (feet)
Buildings or structures[1]	5^2	8^3
Property line adjoining private property	5	5
Water supply wells[4]	50	100
Streams and lakes[4]	50	50
Seepage pits or cesspools	5	5
Disposal field and 100 percent expansion area	5	4^5
Septic tank	0	5^6
On-site domestic water service line	5	5^7
Pressure public water main	10	10^8
Water ditches	50	50

NOTES: When mini-leach fields are installed in sloping ground, the minimum horizontal distance between any part of the distribution system and ground surface shall be 15 feet.

[1] Including porches and steps, whether covered or uncovered, but does not include car-ports, covered walks, driveways and similar structures.

[2] The distance may be reduced to 0 feet for aboveground tanks if approved by the Administrative Authority.

[3] The distance may be reduced to 2 feet, with a water barrier, by the Administrative Authority, upon consideration of the soil expansion index.

[4] Where special hazards are involved, the distance may be increased by the Administrative Authority.

[5] Applies to the mini-leachfield type system only. Plus 2 feet for each additional foot of depth in excess of 1 foot below the bottom of the drain line.

[6] Applies to mini-leachfield-type system only.

[7] A 2-foot separation is required for subsurface drip systems.

[8] For parallel construction or for crossings, approval by the Administrative Authority shall be required.

Table J-2 Mini-Leachfield Design Criteria of Six Typical Soils

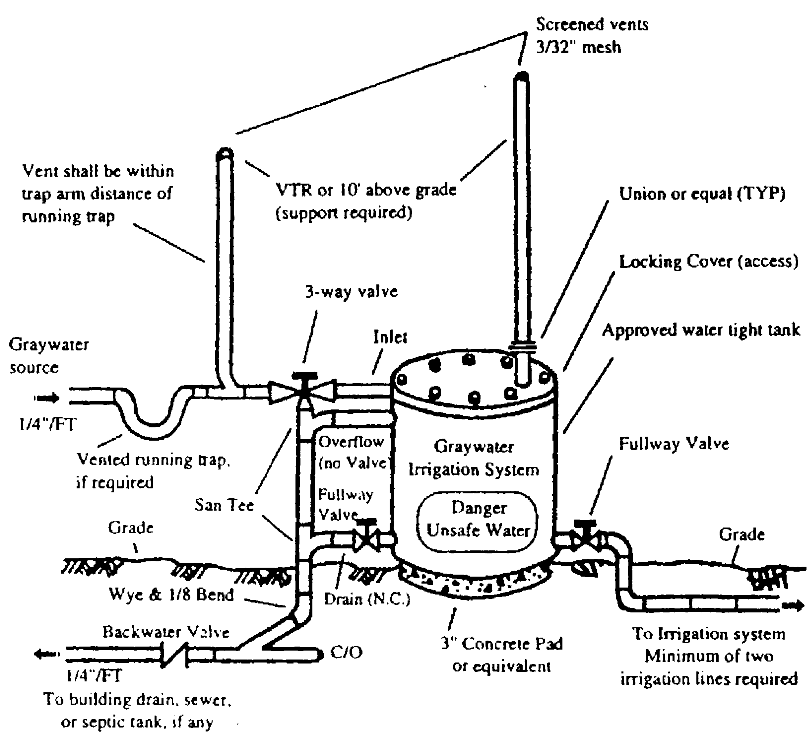
Type of Soil	Minimum sq. ft. of irrigation area per 100 gallons of estimated graywater discharge per day	Maximum absorption capacity, minutes per inch, of irrigation area for a 24-hour period
1. Coarse sand or gravel	20	5
2. Fine sand	25	12
3. Sandy loam	40	18
4. Sandy clay	60	24
5. Clay with considerable sand or gravel	90	48
6. Clay with small amount of sand or gravel	120	60

Table J-3 Subsurface Drip Design Criteria of Six Typical Soils

Type of Soil	Maximum emitter discharge (gal/day)	Minimum number of emitters per gpd of graywater production
1. Sand	1.8	0.6
2. Sandy loam	1.4	0.7
3. Loam	1.2	0.9
4. Clay loam	0.9	1.1
5. Silty clay	0.6	1.6
6. Clay	0.5	2.0

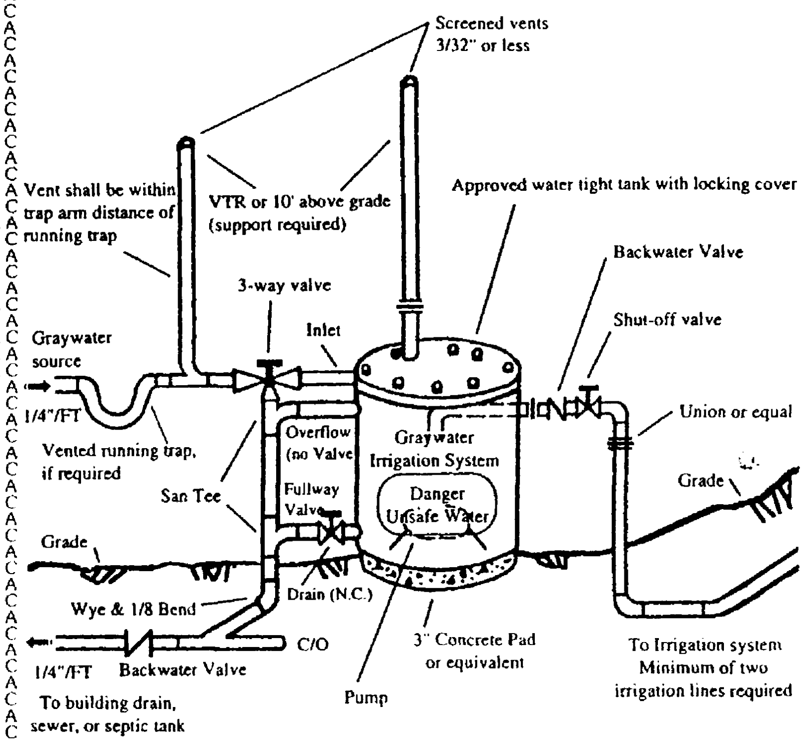
Use the daily graywater flow calculated in Section J-6 to determine the number of emitters per line.

FIGURE 1



Abbreviations
C/O Cleanout
N.C. Normally Closed
VTR Vent Thru Roof

Figure 1—Graywater System Single Tank—Gravity (conceptual)



Abbreviations
C/O Cleanout
N.C. Normally Closed
VTR Vent Thru Roof

Figure 2—Graywater System Single Tank—Pumped (conceptual)

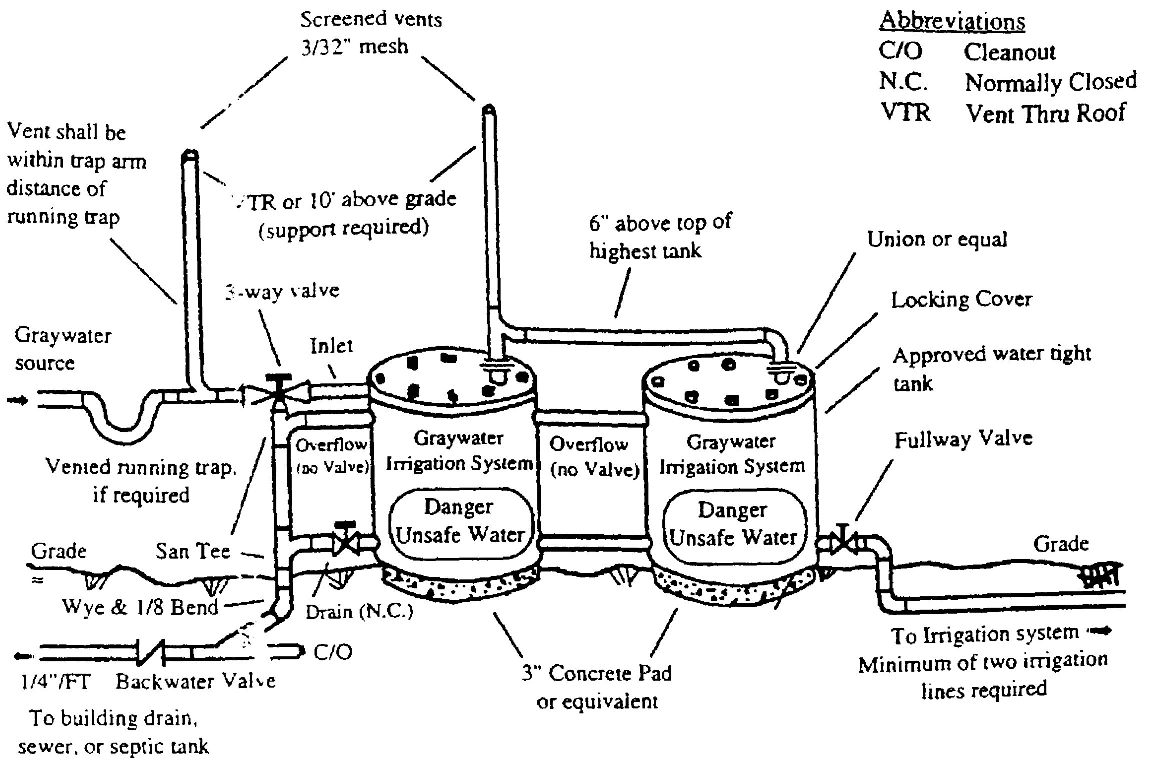


Figure 3—Graywater System Multiple Tank (conceptual)

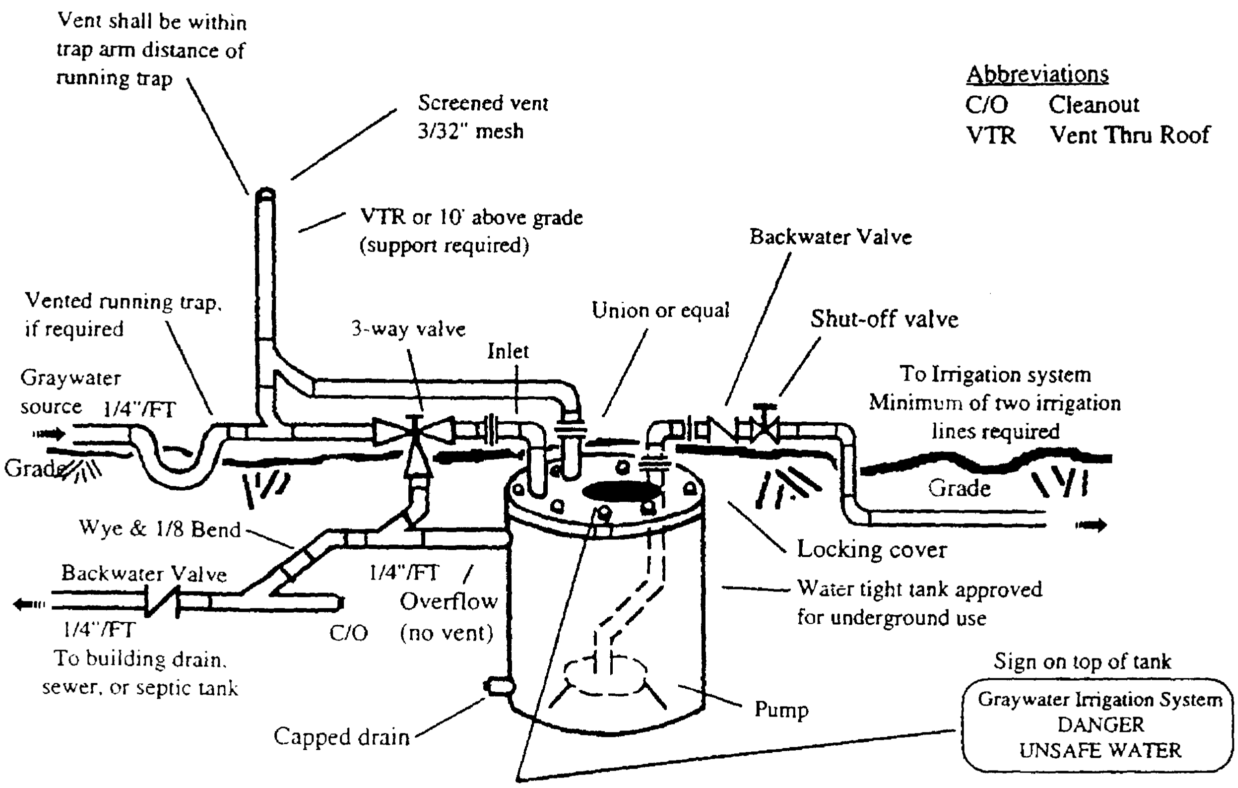


Figure 4—Graywater System Underground Tank (conceptual)

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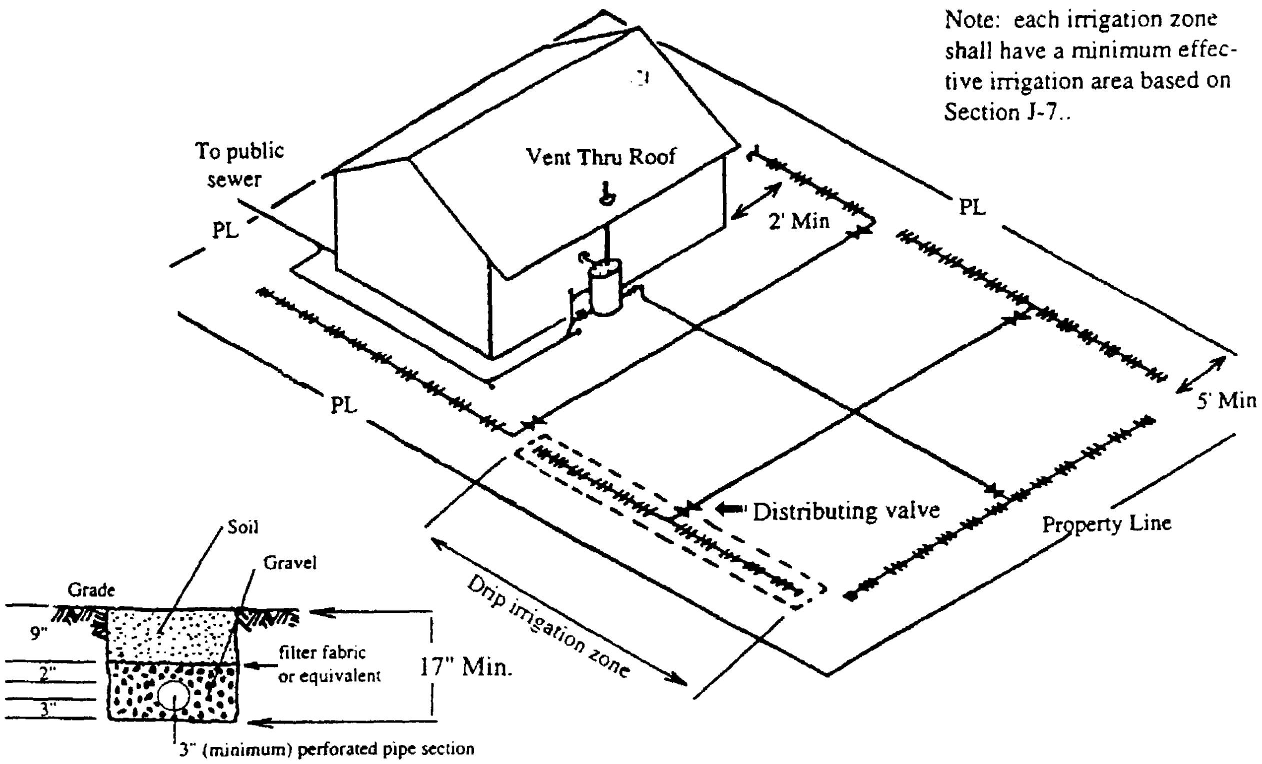


Figure 5—Graywater System Irrigation Layout (conceptual)

Graywater Measures Checklist

Description	Designer	Plan Checker	Inspector
Drawings and Specifications (J-4)			
(J-4, a) plot plan drawn to scale showing:			
lot lines and structure			
direction and approximate slope of surface			
location of retaining walls, drainage channels, water supply lines, wells			
location of paved areas and structures			
location of sewage disposal system and 100% expansion area			
location of graywater system (Table J-1 lists required distances)			
number of bedrooms and plumbing fixtures			
(J-4, b) details of contruction: installation, construction, and materials			
(J-4, c) log of soil formations, ground water level, water absorption of soil			
(J-7) no irrigation point within 5 ft. of highest known seasonal groundwater			
Estimating Graywater Discharge (J-6)			
bedroom #1 (2 occupants)			
additional bedrooms (1 occupant)			
showers, tubs, wash basins: 25 GPD/occupant			
laundry: 15 GPD/occupant			
Required Area (J-7)			
at least two irrigation zones			
each zone to distribute all graywater produced daily without surfacing			
meets Table J-2 design criteria of mini-leachfield OR			
meets Table J-2 design criteria for subsurface drip systems			
Surge Tanks (J-9)			
solid, durable material, watertight when filled, protected from corrosion			
(J-5, a) anchored on dry, level, compacted soil or 3 inch concrete slab			
meets standards for non-potable water			
vented with locking gasketed access opening			
capacity permanently marked on tank			
"GRAYWATER IRRIGATION SYSTEM, DANGER-UNSAFE WATER" permanently marked on tank			
drain and overflow permanently connected to sewer or septic tank			
Valves and Piping (J-10)			
piping downstream of waterseal type trap			
piping marked "DANGER-UNSAFE WATER"			
all valves readily accessible			
backwater valves on all surge tank drain connections to sanitary drain or sewer			
(J-5, a) stub-out plumbing permanently marked			

Graywater Measures Checklist

Description	Designer	Plan Checker	Inspector
Subsurface drip irrigation systems (J-11, a)			
minimu m 140 mesh (115 micron) one inch filter, with a 25 gpm capacity			
filter back-wash to the sewer system or septic tank			
emitter flow path of 1200 microns			
cv no more than 7%, flow variation no more than 10%			
emitters resistant to root intrusion (see CIT list)			
number of emitters determined from Table J-3, minimum spacing 14 inches			
supply lines of PVC class 200 pipe or better and schedule 40 fittings, when			
pressure tested at 40 psi, drip-tight for 5 minutes			
supply lines 8 inches deep, feeder lines (poly or flexible PVC) 9 inches deep			
downstream pressure does not exceed 20 psi (pounds per square inch)			
each irrigation zone has automatic flush valve/vacuum breaker			
Mini-leachfield systems (J-11, b)			
perforated lines minimum 3 inches diameter			
high density polyethylene pipe, perforated ABS pipe, or perforated PVC pipe			
maximum length of perofrated line- 100 feet			
maximum grade- 3 inches/100 feet			
minimum spacing- 4 feet			
earth cover of lines at least 9 inches			
clean stone or gravel filter material from 3/4 to 2 1/2 inch size in trench 3 inch			
deep beneath lines and 2 inches above			
filter fabric covers filter material			
Inspection (J-5, a)			
system components identified as to manufacturer			
irrigation field installed at same location as soil test, if required			
installation conforms with approved plans			
Testing (J-5, b)			
surge tank remains watertight as tank is filled with water			
flow test shows all lines and componints remain watertight			

What ' Irrigate?

Greywater can be used to irrigate fruit trees, groundcovers and ornamental trees and shrubs. Salt-tolerant plants such as oleander, bermuda grass, date palms, and native desert plants are well-suited to irrigation with greywater. Avoid using greywater on plants that prefer acid conditions, such as:

Ash	Foxglove	Philodendron	Hydrangea	Camellia
Azalea	Gardenia	Primrose	Oxalis	Xylosma
Begonia	Hibiscus	Rhododendron	Violet	Fern
Dicentra	Impatiens			

Sandy soils are less vulnerable to damage than clay soils because they drain better. In very low rainfall areas, apply fresh water occasionally to leach out accumulated salts. Be aware that some harmful effects are not always visible immediately and may take one or two years to appear. In any case, you should always pay attention to the health of the plants being irrigated and discontinue using greywater if signs of stress are observed.

About The Study

All the detergents and related clothes-washing products were purchased in Tucson during May, 1992. The amounts used were based on the manufacturers' recommended levels for a cool- to warm-water wash in a top-loading machine. Distilled water was used as a source to minimize the effect of widely-varying salt and mineral levels in tap water. The list is presented in alphabetical order and is intended as a basis for comparison only. No endorsement of any product is intended.

This study was based in part on research conducted by the Pima County Extension Service, and was prepared by the Office of Arid Lands Studies, in cooperation with the Soil, Water and Plant Analysis Laboratory, University of Arizona, and sponsored by Tucson Water.

For more information...

on legal requirements to operate a greywater system,
contact Pima County Department of Environmental Quality at **740-3340**
or Arizona Dept. of Environmental Quality in Tucson at **628-6733**
or call **1-800-234-5677, ext. 4667.**

on greywater systems or water conservation, call Tucson Water at **791-4331.**

tucson water

City of Tucson TDD number (Telecommunication Device for the Deaf) **791-2639**

WCO/3 93

GREYWATER AND YOUR DETERGENT

This pamphlet is intended for those conservation-minded people who would like to use washing machine water (greywater) to irrigate their landscapes. **However, the use of greywater and operation of greywater systems are carefully regulated by the Pima County Department of Environmental Quality and the Arizona Department of Environmental Quality.** Contact the Pima County Department of Environmental Quality at **740-3340** for requirements and regulations regarding permits for the construction, operation, and maintenance of greywater systems and use of greywater.

If you plan to use washing machine water to irrigate, you should be aware of the elements present in this water which may affect your plants or soils. Detergents and other clothes-washing products use a variety of chemicals to aid in cleansing. Some of these ingredients can be harmful to your plants. Because labeling on detergent and other clothes-washing products is often incomplete, a study was conducted to evaluate some critical product characteristics which may adversely affect the landscape, including alkalinity, boron, conductivity, sodium, and phosphate.

Alkalinity

Alkalinity refers to the relative amounts of alkaline chemicals in a solution. Sodium, potassium, and calcium are alkaline chemicals; they often are combined with carbonates, sulfates, or chlorides. Plants do ot tolerate high concentrations of alkali salts.

oron

Boron is considered a plant micronutrient, required in only very, very small amounts. Most soils ovide adequate amounts of this chemical. Concentrations only slightly higher than those considered necessary can cause severe injury or death to plants.

onductivity

Conductivity is a simple measure of the amount of dissolved chemicals in a solution. These emicals can be beneficial or harmful. The higher the conductivity, the more dissolved salts and minerals e present. In general, the higher the concentration of dissolved salts and minerals in the water, the greater potential for adverse affects on the environment and plant health.

Sodium

Sodium can act as a plant poison by reducing the plant's ability to take up water from the soil. Too ich sodium can destroy the structure of clay soils, making them slick and greasy by removing air spaces and thus preventing good drainage. Once a clay soil is damaged by sodium, it can be very difficult to restore it to a viable condition.

Phosphate

Phosphate is a plant food and is added to soil as a fertilizer. Soils in the Tuscon area are typically low in phosphate, thus, there may be some benefit to plants if phosphate is present in greywater. This should not be relied upon, however, since many forms of phosphate are not readily usable by plants and soils.

Is Biodegradable Better?

The word biodegradable means that a complex chemical is broken down into simpler components through biological action. Do not be confused by the word biodegradable, which often is used to imply environmentally safe. Harmful chemicals as well as beneficial ones may be biodegradable.

A Note About Chlorine

Although chlorine in bleach and detergents is generally expended in the washing process, some may be left in the greywater that reaches plants. Chlorine should not be used in the garden because it may substitute for similar nutrients, blocking normal metabolic processes. The addition of chlorine to water used for irrigation should be kept to a minimum. Choose your detergent and clothes-washing products keeping in mind that it is better for your plants and soils to have a low alkalinity, boron, conductivity, and sodium content in the water. Personal preference may affect your choice of products, since higher levels of these

Product Name	P or L	Conductivity	Alkalinity	Sodium	Boron	Phosphate
Ajax Ultra	P	1130	219	292	0.040	11.2
Alfa Kleen	L	25.6	16.8	3.71	<<	<<<
All	P	2030	659	492	0.10	NT
All Regular	L	116	29.8	39.3	<<	<<<
Amway	P	939	310	227	<<	4.00
Ariel Ultra	P	1020	247	280	0.030	10.8
Arm and Hammer	P	2450	1160	572	<<	<<<
Bold	L	46.7	68.6	9.74	<<	<<<
Bonnie Hubbard Ultra	P	1560	617	377	0.036	<<<
Calgon Water Softener	P	1290	345	359	<<	22.9
Cheer Free	L	307	80.3	94.7	<<	<<<
Cheer Ultr	P	710	149	171	0.076	<<<
Chlorox 2	P	2880	1430	672	11.2	<<<
Dash	P	1060	482	238	2.14	<<<
Dreft Ultra	P	737	328	189	9.75	<<<
Downy Fabric Softener	L	6.37	NT	<	<<	<<<
Ecovcover	L	132	63.7	24.3	<<	<<<
ERA Plus	L	102	15.3	26.3	<<	<<<
Fab Ultra	P	1140	199	443	<<	21.7
Fab 1-Shot	Pkt	501	09	109	<<	5.26
Fresh Start	P	510	106	132	0.026	8.28
Gain Ultra	P	792	300	180	0.058	<<<
Greenmark	P	1690	568	395	<<	1.67
Ivory Snow	P	258	219	70.8	<<	NT
Oasis	L	89.6	16.2	<	<<	<<<
Oxydol Ultra	P	1030	501	272	11.3	<<<
Par All Temperature	P	2350	431	529	0.049	2.67
Purex Ultra	P	1010	278	231	<<	<<<
Sears Plus	P	2500	1200	635	<<	<<<
Shaklee	L	19.0	12.1	6.48	<<	<<<
Shaklee Basic L	P	1030	285	230	<<	<<<
Snuggle Fabric Softener	L	2.60	NT	<	<<	<<<
Sun Ultra	P	1490	653	335	<<	1.58
Surf Ultra	P	989	302	249	<<	13.7
Tide with Bleach	L	329	58.3	95.0	2.30	<<<
Tide Regular	L	291	61.2	93.8	0.030	<<<
Tide Ultra	P	959	236	243	0.098	10.7
Valu Time	P	1650	460	371	0.034	1.79
White King	P	266	165	74.0	1.83	NT
White Magic Ultra	P	1140	194	273	0.035	18.5
Wisk Advanced Action	L	221	72.4	56.8	7.41	<<<
Wisk Power Scoop	P	1160	360	319	<<	9.77
Woolite	P	1040	22.3	239	0.17	<<<
Yes	L	42.5	10.3	6.40	<<	<<<
Tap Water	n/a	317	118	42.7	0.042	<<<
Distilled/Deionized Water	n/a	2.03	3.78	<	<<	<<<

Legend: P: Powder L: Liquid

<: Less than the sodium detection limit of 1.0 mg/l.

<<: Less than the boron detectionlimit of 0.025 mg/l

Historical Evapotranspiration Values in Inches for July

North Central Coast	monthly	weekly
Novato	5.9	1.3
San Francisco	4.5	1.0
Concord	7.0	1.6
San Jose	6.5	1.5
Monterey	4.3	1.0
San Luis Obispo	4.6	1.0
South Coastal		
Santa Barbara	5.5	1.3
Ventura	5.5	1.3
Los Angeles	6.6	1.5
Laguna Beach	4.9	1.1
San Diego	4.6	1.0
Central Valley		
Auburn	8.3	1.9
Sacramento	8.4	1.9
Modesto/Stockton	8.1	1.8
Fresno	8.4	1.9
Baskersfield	8.5	1.9
Redding	8.5	1.9
South Inland		
San Fernando	7.3	1.7
Pasadena	7.1	1.6
Riverside	7.9	1.8
Ramona	7.3	1.7
San Bernardino	7.9	1.8
High Desert		
Palmdale	9.9	2.3
Lancaster	11.0	2.5
Victorville	11.2	2.5
Bishop	7.4	1.7
Independence	9.8	2.2
Low Desert		
Palm Springs	11.6	2.6
Coachella	12.3	2.8
Needles	12.8	2.9
El Centro	11.6	2.6

ATTACHMENT 5

Revised Graywater Standards., Appendix G Gray Water Systems, Title 24, Part 5, California Administrative Code., March 18, 1997

Revised Graywater Standards

On March 18, 1997, the Building Standards Commission approved the revised California Graywater Standards (attached Appendix G). The most significant change in the standards is that gray water systems can now be used in commercial, industrial, and multifamily projects, as well as single-family residences.

Other changes include: (1) that only one irrigation zone is now required (rather than the previous two); (2) filters are to be sized appropriately to maintain the filtration rate rather than the previously prescribed 1-inch filter; and (3) a new procedure for estimating gray water discharge has been added for commercial, industrial, and institutional projects.

The revised standards will be published officially in the California Plumbing Code in the fall of 1997.

3/18/97

APPENDIX G
GRAYWATER SYSTEMS ~~FOR SINGLE FAMILY DWELLINGS~~
Title 24, Part 5, California Administrative Code

G-1 Graywater Systems. (General)

(a) The provisions of this Appendix shall apply to the construction, installation, alteration and repair of graywater systems for subsurface landscape irrigation. ~~Installations shall be allowed only in single family dwellings. The system shall have no direct connection to any potable water system without an airgap~~. The graywater system shall not be connected to any potable water system without an air gap (a space or other physical device which prevents backflow) and shall not result in any surfacing of the graywater. Except as otherwise provided for in this Appendix, the provisions of the Uniform Plumbing Code (UPC) shall be applicable to graywater installations.

(b) The type of system shall be determined on the basis of location, soil type, and ground water level and shall be designed to accept all graywater connected to the system from the ~~residential~~ building. The system shall discharge into subsurface irrigation fields and may include surge tank(s) and appurtenances, as required by the Administrative Authority.

(c) No graywater system, or part thereof, shall be located on any lot other than the lot which is the site of the building or structure which discharges the graywater; nor shall any graywater system or part thereof be located at any point having less than the minimum distances indicated in Table G-1.

(d) No permit for any graywater system shall be issued until a plot plan with appropriate data satisfactory to the Administrative Authority has been submitted and approved. When there is insufficient lot area or inappropriate soil conditions for adequate absorption of the graywater, as determined by the Administrative Authority, no graywater system shall be permitted. The Administrative Authority is a city or county.

(e) No permit shall be issued for a graywater system which would adversely impact a geologically sensitive area, as determined by the Administrative Authority.

(f) Private sewage disposal systems existing or to be constructed on the premises shall comply with Appendix I of this code or applicable local ordinance. When abandoning underground tanks, Section 722.0 ~~1119~~ of the UPC shall apply. Also, appropriate clearances from graywater systems shall be maintained as provided in Table G-1. The capacity of the private sewage disposal system, including required future areas, shall not be decreased by the existence or proposed installation of a graywater system servicing the premises.

(g) Installers of graywater systems shall provide an operation and maintenance manual, acceptable to the Administrative Authority, to the owner of each system. Graywater systems require regular or periodic maintenance.

(h) The Administrative Authority shall provide the applicant a copy of this Appendix.

G-2 Definitions.

Graywater is untreated ~~household~~ waste water which has not come into contact with toilet waste. Graywater includes waste water from bathtubs, showers, bathroom wash basins, ~~and water from~~ clothes washing machines, and laundry tubs, or an equivalent discharge as approved by the Administrative Authority. It does not include waste water from kitchen sinks, photo lab sinks, dishwashers, or laundry water from soiled diapers.

Surfacing of graywater means the ponding, running off, or other release of graywater from the land surface.

G-3 **Permit.**

It shall be unlawful for any person to construct, install or alter, or cause to be constructed, installed or altered any graywater system in a building or on premises without first obtaining a permit to do such work from the Administrative Authority.

4 **Drawings and Specifications.**

.e Administrative Authority may require any or all of the following information to be included with or in the plot plan before a permit is issued for a graywater system:

(a) Plot plan drawn to scale completely dimensioned, showing lot lines and structures, direction and approximate slope of surface, location of all present or proposed retaining walls, drainage channels, water supply lines, wells, paved areas and structures on the plot, number of bedrooms and plumbing fixtures in each structure, location of private sewage disposal system and 100 percent expansion area or building sewer connecting to public sewer, and location of the proposed graywater system.

(b) Details of construction necessary to ensure compliance with the requirements of this Appendix together with a full description of the complete installation including installation methods, construction and materials as required by the Administrative Authority.

(c) A log of soil formations and ground water level as determined by test holes dug in close proximity to any proposed irrigation area, together with a statement of water absorption characteristics of the soil at the proposed site as determined by approved percolation tests. In lieu of percolation tests, the Administrative Authority may allow the use of Table G-2, an infiltration rate designated by the Administrative Authority, or an infiltration rate determined by a test approved by the Administrative Authority.

(d) A characterization of the graywater for commercial, industrial, or institutional systems, based on existing records or testing.

Inspection and Testing.

(a) Inspection

1. All applicable provisions of this Appendix and of Section 103.5 ~~318~~ of the UPC shall be complied with.
2. System components shall be properly identified as to manufacturer.
3. Surge tanks shall be installed on dry, level, well-compacted soil if in a drywell, or on a level, three inch concrete slab or equivalent, if above ground.
4. Surge tanks shall be anchored against overturning.
5. If the irrigation design is predicated on soil tests, the irrigation field shall be installed at the same location and depth as the tested area.
6. Installation shall conform with the equipment and installation methods identified in the approved plans.
7. Graywater stub-out plumbing may be allowed for future connection prior to the installation of irrigation lines and landscaping. Stub-out shall be permanently marked "GRAYWATER STUB-OUT, DANGER - UNSAFE WATER."

(b) Testing

1. Surge tanks shall be filled with water to the overflow line prior to and during inspection. All seams and joints shall be left exposed and the tank shall remain watertight.

2. A flow test shall be performed through the system to the point of graywater irrigation. All lines and components shall be watertight.

G-6 Procedure for Estimating Graywater Discharge

(a) Single Family Dwellings and Multi-Family Dwellings

The Administrative Authority may utilize the graywater discharge proce-ure listed below, water u... records, or calculations of local daily per person interior water use:

1. The number of occupants of each dwelling unit shall be calculated as follows:

First Bedroom	2 occupants
Each additional bedroom	1 occupant

2. The estimated graywater flows for each occupant shall be calculated as follows:

Showers, bathtubs and wash basins	25 GPD/occupant.
Laundry	15 GPD/occupant.

3. The total number of occupants shall be multiplied by the applicable estimated graywater discharge as provided above and the type of fixtures connected to the graywater system.

(b) Commercial, Industrial, and Institutional Projects

The Administrative Authority may utilize the graywater discharge procedure listed below, water use records, or other documentation to estimate graywater discharge:

1. The square footage of the building divided by the occupant load factor from UPC Table 10-A equals the number of occupants.

2. The number of occupants times the flow rate per person (minus toilet water and other disallowed souces) from UBC Table I-2 equals the estimated graywater discharge per day.

The graywater system shall be designed to distribute the total amount of estimated graywater discharged daily.

G-7 Required Area of Subsurface Irrigation.

Each irrigation zone shall have a minimum effective irrigation area for the type of soil and infiltration rate to distribute all graywater produced daily, pursuant to Section G-6, without surfacing. The required irrigation area shall be based on the estimated graywater discharge, pursuant to Section G-6, size of surge tank, or a method determined by the Administrative Authority. ~~Each proposed graywater system shall include at least two irrigation zones and each irrigation zone shall be in compliance with the provisions of this Section~~.

If a mini-leachfield irrigation system is used, the required square footage shall be determined from Table G-2, or equivalent, for the type of soil found in the excavation. The area of the irrigation field shall be equal to the aggregate length of the perforated pipe sections within the irrigation zone times the width of the proposed mini-leachfield trench.

No irrigation point shall be within five vertical feet of highest known seasonal groundwater nor where graywater may contaminate the ground water or ocean water. The applicant shall supply evidence of ground water depth to the satisfaction of the Administrative Authority.

G-8 Determination of Irrigation Capacity.

(a) In order to determine the absorption quantities of soils other than those listed in Table G-2, the proposed site may be subjected to percolation tests acceptable to the Administrative Authority or determined by the Administrative Authority.

(b) When a percolation test is required, no mini-leachfield system or subsurface drip irrigation system shall be permitted if the test shows the absorption capacity of the soil is less than 60 minutes/inch or more rapid than 5 minutes/inch, unless otherwise permitted by the Administrative Authority.

(c) The irrigation field size may be computed from Table G-2, or determined by the Administrative Authority or a designee of the Administrative Authority.

G-9 Surge Tank Construction. (FIG. 1~~, 2, 3 & 4~~)

(a) Plans for surge tanks shall be submitted to the Administrative Authority for approval. The plans shall show the data required by the Administrative Authority and may include dimensions, structural calculations, and bracing details.

(b) Surge tanks shall be constructed of solid, durable materials, not subject to excessive corrosion or decay and shall be watertight.

(c) Surge tanks shall be vented as required by Chapter 9 of this Code and shall have a locking, gasketed access opening, or approved equivalent, to allow for inspection and cleaning.

(d) Surge tanks shall have the rated capacity permanently marked on the unit. In addition, "GRAYWATER IRRIGATION SYSTEM, DANGER - UNSAFE WATER" shall be permanently marked on the surge tank.

(e) Surge tanks installed above ground shall have ~~a drain and~~ an overflow, separate from the line connecting the tank with the irrigation fields. The ~~drain and~~ overflow shall have a permanent connection to a sewer or to a septic tank, and shall be protected against sewer line backflow by a backwater valve. The overflow shall not be equipped with a shut-off valve.

(f) The overflow and drain pipes shall not be less in diameter than the inlet pipe. The vent size shall be based on the total graywater fixture units, as outlined in UPC Table 7-5 ~~4-3~~ or local equivalent. Unions or equally effective fittings shall be provided for all piping connected to the surge tank.

(g) Surge tanks shall be structurally designed to withstand anticipated loads. Surge tank covers shall be capable of supporting an earth load of not less than 300 pounds per square foot when the tank is designed for underground installation.

(h) Surge tanks may be installed below ground in a dry well on compacted soil, or buried if the tank design is approved by the Administrative Authority. The system shall be designed so that the tank overflow will gravity drain to a sanitary sewer line or septic tank. The tank must be protected against sewer line backflow by a backwater valve.

(i) Materials

1. Surge tanks shall meet nationally recognized standards for non-potable water and shall be approved by the Administrative Authority.
2. Steel surge tanks shall be protected from corrosion, both externally and internally, by an approved coating or by other acceptable means.

G-10 Valves and Piping. (FIG. 1~~, 2, 3 & 4~~)

Graywater piping discharging into a surge tank or having a direct connection to a sanitary drain or sewer piping shall be downstream of an approved waterseal type trap(s). If no such trap(s) exists, an approved vented running trap shall be installed upstream of the connection to protect the building from any possible waste or sewer gasses. Vents and venting shall meet the requirements in Chapter 9 of the UPC. All graywater piping shall be marked or shall have a continuous tape marked with the words "DANGER - UNSAFE WATER." All valves, including the three-way valve, shall be readily accessible and shall be approved by the Administrative Authority. A backwater valve, installed pursuant to this ~~Code~~ Appendix, shall be provided on all surge tank drain connections to the sanitary drain or sewer piping.

G-11 Irrigation Field Construction.

The Administrative Authority may permit subsurface drip irrigation, mini-leachfield or other equivalent irrigation methods which discharge graywater in a manner which ensures that the graywater does not surface. Design standards for subsurface drip irrigation systems and mini-leachfield irrigation systems follow:

(a) Standards for a subsurface drip irrigation system are:

1. Minimum 140 mesh (115 micron) ~~one inch~~ filter with a capacity of 25 gallons per minute, or equivalent, filtration, sized appropriately to maintain the filtration rate, shall be used. The filter back-wash and flush discharge shall be caught, contained and disposed of to the sewer system, septic tank, or with approval of the Administrative Authority, a separate mini-leachfield sized to accept all the back-wash and flush discharge water. Filter backwash water and flush water shall not be used for any purpose. Sanitary procedures shall be followed when handling filter back-wash and flush discharge or graywater.

2. Emitters shall have a minimum flow path of 1200 microns and shall have a coefficient of manufacturing variation (Cv) of no more than seven percent. Irrigation system design shall be such that emitter flow variation shall not exceed plus or minus ten percent. Emitters shall be recommended by the manufacturer for subsurface use and graywater use, and shall have demonstrated resistance to root intrusion. For emitter ratings refer to: Irrigation Equipment Performance Report, Drip Emitters and Micro-Sprinklers, Center for Irrigation Technology, California State University, 5730 N. Chestnut Avenue, Fresno, California 93740-0018.

3. Each irrigation zone shall be designed to include no less than the number of emitters specified in Table G-3, or through a procedure designated by the Administrative Authority. Minimum spacing between emitters is 14 inches in any direction.

4. The system design shall provide user controls, such as valves, switches, timers, and other controllers as appropriate, to rotate the distribution of graywater between irrigation zones.

5. All drip irrigation supply lines shall be polyethylene tubing or PVC class 200 pipe or better and schedule 40 fittings. All joints shall be properly ~~glued~~, solvent-cemented, inspected and pressure tested at 40 psi, and shown to be drip tight for five minutes, before burial. All supply lines will be buried at least eight inches deep. Drip feeder lines can be poly or flexible PVC tubing and shall be covered to a minimum depth of nine inches.

6. Where pressure at the discharge side of the pump exceeds 20 pounds per square inch (psi), a pressure reducing valve able to maintain downstream pressure no greater than 20 psi shall be installed downstream from the pump and before any emission device.

7. Each irrigation zone shall include ~~an automatic~~ a flush valve/~~vacuum breaker~~ anti-siphon valve to prevent back syphonage of water and soil.

(b) Standards for a mini-leachfield system are (~~Figure 5~~):

1. Perforated sections shall be a minimum 3-inch diameter and shall be constructed of perforated high density polyethylene pipe, perforated ABS pipe, perforated PVC pipe, or other approved materials, provided that sufficient openings are available for distribution of the graywater into the trench area. Material, construction and perforation of the piping shall be in compliance with the appropriate absorption field drainage piping standards and shall be approved by the Administrative Authority.

2. Clean stone, gravel, or similar filter material acceptable to the Administrative Authority, and varying in size between 3/4 inch to 2 1/2 inches shall be placed in the trench to the depth and grade required by this Section. Perforated sections shall be laid on the filter material in an

approved manner. The perforated sections shall then be covered with filter material to the minimum depth required by this Section. The filter material shall then be covered with landscape filter fabric or similar porous material to prevent closure of voids with earth backfill. No earth backfill shall be placed over the filter materia'.cover until after inspections and acceptance.

3. Irrigation fields shall be constructed as follows:

	MINIMUM	MAXIMUM
Number of drain lines per irrigation zone	1	—
Length of each perforated line	—	100 feet
Bottom width of trench	6 inches	18 inches
Total depth of trench	17 inches	18 inches
Spacing of lines, center to center	4 feet	—
Depth of earth cover of lines	9 inches	—
Depth of filter material cover of lines	2 inches	—
Depth of filter material beneath lines	3 inches	—
Grade of perforated lines	level	3 inches/100 feet

G-12 Special Provisions

(a) Other collection and distribution systems may be approved by the Administrative Authority as allowed by Section ~~201~~ 301of the UPC.

(b) Nothing contained in this Appendix shall be construed to prevent the Administrative Authority from requiring compliance with stricter requirements than those contained herein, where such stricter requirements are essential in maintaining safe and sanitary conditions or from prohibiting graywater systems. The prohibition of graywater systems or more restrictive standards may be ·dopted by the Administrative Authority by ordinance after a public hearing.

G-13 Health and Safety

(a) Graywater may contain fecal matter as a result of bathing and/or washing of diapers and undergarments. Water containing fecal matter, if swallowed, can cause illness in a susceptible person. Therefore, graywater shall be not be contacted by humans, except as required to maintain the graywater treatment and distribution system.

(b) Graywater shall not include laundry water from soiled diapers.

(c) Graywater shall not be applied above the land surface or allowed to surface and shall not be discharged directly into or reach any storm sewer system or any water of the United States.

(d) Graywater shall not be used for vegetable gardens.

Table G-1 Location of Graywater System

Minimum Horizontal Distance (in feet) From	Surge Tank	Irrigation Field
Buildings or structures[1]	5 ft[2]	8 ft[3]
Property line adjoining private property	5 ft	5 ft[4]
Water supply wells[5]	50 ft	100 ft
Streams and lakes[5]	50 ft	50 ft
Seepage pits or cesspools	5 ft	5 ft
Disposal field & 100% expansion area	5 ft	4 ft[6]
Septic tank	0 ft	5 ft[7]
On-site domestic water service line	5 ft	5 ft[8]
Pressure public water main	10 ft	10 ft[9]
Water ditches	50 ft	50 ft

Notes: When mini-leach fields are installed in sloping ground, the minimum horizontal distance between any part of the distribution system and ground surface shall be fifteen feet.

1. Including porches and steps, whether covered or uncovered, but does not include car ports, covered walks, driveways and similar structures.
2. The distance may be reduced to zero feet for above ground tanks if approved by the Administrative Authority.
3. The distance may be reduced to two feet~~, with a water barrier, by the Administrative Authority, upon consideration of the soil expansion index~~.
4. <u>For subsurface drip irrigation systems, 2 feet from property line</u>.
5. Where special hazards are involved, the distance may be increased by the Administrative Authority.
6. Applies to the mini-leachfield type system only. Plus two feet for each additional foot of depth in excess of one foot below the bottom of the drain line.
7. Applies to mini-leachfield type system only.
8. A two foot separation is required for subsurface drip systems.
9. For parallel construction or for crossings, approval by the Administrative Authority shall be required.

Table G-2 Mini-Leach Field Design Criteria of Six Typical Soils.

Type of Soil	Minimum sq. ft. of irrigation area per 100 gallons of estimated graywater discharge per day.	Maximum absorption capacity, minutes per inch, of irrigation area for a 24-hour period.
1. Coarse sand or gravel	20	5
2. Fine sand	25	12
3. Sandy loam	40	18
4. Sandy clay	60	24
5. Clay with considerable sand or gravel	90	48
6. Clay with small amount of sand or gravel	120	60

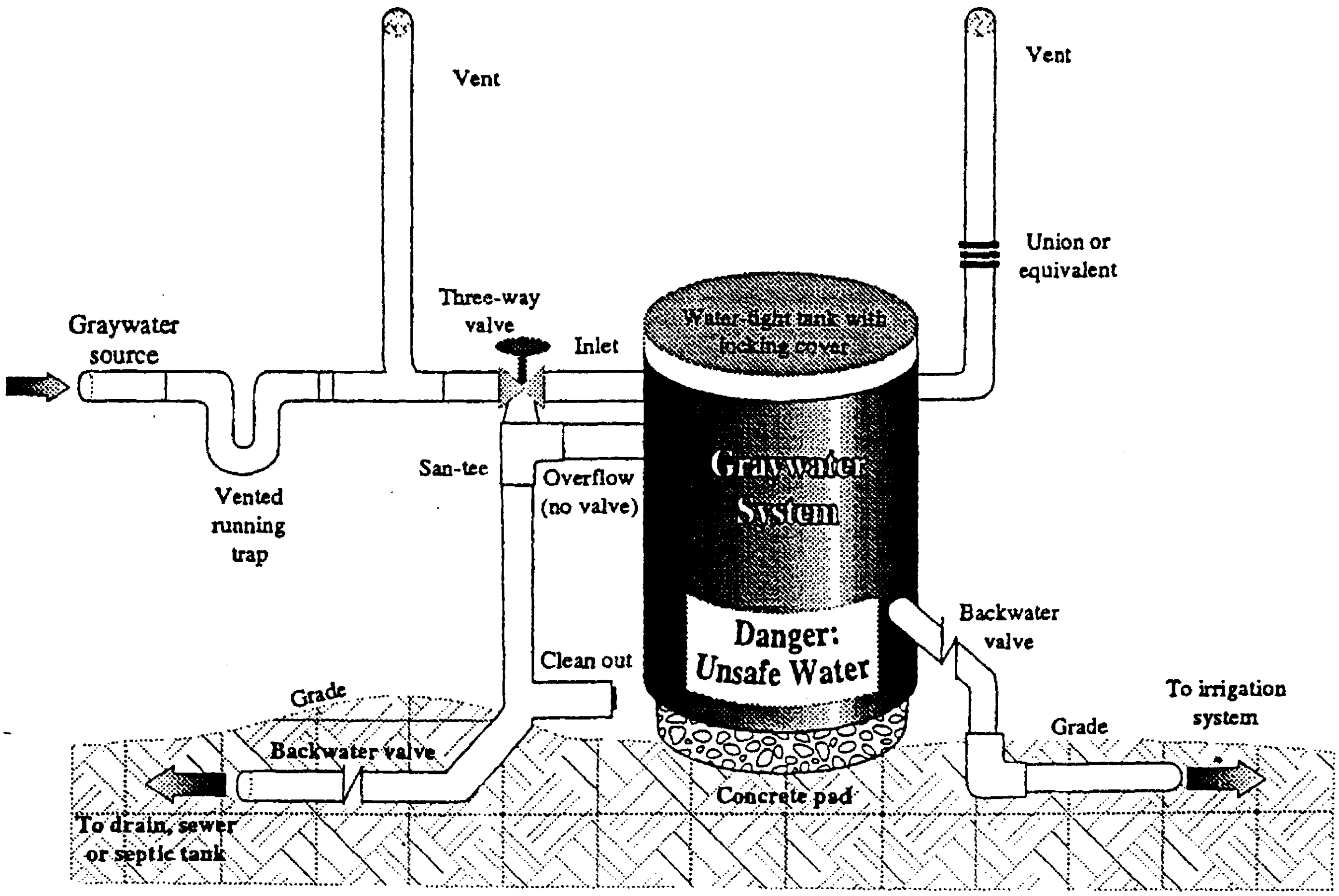
Table G-3 Subsurface Drip Design Criteria of Six Typical Soils.

Type of Soil	Maximum emitter discharge (gal/day)	Minimum number of emitters per gpd of graywater production
1. Sand	1.8	.6
2. Sandy loam	1.4	.7
3. Loam	1.2	.9
4. Clay loam	0.9	1.1
5. Silty clay	0.6	1.6
6. Clay	0.5	2.0

Use the daily graywater flow calculated in Section G-6 to determine the number of emitters per line.

GRAYWATER SYSTEM
(Conceptual)

Figure 1
Date: November, 1996



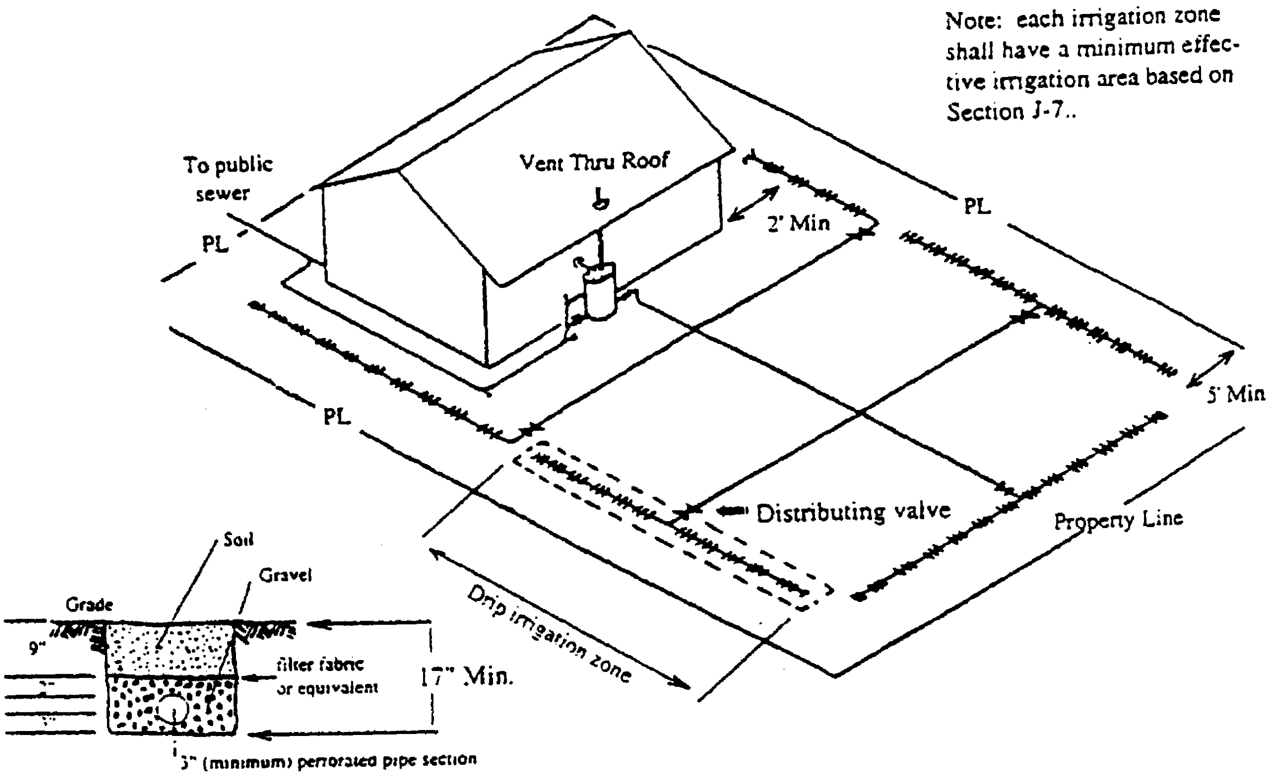


Figure 2—Graywater System Irrigation Layout (conceptual)

ATTACHMENT 6

General Assembly of Virginia., House Joint Resolution No. 587. February 19, 1997

GENERAL ASSEMBLY OF VIRGINIA -- 1997 SESSION

HOUSE JOINT RESOLUTION NO. 587

Requesting the Department of Environmental Quality and the State Department of Health to study examples of water reuse and conservation programs in the United States and to examine any documented adverse health impacts from such programs in order to determine if similar programs could be implemented in Virginia.

Agreed to by the House of Delegates, February 2, 1997
Agreed to by the Senate, February 19, 1997

WHEREAS, the long-term ecological and economic interests of Virginia compel the Commonwealth to examine the capacity of water supply and sewage treatment facilities, the growing problems associated with stormwater runoff, and the potential gains to be realized from encouraging water conservation and reuse whenever feasible; and

WHEREAS, population growth and economic development will place increasing demands on water supplies and on treatment and stormwater management capacities for the foreseeable future; and

WHEREAS, water systems across Virginia are experiencing water treatment and supply capacity constraints; and

WHEREAS, these areas include some of the Commonwealth's poorest localities in Southwest Virginia and on the Eastern Shore and some of its most populous cities such as Virginia Beach and Newport News; and

WHEREAS, the term "gray water" is used to refer to waste water other than sewage water from toilets and other problematic wastes; and

WHEREAS, rain water collection and gray water reuse can provide multiple water conservation benefits through decreased demands on public treatment and supply infrastructures; and

WHEREAS, rain water and gray water reuse may help reclaim otherwise wasted nutrients and reduce nutrient discharges and turbidity problems in Virginia's waterways; and

WHEREAS, state and local governments in some areas of the United States have found feasible methods for reusing gray water to reduce fresh water consumption and diminish sewage infrastructure needs; and

WHEREAS, rain collection and gray water reuse encourage water conservation and environmental awareness; and

WHEREAS, the Commonwealth wishes to protect public health, promote wise use of its natural resources, increase voluntary participation of its citizens in conservation activities, and encourage innovation in the management of its natural resources; now, therefore, be it

RESOLVED by the House of Delegates, the Senate concurring, That the Department of Environmental Quality and the State Department of Health, with input from local governments and concerned citizens, be requested to study examples of water reuse and conservation programs in the United States and to examine any documented adverse health impacts from such programs in order to determine if similar programs could be implemented in Virginia. The study shall: (i) evaluate experiences of state and local governments which have developed procedures, parameters, and programs encouraging the reuse of gray water and the collection of rainwater, (ii) evaluate any documented information on adverse health impacts experienced from gray water reuse, (iii) develop guidelines for appropriate gray water reuse in the Commonwealth, and (iv) make recommendations on incentives to encourage rainwater collection and gray water reuse among appropriately targeted audiences.

All agencies of the Commonwealth shall provide assistance to the Department of Environmental Quality and the State Department of Health for this study, upon request.

The Department of Environmental Quality and the State Department of Health shall complete their work in time to submit their findings and recommendations to the Governor and the 1998 Session of the General Assembly as provided in the procedures of the Division of Legislative Automated Systems for the processing of legislative documents.

ATTACHMENT 7

General Assembly of Virginia., House Bill No. 912. January 26, 1998

989031442

HOUSE BILL NO. 912

Offered January 26, 1998

A BILL to amend the Code of Virginia by adding in Article 10 of Chapter 6 of Title 32.1 a section numbered 32.1-248.2, relating to gray and rain water use guidelines.

Patron—Ruff

Referred to Committee on Conservation and Natural Resources

Be it enacted by the General Assembly of Virginia:

1. That the Code of Virginia is amended by adding in Article 10 of Chapter 6 of Title 32.1 a section numbered 32.1-248.2 as follows:

§ 32.1-248.2. Use of rainwater and reuse of gray water.

A. The Department shall develop by January 1, 1999, guidelines regarding the use of gray and rain water. The guidelines shall describe the conditions under which gray and rain water may appropriately be used and for what purposes. The guidelines shall include categories of used water, such as types of used household water and used water from businesses, which are appropriate for reuse. The guidelines shall include a definition of gray water that does not include used toilet water.

B. The Department, in conjunction with the Department of Environmental Quality, shall promote the use of rain water and reuse of gray water as means to reduce fresh water consumption, ease demands on public treatment works and water supply systems, and promote conservation.

Official Use By Clerks

Passed By The House of Delegates		**Passed By The Senate**	
without amendment	☐	without amendment	☐
with amendment	☐	with amendment	☐
substitute	☐	substitute	☐
substitute w/amdt	☐	substitute w/amdt	☐

Date: ________________ Date: ________________

Clerk of the House of Delegates — Clerk of the Senate

989031442

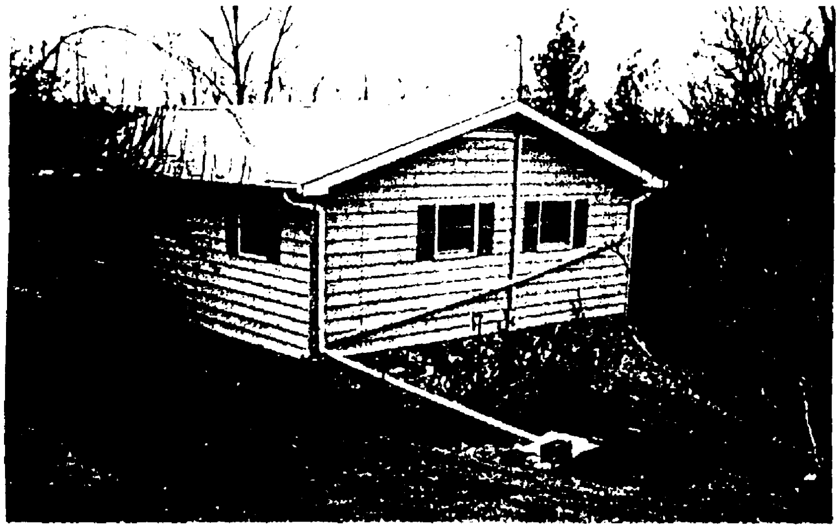
HB912

1/27/98 13:29

ATTACHMENT 8

Evaluation of Rooftop Rainfall Collection-Cistern Storage Systems in Southwest Virginia.
Virginia Polytechnic Institute and State University 1998, Virginia Water Resources Research Center

EVALUATION OF ROOFTOP RAINFALL COLLECTION-CISTERN STORAGE SYSTEMS IN SOUTHWEST VIRGINIA



Virginia Water Resources Research Center

Virginia Tech

Virginia Polytechnic Institute and State University

1998

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ACKNOWLEDGMENTS

This project was in part supported by funds from the Virginia Water Resources Research Center, the Powell River Project, and the Service-Learning Center at Virginia Tech. Mr. Gary Dingus, Virginia Cooperative Extension and Ms. Rhonda Sluss, State Health Department, Dickenson County facilitated the survey and water sampling of cisterns in Dickenson County. Ms. Jennifer Krall assisted with developing the survey.

Special acknowledgments are due to many Dickenson County households who enthusiastically participated in survey and water testing conducted through this project.

ABSTRACT

Many communities in the southwest Virginia coalfields lack safe and adequate drinking water supplies. Extending public water lines to these communities is generally cost-prohibitive because of the rough and elevated terrain and the low number of households in each community. To meet domestic water needs, alternate water sources such as roof top collection of rainfall and cistern storage, and water hauling have been used for many years. The purpose of this project was to gather information about cistern use, properties, and management in the isolated communities of southwest Virginia. Dickenson County, where a large number of cisterns are used, was selected as the model study site for conducting a survey of cistern use and testing cistern water supplies. The survey indicated that more than 30 percent of the households in the surveyed areas depend on cisterns for their drinking water needs, and that 20 percent of the cisterns run dry at least once a month. Cistern waters, in general, are of good quality. However, because of poor maintenance, more than 65 percent of the cisterns tested for coliform bacteria failed to meet the federal drinking water standards established by the U.S. EPA for public water systems. This was the only water quality parameter tested and found to indicate a potential health threat to cistern water users in the study. Based on the survey, water testing results, and cistern use case studies found in the literature, recommendations were made for cistern maintenance and renovation in Dickenson County. It is expected that the results and finding of this study will be applicable to other areas of Virginia.

INTRODUCTION

Many communities in the Southwest Virginia coalfields lack safe and adequate drinking water supplies. In many of these communities, the availability of adequate and safe water from wells and natural springs is limited especially on mountain ridges. Providing water supplies to these communities through a public water distribution system is generally cost-prohibitive because of the rough and elevated terrain and the small number of households in each community. To meet drinking and domestic water needs, alternate water sources, such as roof top collection of rainfall and cistern storage, and water hauling have been used for many years. Drinking water problems in the coalfield communities of Southwest Virginia and probable solutions to these problems were discussed at the Southwest Virginia Water Symposium '96 held in Abingdon, Virginia on October 30, 1996 (31).

A cistern is a water storage facility, usually a tank, connected to a rooftop rainwater-runoff collection system (Figure 1). It is commonly constructed of poured concrete, concrete blocks, plastic, or plastered blocks. Rainwater runoff from the roof is collected into a cistern that is connected to the roof gutter by a drainpipe called a downspout. The water is stored in the cistern and is usually pumped to the house through a pipe distribution system.

In many isolated communities of Southwest Virginia, where extending public water lines is cost-prohibitive, a rainfall collection-cistern system can be considered a viable option for meeting water demand. However, little information is available about the water quality or the reliability of cisterns as a water source in Southwest Virginia. There is a need to establish guidelines for proper cistern use and maintenance in those areas where other sources of drinking water are not available or affordable.

OBJECTIVES

The overall goal of this project was to gather information on cistern use, properties and management in the isolated communities of Southwest Virginia, and develop guidelines for proper cistern use and maintenance. Specific objectives of this project were:

1. Survey cistern use in a selected county.
2. Determine water quality of selected cisterns.
3. Identify water quality problems associated with cistern use.
4. Make recommendations for improved cistern management.
5. Provide general guidelines for cistern improvement and renovation

To accomplish this goal, Dickenson County (where a large number of cisterns are used) (17), was selected as a model study site. It is expected that the results and findings of this study will be applicable to other areas of Virginia.

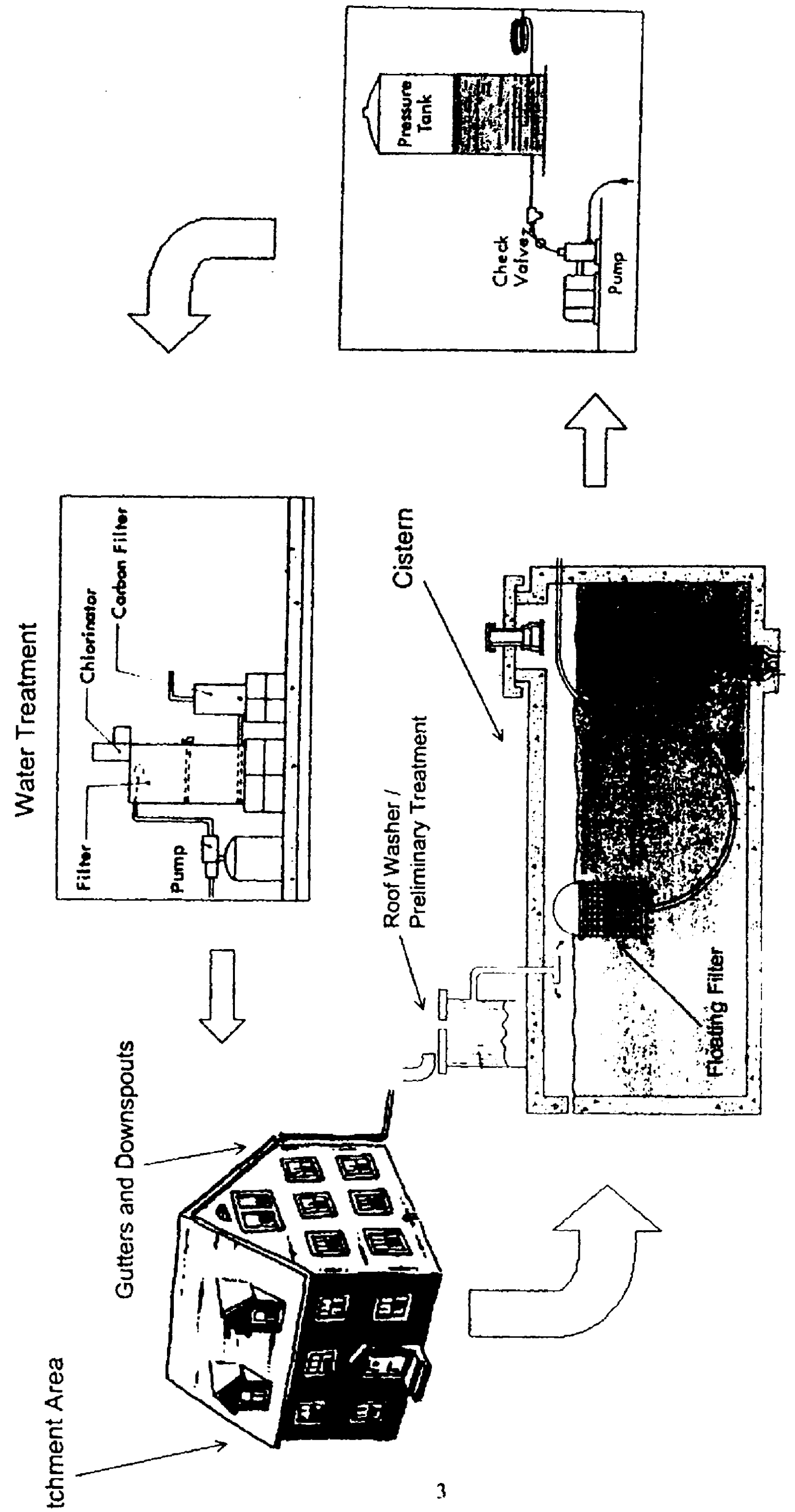

Figure 1. Schematic view of a rooftop rainfall collection-cistern storage system

RAINWATER COLLECTION/ CISTERN SURVEY

Method

A survey was developed and reviewed by the Dickenson County Extension and the Department of Health personnel. After reviewer comments were incorporated, the survey (Appendix A) was mailed to 60 households, previously identified as cistern users, in 6 communities (Clinchco, Dante, Coeburn, Nora, Cleveland, and Clintwood) in Dickenson County on January 29, 1997. Thirty-two surveys (53%) were completed and returned. The results of the survey were compiled using the Microsoft Access database system. After reviewing the results of the initial survey, a follow-up questionnaire was distributed in July 1997 to 15 households who had returned the initial survey to clarify some of the responses.

Survey Results

Survey results were summarized under the following general categories: cistern use, cistern properties, cistern water quality, and cistern maintenance.

Cistern Use

There were a few cases in which more than one household shared the same cistern, but generally there was an average of one cistern per household and three users per cistern. For surveyed households, 31 percent of the households depended on their cisterns for drinking water. Bottled water, natural springs, wells, and hauled water were also used as drinking water sources (Figure 2). Other cistern water uses were: toilets (100%), bathing (97%), laundry (91%), dishes (91%), and cooking (47%) (Figure 3).

The survey revealed that 78 percent of the households have cisterns that run dry at least occasionally (Figure 4). When a dry cistern occurred, a majority of the cistern users hauled water to refill them.

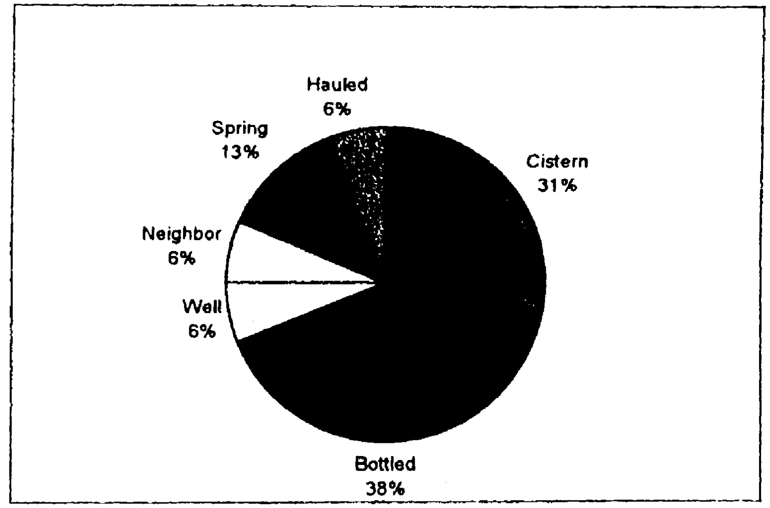

Figure 2. Household drinking water sources.

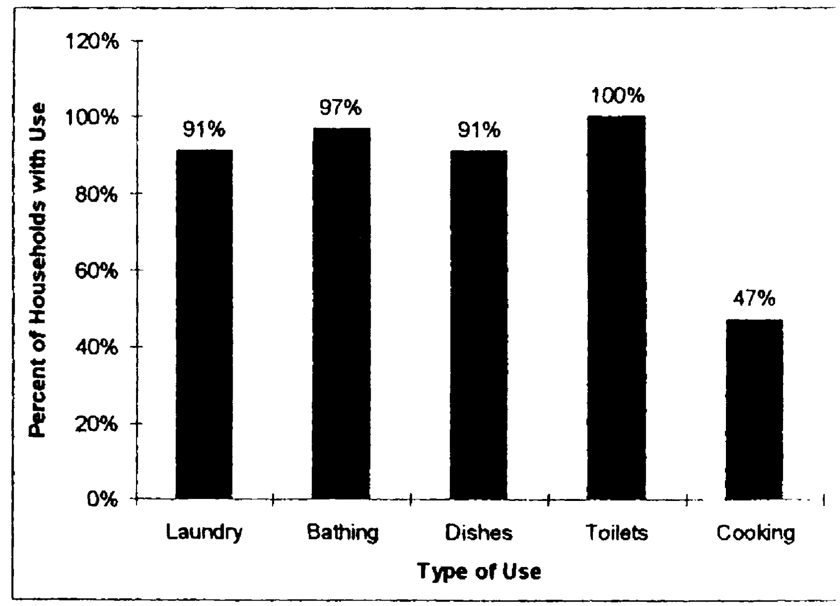

Figure 3. Household use of cistern water.

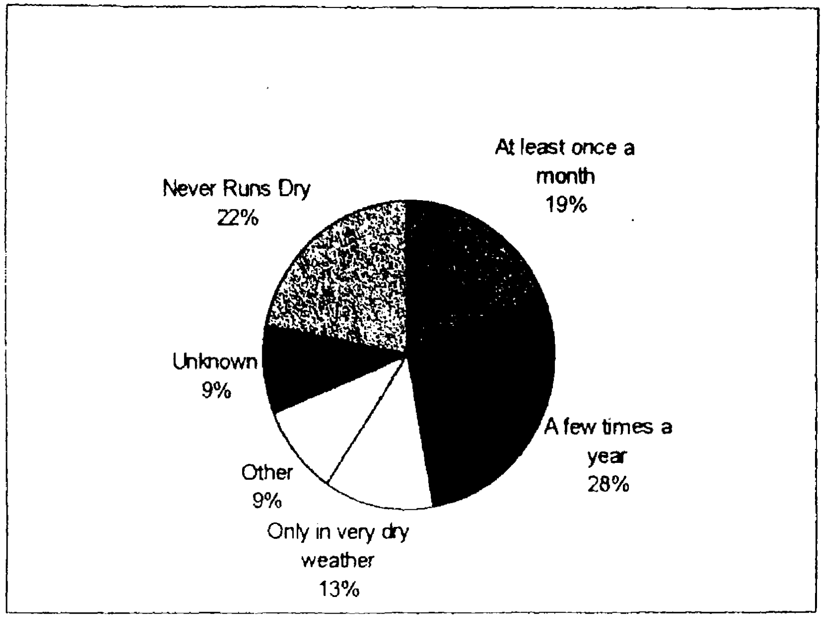

Figure 4. Frequency of the cistern running dry.

Cistern properties

Cistern age in Dickenson County varied from less than ten years to greater than 50 years. Thirty-eight percent of the cisterns were less than 10 years old, 49 percent were 11-49 years old, and 13 percent were 50 years or older (Figure 5). A majority of these cisterns were installed by the owner/previous owner of the house (60%) or by a contractor (31%). Ninety-seven percent of the cisterns were constructed of poured, reinforced concrete or concrete blocks (Figure 6). Most cisterns have an inside liner or, more commonly, a coating of paint on the inner wall (Figure 7). Cistern volume ranged from 750 to 14,500 gallons, with an average volume of 5,300 gallons. Seventy-five percent of the cisterns were installed below ground. However, a few were installed above ground and some were partially buried.

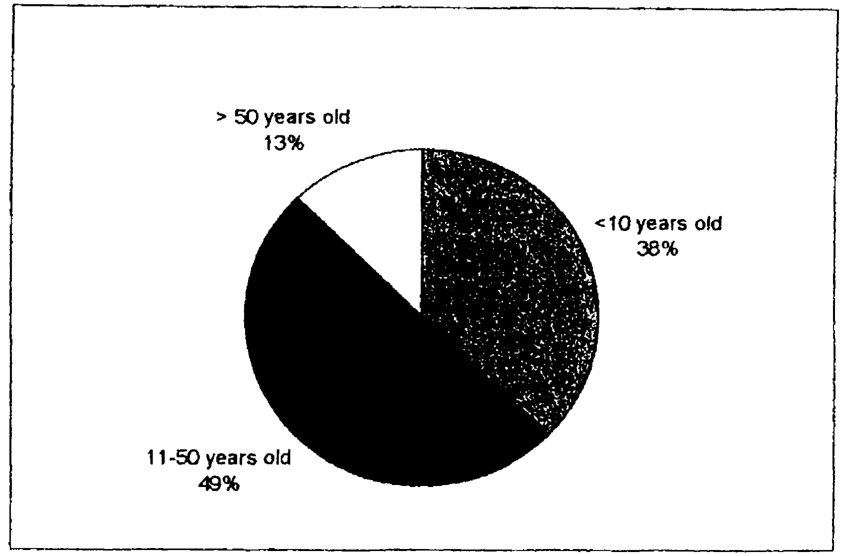

Figure 5. The average age of the cisterns.

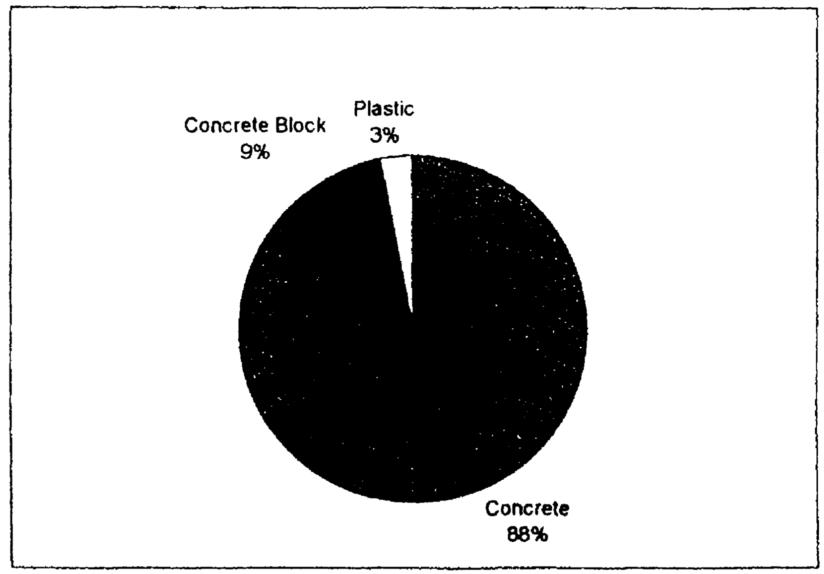

Figure 6. Materials used for building the cisterns.

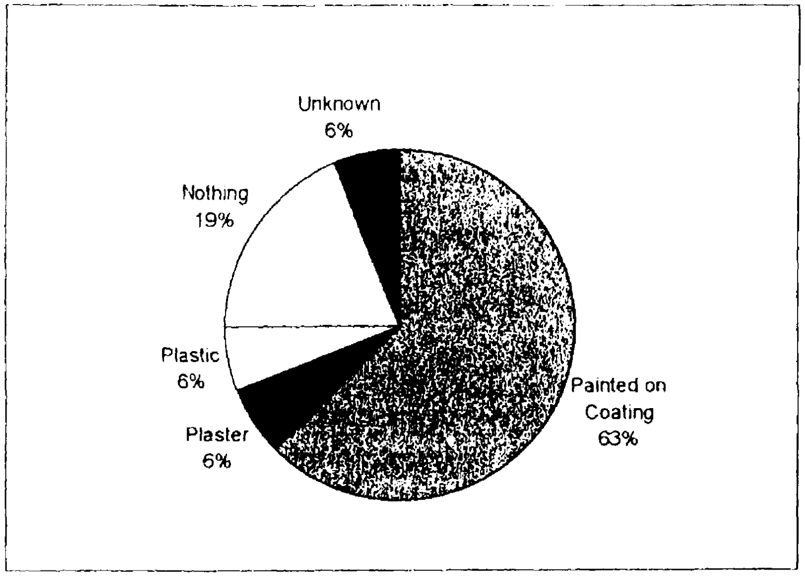

Figure 7. Materials used to line the cisterns

Sixty-seven percent of the house roofs have shingles, 27 percent have metal roofs (usually tin), and 3 percent of the houses have slate roofs (Figure 8). Nineteen percent of the metal roofs were painted. The majority of the houses had unpainted aluminum gutters (62%). Of the remaining gutter types, 19 percent were metal other than aluminum, 3 percent were vinyl, and 16 percent had some other type of gutter or no gutter at all (Figure 9).

Cistern Water Quality and Maintenance

As illustrated in Figure 10, major water quality problems noted by cistern users were odor (50%), unusual taste (28%), unusual color (19%), and cloudiness (13%). These problems were observed seasonally (13%), when cistern water level was low (22%), or after a rainfall (13%). Six percent of the cistern users experienced these water quality problems all of the time (Figure 11). Forty percent of the cistern water users observed solid material in their water on a regular basis. Timing of the presence of solid material appearance varied, with 25 percent of the occurrences reported after rainfall events (Figure 12).

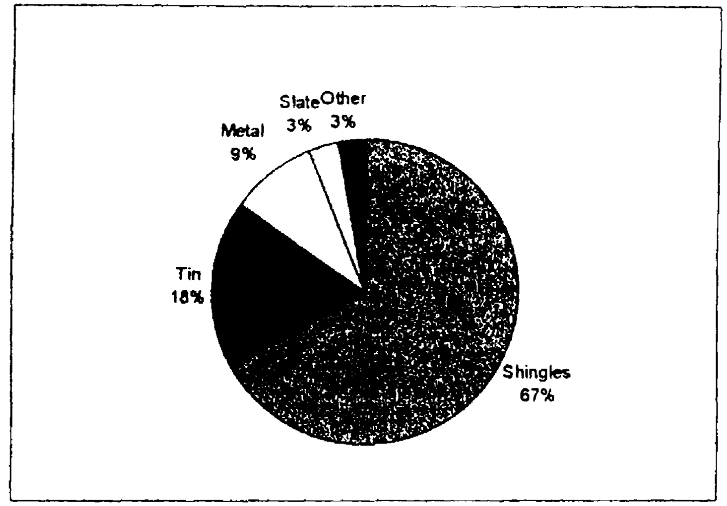

Figure 8. Roof surface material.

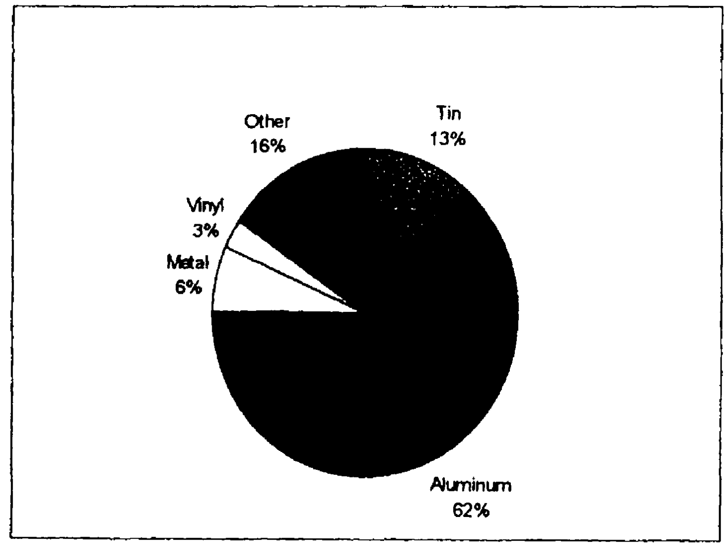

Figure 9. Roof gutter material.

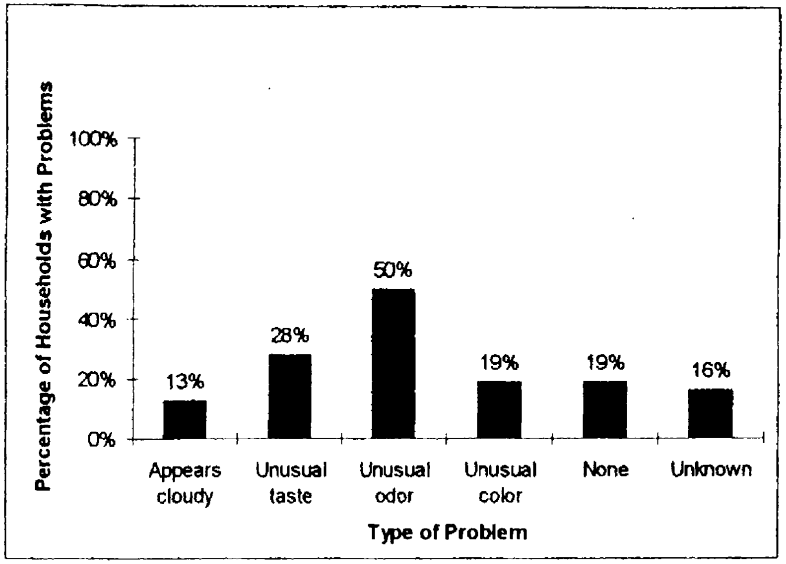

Figure 10. Cistern water quality problems.

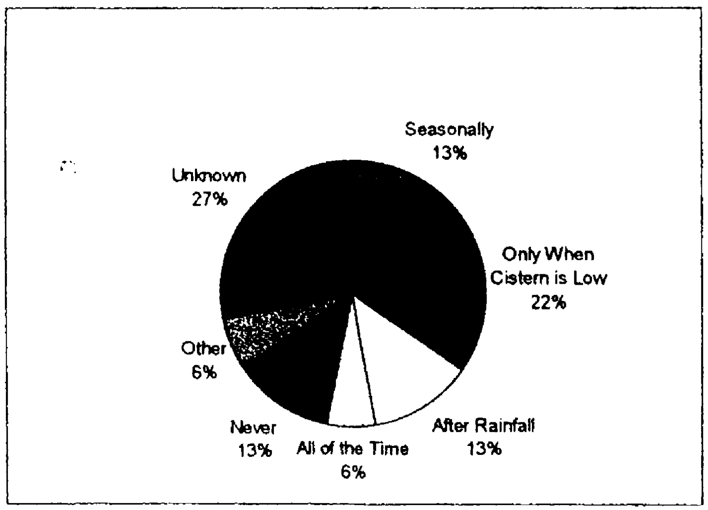

Figure 11. Occurrence of cistern water quality problems.

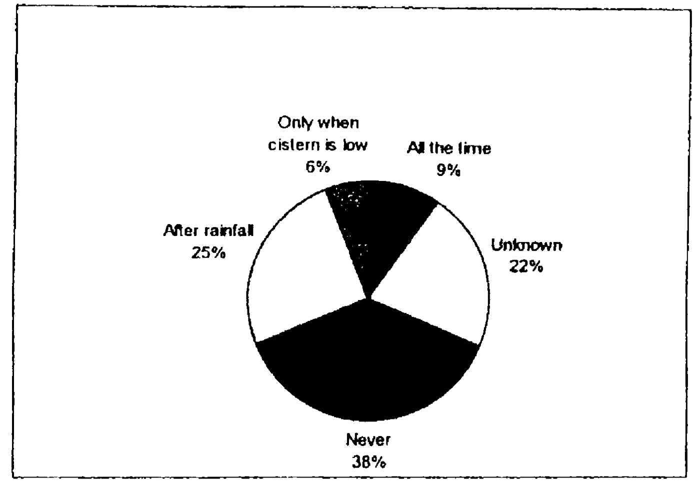

Figure 12. Timing of solid material appearing in cistern water.

About 50 percent of the cistern users who reported water quality problems took appropriate measures to alleviate the problem, such as adding bleach/chlorine (58%) or changing the filters in the cistern and/or water treatment system (24%) (Figure 13). Twelve percent of the users added water to the cistern and 6 percent of the users emptied and cleaned the cistern to correct water quality problems. Fifty-three percent used a filter to improve water quality. Common filter materials included large gravel, small gravel, charcoal, and sand.

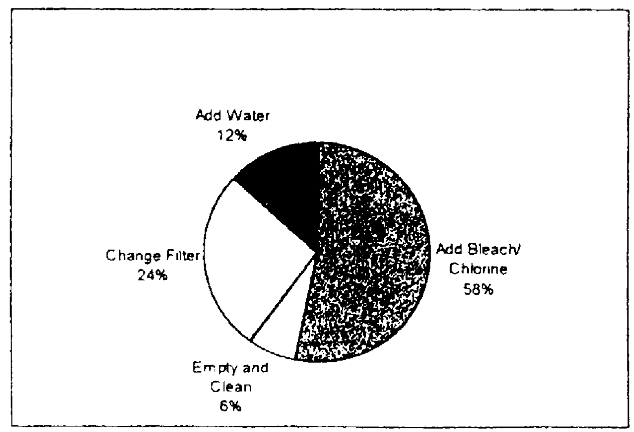

Figure 13. Actions taken to alleviate water quality problems.

The frequency of routine cistern cleaning varied. Fifty-seven percent of the cistern users reported that they cleaned their cisterns once a year, 6 percent cleaned twice a year, 9 percent cleaned once a month, and 6 percent cleaned their cisterns as needed. Nineteen percent of the cistern users never cleaned their cisterns (Figure 14). Eighty-seven percent of those who cleaned their cisterns used a cleaning agent such as bleach and chlorine with water.

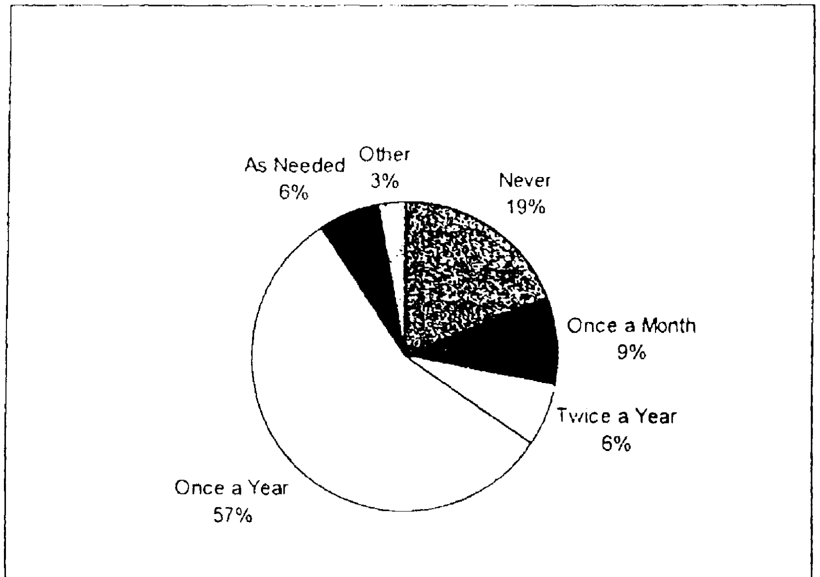

Figure 14. Frequency of Cistern Cleaning.

Cracks and holes in the cisterns were the most common problem and 47 percent of the cisterns needed repairs to prevent leakage. Some cistern users re-coated the inside lining of the cistern yearly to stop leakage. The estimated cost for upkeep of the cisterns surveyed is about $140.00 per year.

It should be noted that 44 percent of the cisterns are situated in close proximity to potential contamination sources (Figure 15) such as septic systems (31%), underground storage tanks (3%), and animal lots (9%).

These sources of contamination may pose a threat to water quality if cracks and holes in the cisterns are not repaired.

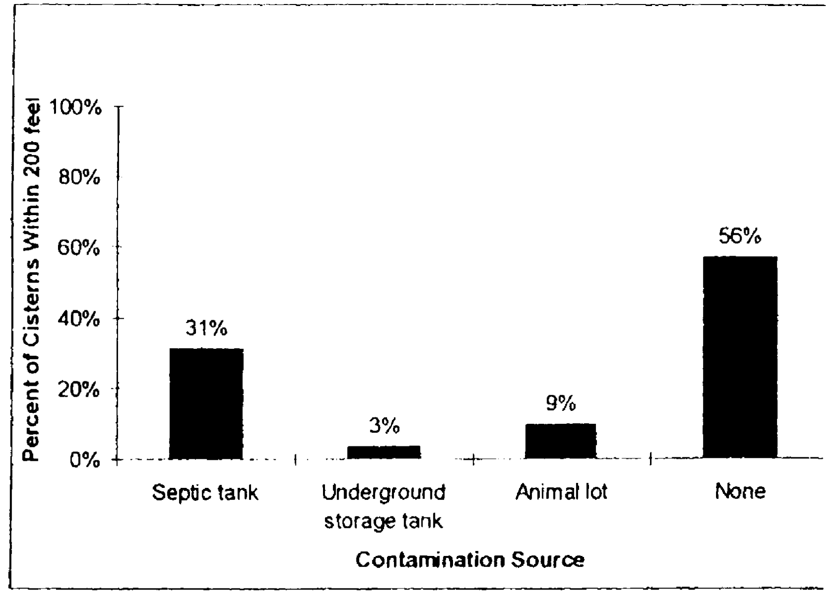

Figure 15. Pollution Sources Within 200 Feet of the Cistern.

TESTING OF THE CISTERN WATER

Method

Water from 33 Dickenson County cisterns was sampled and tested in 1993 as part of the Household Water Quality Testing and Information Program (17). These included cisterns in the communities of Nora, Cleveland, and Clintwood. To expand the 1993 cistern water quality database, a decision was made to target cisterns that were not tested in 1993. As a result, the three communities of Clinchco, Coeburn, and Dante were identified for sampling and testing. A community meeting for cistern users, arranged by the Dickenson County Extension staff, was held on April 14, 1997 in the Dickenson County Extension office. During this meeting, the project goals were explained to the audience, the sampling procedures were described, and bottles for general water chemistry and bacteriological analyses were distributed to 18 cistern users. Water sampling was conducted on April 18, 1997, and all samples were returned to the local Extension office for immediate delivery to the Biological Systems Engineering Department's (BSE) Water Quality Laboratory at Virginia Tech in Blacksburg.

A follow-up water-sampling program for heavy metals was conducted in July 1997 (the Dickenson County cistern water was not tested for heavy metals in 1993) for 15 household cisterns in Clinchco and Dante. Fifteen out of 18 sampling bottles were returned. Each sample was tested for lead, cadmium, copper, and zinc in the Civil Engineering Department's Environmental Engineering Laboratory at Virginia Tech. These metals were selected for analyses based on a literature survey that showed the possible presence of these metals in cistern water because of the type of roof metal, shingles, paint, and pipe distribution systems used in the rainwater collection and cistern storage process.

Water quality analyses were conducted using standard analytical procedures (22,25), and the analytical results are broken down into three sections. Section 1 reports the 1997 water test results (18 households) for general chemistry and bacteriological analyses. In section 2, the 1997 data for general chemistry and bacteriological analyses are integrated with the 1993 data (17) to obtain a broader picture of cistern water

quality. Section 3 reports the results of the 1997 metals analyses.

Section 1. 1997 Water Test Results

Results of the 1997 water testing program, along with the U.S. EPA federal drinking water standards established for public water systems, are presented as average values and the percentage of cisterns that meet the federal drinking water standard for each constituent (Table 1). A description of the significance of each of the water quality parameters is included in Appendix B.

Fifty percent of the cisterns met all of the tested federal drinking water standards. Failure to meet the federal drinking water standards that have been established for public water systems was usually due to high total coliform. A "total coliform positive" test indicates that the water has been polluted with animal or human waste, most likely from bird droppings. Other failures were due to high iron levels (6%) and the presence of E. coli bacteria (6%).

Sodium concentrations greater than 20 mg/l were measured in some cisterns and may have resulted from the use of water softeners. For individuals suffering from health problems such as heart disease or high blood pressure the maximum recommended sodium concentration in drinking water is 20 mg/l. Twenty-two percent of the cisterns tested in 1997, and about 14 percent of the cisterns in the combined testing (1993 and 1997 data) had sodium levels higher than 20 mg/l. The maximum sodium concentration was 38 mg/l. Sodium levels of up to 100 mg/l (the World Health Organization (WHO) standard is 200 mg/l) will not pose a threat to healthy individuals.

Table 1. Summary of 1997 Test Results (n=18)

Parameter	Federal Drinking Water Standard	Average Value	Percent that Meet The Federal Drinking Water Standard
Iron (mg/L)	0.3	0.14	94
Manganese (mg/L)	0.05	0.01	100
Hardness (mg/L)	180.0	34.96	100
Sulfate (mg/L)	250.0	2.65	100
Chloride (mg/L)	250.0	43.33	100
Fluoride (mg/L)	2.0	0.11	100
TDS (mg/L)	500.0	79.72	100
pH	6.5-8.5	7.26	100
Copper (mg/L)	1.0	0.01	100
Sodium (mg/L)	100.0	9.50	100
Nitrate (mg/L)	10.0	0.42	100
Total Coliform	0.0	-	50
E. coli	0.0	-	94

Section 2. Water Test Results — 1997 and 1993 data Combined

A combined total of 51 water samples from Dickenson County were analyzed in 1993 and 1997, the results of which are presented in Table 2. When the 1993 and 1997 data are combined, the federal drinking water standards are only met 100 percent of the time for fluoride, copper, and nitrate. However, by comparing Tables 1 and 2, it is obvious that iron, sodium, and bacteria remain the dominant water problems with these cisterns.

Table 2. Summary of Combined 1993 and 1997 Test Results (n=51)

Parameter	Federal Drinking Water Standard	Average Value	Percent that Meet the Federal Drinking Water Standard
Iron (mg/L)	0.3	0.152	88
Manganese (mg/L)	0.05	0.011	96
Hardness (mg/L)	180.0	48.9	96
Sulfate (mg/L)	250.0	15.7	98
Chloride (mg/L)	250.0	60	98
Fluoride (mg/L)	2.0	0.04	100
TDS (mg/L)	500.0	100	98
pH	6.5-8.5	7.0	84
Copper (mg/L)	1.0	0.012	100
Sodium (mg/L)	100.0	10.38	98
Nitrate (mg/L)	10.0	0.45	100
Total Coliform	0.0	-	33
E. coli	0.0	-	90

Section 3. Heavy Metals Analysis — 1997 Samples

Table 3 shows the results for metals analysis. All fifteen samples that were analyzed met the federal drinking water standards for lead, cadmium, copper, and zinc.

Table 3. Summary of 1997 Heavy Metal Analysis (n=15)

Parameter	Federal Drinking Water Standard	Min. Concentration	Max. Concentration	Average Value	Percent that Meet Federal Drinking Water Standard
Lead (micro-g/L)	15	BDL*	13	2.27	100
Cadmium (micro-g/L)	5	BDL	0.210	0.06	100
Copper (micro-g/L)	1000	2	118	21.73	100
Zinc (mg/L)	5	0.03	0.73	0.16	100

* BDL: Below Detection Limit

DICKENSON COUNTY CISTERN EVALUATION

Summary

Surveys and water quality data of cisterns in Dickenson County were analyzed to identify cistern water quantity and quality, and maintenance problems.

More than 30 percent of the households in the surveyed areas depend on cisterns for their drinking water needs. According to Figure 4, 22 percent of the cisterns never run dry, while 19 percent run dry at least once a month. The amount of water that can be harvested through a rainfall collection-cistern storage system depends on the amount of rainfall, and the [illegible] of the roof surface area. The amount of rainfall is the common denominator for all households. To collect 1000 gallons of water from a two-inch rainfall, a roof surface area of 1200 square feet is needed (6). When a cistern runs dry, it indicates that there is an inadequate roof surface area for rainfall harvesting, a high level of water consumption by the household, or a loss of water through leakage.

Possible sources of cistern water contamination come from the rainfall

water. It may contain air contaminants originating from vehicle emissions, pesticides, fertilizers, and dust, various materials used in the construction of the roof, gutters, pipes, and cistern, and improper maintenance of the roof, gutters, and cistern. In general, the rainwater in Virginia is of good quality for harvesting purposes. Most water quality problems occur after the rainfall is collected. Water quality analyses indicate that maintenance is the major problem with cisterns that show inadequate water quality.

More than 65 percent (Table 2) of the cisterns failed to meet the federal drinking water standards for public water systems for coliform bacteria, and it appears to be the only water quality parameter that poses a health threat with households using cisterns in these communities. The coliform bacteria in cistern water may originate from improper gutter and pipe maintenance, lack of a filter or improper filter maintenance. The bacteriological problem can be alleviated with proper maintenance.

Sodium concentrations greater than 20 mg/l were measured in some cisterns and may have resulted from the use of water softeners. Twenty-two percent of the cisterns tested in 1997, and about 14 percent of the cisterns in the combined testing (1993 and 1997 data) had sodium levels higher than 20 mg/l. The maximum sodium concentration in one cistern was 38 mg/l. Sodium levels up to 100 mg/l (the WHO standard is 200 mg/l) will not pose a threat to healthy individuals. For individuals suffering from health problems such as heart disease or high blood pressure, the maximum recommended sodium concentration in drinking water is 20 mg/l.

Excess iron concentrations were measured in some cisterns, but this does not pose a health problem in healthy individuals. The survey indicated several nuisance water quality problems such as cloudiness, unusual taste, odor, and color. These problems can be eliminated or controlled by using appropriate filters, periodic cleaning of the cistern, and installing a "first flush" device to divert the first 15-20 minutes of the rainfall away from the cistern. Ten gallons of rainfall per a thousand square feet of roof area is sufficient to rid the rooftop of contaminants (8).

RECOMMENDATIONS FOR PROPER CISTERN MAINTENANCE

Proper construction and maintenance of a roof collection/cistern system will enhance the water quality for domestic use. Taking into account the potential pollutants and sources of pollution in a cistern system, the following recommendations are made to obtain the highest possible water quality in an existing rainwater collection-cistern system (2,3,8,11,20,30).

Clean roof surfaces and gutters of animal droppings and leaves. Monthly sweeping and clearing of the roof surface and gutters can decrease the potential for water contamination. Installing a fine screen mesh over the gutter will alleviate the leaf problem, and greatly reduce the animal-dropping problem. The roof surface gutters, supporting brackets, and downspout (inflow pipe to the cistern) should be checked at least once a year and repaired if necessary.

Divert the first 15-20 minutes of a rainfall event. Water from the beginning of the rainfall event may contain dust and other pollutants and should be diverted from the cistern. To divert the first flush, the downspout should be disconnected from the cistern during dry periods. Then 15-20 minutes after the rain begins, the downspout should be moved back into position so that the water flows into the cistern. Commercial, automatic rainfall first-flush devices are available for about $600 (1997 price list).

Check the cistern at least once a year for possible leaks. This task must be performed during a dry period, i.e., when water is not added to the cistern through rainfall. During the leak detection test, the cistern water should not be used over a 24-hour period. To perform the test, a clean graduated stick should be used to measure the water level in the cistern at the beginning and at the end of the 24-hour period. If there is a measurable drop in the water level over this period, the cistern is leaking and should be repaired. Also, a leak can be observed as wet spots on the cistern walls, base, and surrounding soils. Where wet spots have appeared on the walls, apply a cement/water mixture on the inside and finish it off with a layer of waterproof plaster. If there has been evidence of leakage but no wet spots have been discovered on the walls, the cistern floor should be treated with a cement/water mixture and finished off with a layer of waterproof plaster. Repair all leaks when the cistern is empty.

Equip all cisterns with some type of filter if the water is used for drinking purposes. However, improper maintenance of the filter is a major source for bacteriological contamination of cistern water. A filter failure may be detected by a change in water taste or appearance. However, the only sure method to detect bacteriological pollution is by having the water tested. A semi-annual water-testing schedule is recommended.

Commercial filters such an activated carbon filter should be maintained and replaced according to directions provided by the manufactures. If a sand filter is used, the sand should be washed with clean water twice a year or renewed if necessary. Other types of strainers, filters, or screens must be checked and repaired as necessary.

Remove deposits from the bottom of the tank as periodically necessary. Bottom deposits may not only affect water quality but can reduce the storage volume as well. Depending on the situation, bottom deposits may be removed as often as annually or as seldom as every 3-5 years.

Disinfect the cistern after repair work or the installation of a new tank. The tank interior should be scrubbed down with a solution of one-fourth cup (75 ml) of 5% chlorine bleach to 12 gallons of water. Alternatively, a solution of 2 pounds of baking powder to 2.5 gallons of water may be used. After scrubbing, the tank should be left empty for 36 hours and finally washed down with clean water.

CISTERN RENOVATION OR CONSTRUCTING NEW SYSTEMS

Detailed information for the design of a rainfall collection-cistern storage system is given in the Virginia Water Resources Research Center's publication (31). Based on a literature review, some elements of the renovation and design are described below (1,4,6,7,9,10,12,13,14, 15,19,21,23,24,26,27,28,29).

Roofing Materials

Various types of roofing materials can contribute to contamination of runoff water. Roofs with tar and shingles are known to add copper to runoff. Asphalt and shingle roofs are not as efficient at collecting rainwater, and can more easily pick up dust, soot and other material. Shingles also add gravel grit that can build up in the gutters and the pipes leading to the cistern. Galvanized steel is not resistant to weathering, and a roof made of this material can greatly increase the amounts of lead and cadmium present in the runoff. For this reason, galvanized steel roofing should be avoided, as well as any paint, coatings, flashing, or roofing materials that may contain lead, cadmium, or copper. Nontoxic, smooth, dense roofing materials that do not accumulate organic matter or form small pools of water should be used. Aluminum roofing is generally recommended for rooftop rainwater catchment systems because it holds up well and corrodes very little in comparison to other materials. Aluminum roofing may add a trace amount of aluminum to the water but will not pose a major health risk nor affect the taste. The FDA as a safe product for human consumption should certify any paint, sealant or coating to be used on the roof. Read the label for an explanation of the approved uses of the material before applying it to the rooftop.

Regardless of the roofing material used, the roof can become contaminated from the buildup of organic material. This material may include leaves, tree branches, animal and bird droppings, and other solids. Most of the organic material buildup comes from trees too close to the house. The buildup of organic material on a rooftop can be reduced if tree branches hanging over the rooftop are removed and trees are kept away from the house. Anything that attracts birds should be

removed to cut down on the amount of droppings.

Conveyance system

The conveyance system includes gutters, downspouts, return pipes (described later), and the flushing device (roof washer). Its purpose is to transport rainwater from the roof to the cistern. The gutters and downspouts for a rooftop rainfall collection system are constructed similarly to those for controlling stormwater. Instead of directing water onto the lawn, the downspout connects to a pipe (usually PVC) that takes water to the cistern. Because several pipes are usually used, there is the opportunity for water to leak or the pipe to clog. Organic material caught in pipes can adversely affect the water's taste, smell and color. Designing a system that can be easily maintained will minimize these problems.

Gutters

For maximum effectiveness, gutters should be six inches wide, and made of a seamless .0025 inch aluminum. The gutter should be covered with a one-fourth to one-half inch steel mesh screening. The gutter coating should be certified by the FDA to be non-toxic and contains no heavy metals and should be FDA approved. Check the packaging label for FDA approval. The slope along the gutter should be from 1/16 inch per foot to 1/8 inch per foot in the direction of the nearest downspout. The gutters should have hangers every three feet to prevent damage during storms. A gutter should not run longer than 60 feet without a downspout so that the gutters will not overflow or be damaged in a storm.

Downspouts

The downspouts should be covered with a one-fourth inch steel basket-strainer. The number of downspouts to be installed depends on the size of the roof area to be drained. One four-inch diameter downspout can drain about 600 square feet of roof area. Unless the water is going to be piped through the basement, downspouts should be put on the corners of the house to simplify running the pipes to the cistern.

To help with maintenance, there should be a cleanout opening at the bottom of every downspout, where it connects to the PVC return pipe. A one-fourth inch screen should be placed at each cleanout to catch solid material that may have passed through the gutter screen.

Return pipes

The return pipes transport rainwater from the downspouts to the cistern (or to the roof washer). The return pipe should be Schedule 40 PVC or a comparable material. To trap sediment, the return pipe should be set about one-half inch above the outlet from the downspout. A four-inch diameter pipe will easily carry all runoff from the downspouts. Pipe bends should not exceed 45° so there will be less stress on the pipes and fittings. To maintain an adequate flow within the return pipe, there should be a [illegible] of at least one-fourth inch per foot of pipe length. There should be cleanout openings on both ends of all horizontal pipes.

Flushing Device (Roof Washer)

A roof washer is a simple device that diverts the first portion of rainfall (which carries the [illegible] pollutants and roof contaminants) to a container other than the cistern. The container stores the first part of the rain and after the container fills, the water flows directly into the cistern. Generally, the roof washer is placed directly over the cistern allowing the overflow to empty directly into it. Its entrance must be effectively screened (1/16-inch steel mesh) to keep all wildlife and insects out of the water. The roof washer should hold 10 or more gallons for every 1000 square feet of roof area. Automatic roof washers are available commercially. A roof washer designed for a catchment area of 3000 square feet can be purchased for approximately $600 (1997 price listing).

The Cistern (Storage Tank)

Cistern material and construction

Concrete-made cisterns are highly recommended for several reasons. Concrete buffers the water with calcium carbonate so the water becomes less corrosive to plumbing and fixtures. Cast-in-place reinforced concrete cisterns last many years, and although more

expensive, the long-term benefits outweigh the cost.

The inside surface of the cistern should be smooth and clean. Vinyl liners are not recommended because they maintain the high corrosiveness of the rainwater. The cistern walls should be at least 6 inches thick. Manhole or other covers should have openings of at least 24 inches, and rise eight or more inches above the ground. The cover should be watertight, overlap the framed opening, and extend vertically down around the frame at least two inches. Locks should be installed to prevent accidents and contamination. To prevent the entrance of animals, insects and pollutants, all openings into the cistern should be screened.

Overflows or drains from the cistern should not be connected to any sewage lines. All drain water should flow into the ground. To facilitate the disinfection process (discussed later), the cistern wall should be marked to indicate the volume in gallons at various water levels.

A cistern is a heavy structure (500 gallons of water weighs two tons). Therefore, the foundation of the cistern needs to be solid. If the selected site does not have appropriate soil, installation of a gravel foundation should be considered. The gravel will provide a strong foundation as well as adequate drainage. Soils around the cistern should be well drained to allow surface runoff to move quickly past the cistern. The cistern should be located at least 100 feet away from possible sources of contamination such as septic tanks and drain fields, animal lots and outhouses, and at least 10 feet away from any watertight sewer lines.

Cistern placement

The cistern should be placed on the highest ground near the house to cut down on pumping costs. It should never be located in a position that is subject to flooding such as a basement. The cistern should be easily accessible for cleaning, the annual removal of sediment, and to a water truck, in case it needs to be periodically refilled. Keeping trees away from the concrete cistern will prevent roots from penetrating the tank and possibly damaging it. An underground cistern placed outside the house has several advantages. The ground will protect the cistern water from freezing during the winter, and allow it to remain cool in the summer. An underground cistern is not unsightly, nor takes up a large amount of space next to the house.

Water Distribution System

The pump, pressure tank, and pipes that transport water from the cistern to the point of use are collectively called the distribution system.

Pump

The pump and pressure tank work together to get water to the highest point in the house. The pump propels the water and sends it to the pressure tank. From there, the water has to make it to the highest point in the house with a sufficient amount of pressure for household operations. A centrifugal jet pump is most commonly used in homes. It is economical, reliable, and requires little maintenance. Also, it is ideal for a cistern storage-distribution system because of its ability to provide high capacity with less pressure. The pump size is determined according to the pressure requirement at the highest point in the house. Generally a three-quarter horsepower (hp) pump is effective for most home applications. Because there will be filters and disinfection devices within the system, anything smaller might not provide the required power to adequately supply the household with water. The pump that is used must be able to provide a flow of at least 6 gallons per minute. However, there are cases when a larger pump may be needed, i.e., if there are a number of bathrooms. Pumps that will meet these requirements are available for as low as $250 (1997 price list). Less expensive pumps are available for about $140, but the life of these pumps is only about 3-5 years.

A floating filter intake should be installed to collect water one foot below the surface water in the cistern. This is generally considered to be the best water in the cistern, i.e., the water below any floating scum but above the bottom sediment level. The floating filter can be connected to the pump via a flexible plastic hose that allows it to rise and fall with the water level. A 50-micron floating filter will cost about $200 (1997 price list).

Pressure Tank

A pressure tank is used in the water distribution system to provide a constant water pressure at the faucet and to extend the life of the pump by keeping it from turning on and off every time a faucet is used. The pressure tank is a container filled with air and water under pressure. This pressure is created by the pump forcing water into the tank until the air is compressed enough to provide a pressure of about 40 pounds per square inch (psi). The pump can be turned off automatically by a pressure control switch. Water flows out of the tank and the pressure drops when a faucet is opened, When the pressure gets low (around 20 psi), the pressure control switch is activated to turn the pump back on. Most pressure tanks are designed to automatically do this and there is no need for any special controls.

The pressure tank volume should be determined from the peak flow capacity of the pump. The most common size tank for household use is 42 gallons. Several sources suggest that the pressure tank be ten times the pump capacity in gallons per minute. However, this usually turns out to be much too large. About 10-15 gallons per person in the household is a reliable sizing guide.

A pressure tank made of galvanized metal should have some sort of expandable diaphragm within its interior. The diaphragm prevents water from absorbing air in the tank that causes a decrease in its efficiency and an increase in operating costs. The diaphragm also keeps the water from coming into contact with the galvanized metal tank, thus preventing heavy metals from entering the water. A 42 gallon pressure tank costs $150-$250 (1997 price list).

Water Quality Control

The ultimate goal of water quality control in a cistern is to produce water that is safe for drinking purposes and does not cause undesirable effects such as staining of laundry and fixtures. This goal can be achieved by incorporating several treatment components within the system.

Preliminary Treatment

A preliminary treatment mechanism should be incorporated between the catchment area (roof) and the cistern to remove any solids and other impure material from the water before they can enter the cistern. Some cisterns are equipped with a sediment-settling chamber. The roof runoff enters this chamber first and then the chamber overflow enters the cistern. Incorporating permanent cinderblock, gravel, fiberglass, charcoal, or sand filters into the system can serve as a preliminary treatment mechanism.

In-Cistern Treatment

To obtain safe and bacteria free water, the cistern water should be routinely disinfected. While an automatic disinfecting device could be installed, the cistern can be easily disinfected manually by adding one ounce of laundry bleach for every 200 gallons of water in the cistern. If a noticeable chlorine taste develops, then the dosage should be reduced to one ounce for every 400 gallons of water. Clorox and Purex are recommended because they do not contain heavy metals that may be found in some generic and low-cost brands. However, any brand of bleach will act as a disinfectant agent as long as it is free of heavy metals. Also, avoid using laundry bleaches that contain additives.

Rainwater can be very corrosive and cause deterioration of the in-house water distribution pipes and fixtures. Pipe corrosion may result in leaching of heavy metals into the water. The best way to prevent corrosion is to add a neutralizing agent to the cistern water. Common neutralizing compounds and their appropriate dosages per 1000 gallons of water are: limestone (2 oz), quick lime (1 oz), hydrated lime (1 oz), soda ash (1 oz), and caustic soda (1.5 oz). The addition of these agents should only be done after a rainfall and fresh water has been added to the cistern since it was last neutralized. In some cases, a large piece of limestone can be added to the cistern to neutralize the water. While this may be effective for corrosion protection, it may cause an increase in water hardness.

Post-Cistern Filtration and Treatment

There are several alternatives for water treatment after the water leaves the cistern and before it reaches the faucet. A treatment unit called Point of Entry (POE) system can be installed immediately after the pressure tank. This allows all the water that comes into the house to be treated before it reaches any faucet or appliance. However, because of the relatively high cost, this option may not be feasible. Another treatment option is called the Point of Use (POU) unit. The POU unit treats the water when it reaches a particular faucet where a small treatment unit (the type used depends on the nature of the contamination) is attached. The advantage of the POU system is that only the water at a few taps would be treated, i.e., the water that is used for drinking and cooking. This can be accomplished for a relatively low price. The disadvantage is that the remaining taps have untreated water, which could be inconvenient at times. The POE and POU units usually consist of various types of filters. Since organic matter, bacteria, odor, and taste are the major water quality problems in the rooftop rainfall collection systems, the use of a Granular Activated Carbon (GAC) filter is highly recommended. When compared to other filters, the GAC filter is relatively expensive, however, it has many advantages. The GAC filter can remove algae, protozoa, some bacteria and viruses, many pesticides, and other organic chemicals. It is also effective in removing many of the taste and odor problems. In addition, it is effective in removing excess chlorine and chlorine by-products that may be present in treated cistern water. The GAC filter is easy to maintain by replacing the filter according to an established schedule. The disadvantage of using this type of system is that it is not very effective in removing coliform from the water.

According to the federal standards for public water systems, the acceptable amount of a total coliform count is zero. Coliform bacteria occur naturally in the intestines of warm-blooded animals (fecal coliform) and non-fecal coliform bacteria. Escherichia coli (E. Coli) is a species of fecal coliform bacteria and its presence in a water sample indicates that more harmful disease causing organisms may be present. As part of a "multiple barrier" approach to water treatment, some sort of disinfecting treatment should be used in conjunction with the GAC filter. This could be accomplished by using the disinfection treatment method using laundry bleach to disinfect the cistern water before the water enters the carbon filter.

Another treatment system that could be used is ultraviolet radiation. This method of disinfection is recommended after carbon filtration. Ultraviolet radiation is a method that employs a light chamber to effectively kill any organism in the water. Low-pressure mercury lamps, similar to the common florescent bulbs, are often used for this purpose. To accomplish the treatment, water flows through a chamber that is subjected to the light from these special bulbs. This process leaves no unpleasant tastes, no disinfection by-products, is inexpensive to install and operate, and requires almost no maintenance. An ultraviolet radiation unit appropriate for household use costs about $800 (1997 price list).

APPENDIX A — Cistern Survey Sheet

Name ______________________________ Telephone __________
Address ____

I. Cistern Properties

What is the age of the cistern? <5 yr. 6-10yr. 11-20yr. 21-50yr. >50yr. Unknown Other ____________________

Who installed the cistern? You Contractor Previous Homeowner Unknown Other ____________________

What is the cistern made of? Concrete Plastic Wood Other ____________________

What is the inside of the cistern lined with? Plastic liner Painted-on-coating Nothing Unknown Other __________

What is the size of the cistern? ____________________ Unknown

Is the cistern above or below ground? Above Below Unknown

What is the gutter on your roof made of? ____________________

What type of roofing material do you have on your house? __________

Is your roof painted? Yes No Unknown

Do you have any of following within 200ft of the cistern? (Circle all that apply): Septic tank Underground storage tank Animal lot None Other ______________________________

II. Water Quantity

How many persons and households use the cistern?

No. of persons ________ No.of households ____________________

For what purposes do you use the cistern water? (Circle all that apply)

Laundry Bathing Dishes Toilets
Drinking/cooking Other ______________________

If you did not circle drinking/cooking for the previous question, from what sources do you get your drinking water?

Bottled Trucked in from public water supply Neighbor Unknown
Other ___________

Does the cistern ever run dry? Yes No

If Yes, how often does this occur on an average over the course of a year?

Once a week Once a month Every couple of months Once a year
Unknown Other ______________________

Do you attempt to refill the cistern when it is dry or when it freezes during the winter? Yes No

If No, what do you use as a water source if water for each of the following tasks are usually supplied by the cistern?

Laundry ______________________
Bathing ______________________
Dishes ______________________
Toilets ______________________
Cooking\Drinking ______________________
Other ______________________

III. Water Quality

Is there solid material (dirt) in the cistern water? Yes No Unknown

How often does this occur? All the time After rainfall
Only when cistern is low Seasonally Never Unknown
Other ______________________

Does the water from the cistern ever have the following problems: (circle all that apply)

Appear cloudy Unusual taste Unusual odor Unusual color
None Unknown Other ______________

How often does this occur? (Circle all that apply)

All the time Seasonally After rainfall Only when cistern is low
Never Unknown Other ______________________

When the cistern water has any of the problems circled above, do you do anything about the problem?

Yes No Unknown

If Yes, please explain ______________________

IV. Maintenance of the Cistern

What do you use to clean the cistern?

Bleach and water Nothing Other ___________

How often do you clean the cistern?

Once a week Once a month Once a year Never
Other ______________

Did the cistern ever need repairs? Yes No

If Yes, what was repaired? (Explain) ___________

Do you use a filter to treat the water in the cistern? Yes No

If Yes, what type of filter? ______________________

What is the estimated cost for upkeep of the cistern on a yearly basis?
$ ______________________

APPENDIX B — DESCRIPTION OF WATER QUALITY PARAMETERS

Iron. Iron in water does not usually present a health risk. It can be objectionable if present in concentrations greater than 0.3 mg/L. Excessive iron can leave brownish orange stains on plumbing fixtures and laundry. It may give water and/or beverages made with tap water a bitter, metallic taste and discolor them.

Manganese. Manganese does not present a health risk. However, if present in concentrations greater than 0.05 mg/L, it may give water a bitter taste and produce black stains on laundry, cooking utensils, and plumbing.

Hardness. Hardness is a measure of calcium and magnesium in water. Hard water does not present a health risk. However, it prevents soap from lathering, decreases the cleaning action of soaps and detergents, and leaves "soap scum" on plumbing fixtures, and scale deposits on water pipes and hot water heaters. A softening treatment is highly recommended for water with a hardness rating above 180 mg/L. Water with a hardness of 60 mg/L or less does not need softening.

Sulfate. High sulfate concentrations may result in adverse taste or cause a laxative effect. Sulfates are often naturally present in groundwater and may be associated with other sulfur-related problems, such as hydrogen sulfide gas. This gas may be caused by the action of sulfate-reducing bacteria, as well as by other types of bacteria (possibly pathogenic bacteria) on decaying organic matter. While it is difficult to test for the presence of this gas in water, it can be easily detected by its characteristic "rotten egg" odor, which may be more noticeable in hot water. Water containing this gas may also corrode iron and other metals in the water system, and may stain plumbing fixtures and cooking utensils. Sulfate is of concern when present in concentrations greater than 250 mg/L.

Chloride. The drinking water standard for chloride is 250 mg/L. Chloride in drinking water is not a health risk. Natural levels of chloride are generally low. High levels present in drinking water usually indicate

contamination from a septic system, road salts, fertilizers, industry, or animal wastes. Increased levels of chloride may speed the corrosion of metal pipes and cause pitting and darkening of stainless steel.

Fluoride. The federal drinking water standard for public water systems for fluoride is 2 mg/L. Fluoride is primarily of concern from the standpoint of its effect on teeth and gums. Small concentrations of fluoride are considered to be beneficial in preventing tooth decay. However, moderate amounts can cause brownish discoloration of teeth, and high fluoride concentrations can lead to tooth and bone damage.

Total Dissolved Solids (TDS). The federal drinking water standard for TDS is 500 mg/L. TDS is a combination of several chemicals including chloride, sodium, sulfate, hardness, and alkalinity. High concentrations of TDS may cause a salty or bitter taste and deteriorate household plumbing and appliances.

pH The pH indicates whether water is acidic or alkaline. The EPA has set a suggested range between 6.5 and 8.5 on the pH scale for drinking water. In addition, acidic water can cause corrosion in pipes and may cause toxic metals from the plumbing system to be dissolved in drinking water. The life of plumbing systems may be shortened due to corrosion, requiring expensive repair and replacement of water pipes and plumbing fixtures

Sodium. Sodium levels up to 100 mg/l (the World Health Organization's standard is 200 mg/L) will not pose a threat to healthy individuals. Sodium can be a health hazard to people suffering from high blood pressure or cardiovascular problems, or kidney diseases. For those on low-sodium diets, 20 mg/L is suggested as a maximum level for sodium in drinking water, although a physician should be consulted in individual cases.

Nitrate-Nitrogen. High levels of nitrate may cause methemoglobinemia, or "blue-baby" disease, in infants. Though the federal drinking water standard for nitrate is 10 mg/L, it is suggested that water with greater than 1 mg/L nitrate concentration not be used for feeding infants. Levels of 3 mg/L or higher may indicate excessive contamination of the water supply by commercial fertilizers and/or organic wastes from septic systems or agricultural operations.

Coliform. Coliform bacterial detection is simply an indication of the possible presence of pathogenic, or disease-causing, organisms. However, coliforms are always present in the digestive systems of all warm-blooded animals and can be found in their wastes. Coliforms are also present in the soil and in plant material. Other possibilities (in the case of cisterns) include contamination of the household plumbing, or filters. Coliform bacteria is of concern if a detection of coliform bacteria is confirmed by a total coliform analysis resulting in a detection rate above zero.

E. *coli*. (*Esherichia coli*) is a member of the fecal coliform group of bacteria. The occurrence of E. *coli* is an indicator of recent fecal contamination of the drinking water and the possible presence of pathogenic organisms, which is the major source of many enteropathogenic diseases transmitted through water. E. *coli* is found in the feces of warm-blooded animals. E. *Coli* contamination is of concern if a detection of above zero is confirmed.

Cadmium. The federal drinking water standard for cadmium in public water supplies is 5 μg/L (micro-g/l). Cadmium is highly toxic and minute quantities of cadmium are suspected of being responsible for adverse changes in the arteries of human kidneys. Cadmium also causes generalized cancers in laboratory animals and has been linked epidemiologically with certain human cancers. Cadmium may enter water as a result of the deterioration of galvanized pipe.

Copper. The EPA drinking water standard for copper in public drinking water supplies is 1.4 mg/L, the maximum level recommended to protect people from acute gastrointestinal illness. Lower levels of dissolved copper may also give water a bitter or metallic taste and produce blue-green stains on plumbing fixtures. Consequently, federal standards have established a SMCL (Secondary Maximum Contaminant Level) for copper of 1.0 mg/L in household water.

Lead. The federal drinking water standard for lead in public drinking

water supplies is 15 μg/L (micro-g/l). Lead is a serious cumulative body poison. Natural water seldom contains more than 5 μg/L. Lead in the water supply may originate from the dissolution of old lead plumbing or solder from the pipe joints.

Zinc. The federal drinking water standard for zinc is 5 mg/L. Zinc is an essential and beneficial element in human growth. Concentrations above 5 mg/L can cause a bitter astringent taste. Zinc most commonly enters the domestic water supply from deterioration of galvanized iron and dezincification of brass. In such cases, lead and cadmium also may be present in water because they are impurities of the zinc used in galvanizing.

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Food and Drug Administration
Office of Consumer Affairs
(HFE-88)
5600 Fishers Lane
(room 16-85)
Rockville, Maryland 20857
http://www.fda.gov/
oca/guide.htm

National Climatic Data Center
Federal Building
151 Patton Avenue
Asheville NC 28801-5001
for data:
http://www.ncdc.noaa.gov/pub/
data/coop-precip/virginia.txt
home page:
http://www.ncdc.noaa.gov

Water Ace Pump Co.
Ashland, Ohio 44805
1-800-942-3343

National Drinking Water
Clearinghouse
West Virginia University
P. O. Box 6064
Morgantown, WV 26506-6064
1-800-624-8301

Farm & Ranch Service
Supply Company
P. O. Box 10165
San Antonio, TX 78210
(800) 292-0007
concrete tanks, roof washers,
floating filters

Rainwater Collection Over
Texas
201 Thurman Rd.
San Marcos, TX 78666
(800) 222-3614 (512) 353-4949
rainwater systems,water
conservation products

Rain Man Waterworks
P. O. Box 972
Dripping Springs, TX 78620
(512) 858-7020

U.S. HCN Data for Virginia
http://cdiac.ESD.ORNL.GOV/
r3d/ushcn/statepcp.html#VA_