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A STUDY OF GREYWATER

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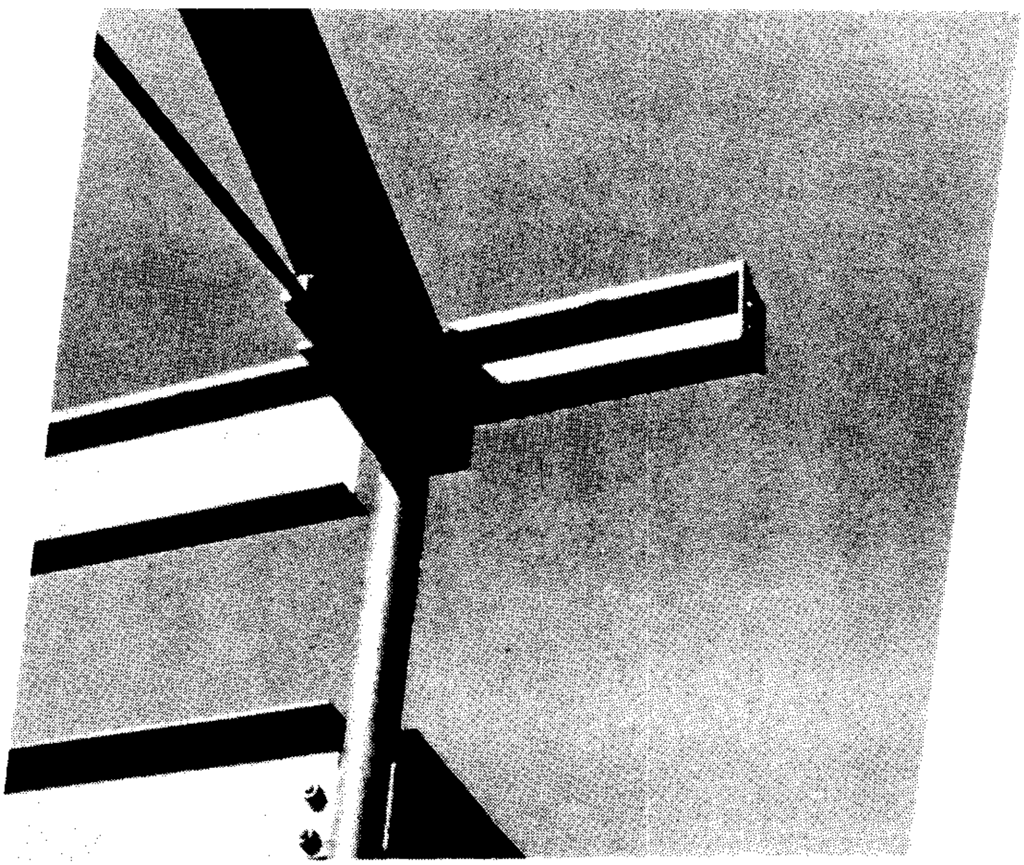

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EXECUTIVE SUMMARY

As Florida's water reserves decline at an accelerated rate, new and innovative concepts of resource conservation must be adhered to. Over-development spurred by population growth and subsequent water demand are seemingly inevitable. Climatic and hydrogeologic forces such as drought and saltwater intrusion are often unpredictable and virtually impervious to man's efforts to reverse them. Techniques in water reclamation and reuse have proven effective in reducing groundwater contamination and aquifer overdraft in an already stressed ecosystem within the state of Florida. Greywater reuse is yet another resource management initiative whose time has come in helping to relieve the growing burden.

Growth management is essential for proper use and preservation of Florida's water resources. As the common denominator in virtually every ecosystem, water resources serve as the cornerstone of human society's sustainment. To meet Florida's growing demand for water, the pace of regeneration and subsequent reuse must be accelerated. As a consequence, water reuse and resource sustainable design are rapidly evolving within the current trends of environmentally conscious construction. This concept of reuse has since spawned interest in a new generation of resource optimization. Reuse technologies have the potential to play an increasing role in water conservation, expanding potential reuse markets far beyond municipal reclamation alone. The purpose of this study therefore, was to effectively communicate and identify on-site water reuse alternatives that offer substantial economic and environmental incentives for optimizing global water resources.

Protecting the water supply in Florida is vital to the quality of life the state presently enjoys. Reuse systems are a cost effective alternative to maintain an ample water supply, but there is also a constraint to implementation of such systems, which is to provide for consumer safety and to not create a maintenance problem that overweighs the initial value of the system.

The research and test simulation facility utilized in this study have shown the potential for greywater usage, but also identified the need to continue to monitor the model greywater system with added design features. Better system design is an ongoing process, but this study has provided an excellent foundation for such further study, modification, and economic evaluation.

This research and model have provided a vehicle for future studies, that allow for the potential to provide the consumers in Florida a cost effective alternative to the continued over use of the aquifer. Since the model is full size, it will create a mechanism to conduct further research in areas that were beyond the scope of this report. The model stands ready to be modified and adapted to accommodate additional research.

ACKNOWLEDGMENTS

The following graduate students had varied and integrated roles in the production of this research project. The initial literature search was headed up by Kevin Grosskopf. Brian Wetherington was heavily involved with the field construction of the test facility. His hands-on effort, coupled with Brent Elliot's assistance created a high quality field model. Roberta Marstellar worked diligently in the field model testing with a focus on present and future applications of greywater systems. The compilation of all the various aspects of this report were edited and reviewed by Rob Wubbenhorst. In addition to the graduate students, Ken Klotz reviewed the concept and provided recommendations throughout the project.

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CHAPTER 1
WATER RESOURCE OPTIMIZATION

1.0 Introduction

An issue of concern in Florida is the increased demand for potable water exceeding the supply. This demand is caused by a myriad of reasons, and many of the contributing applications do not always need to use potable water. Exploration of better water resource utilization is the goal of this research. Methods for substituting non-potable water in specific applications with necessary standards and plumbing safeguards in place are investigated and presented in this report. Reclaimed and "greywater" reuse strategies to reduce potable water demand and wastewater discharge levels are explained and presented in detail as alternative resource management options.

1.1 Water Resources and Urban Development in Florida

The population of the State of Florida is increasing from urban and rural growth. Centered around tourism, agriculture, and industry, Florida continues to experience a population growth of nearly 3.5% annually. This has spurred increased potable water withdrawal and wastewater disposal into an already stressed environment, resulting in elevated costs and environmental degradation. Groundwater sheds that provide the primary source of Florida's potable water are increasingly subjected to growing contamination from massive wastewater disposal and saltwater intrusion. Continued domestic water withdrawal and contamination that far exceeds the rate of natural recharge and purification illustrate the need for alternative water reuse strategies.

1.1.1 *Geologic and Hydrologic Continuum*

The majority of the state's water withdrawn for potable and non-potable use originates from the groundwater sheds of the aquifer system beneath the Floridan Plateau. This natural resource is replenished by the precipitation of condensed water vapor within the troposphere. The surface water from such rains, sleet, or hail flow into surface waters or may evaporate to recondense once again. A small percentage of the remaining precipitate may infiltrate into the ground and percolate downward through permeable soil layers and porous calcareous limestone, created by the cementation of sand granules and oolites over millions of years. Eventually, an even lesser amount of surplus water will reach a saturation zone where it may be discharged again by springs or wells. It is estimated that the duration of this journey, referred to as the hydrologic cycle, may range from 20 years to thousands of years.[2] The hydrologic cycle illustrated in Figure 1.1 on the following page represents the ultimate water reuse process. The finite amount of water on the planet undergoes continuous recycling and reuse and regeneration while traveling through the various stages of the hydrologic continuum.

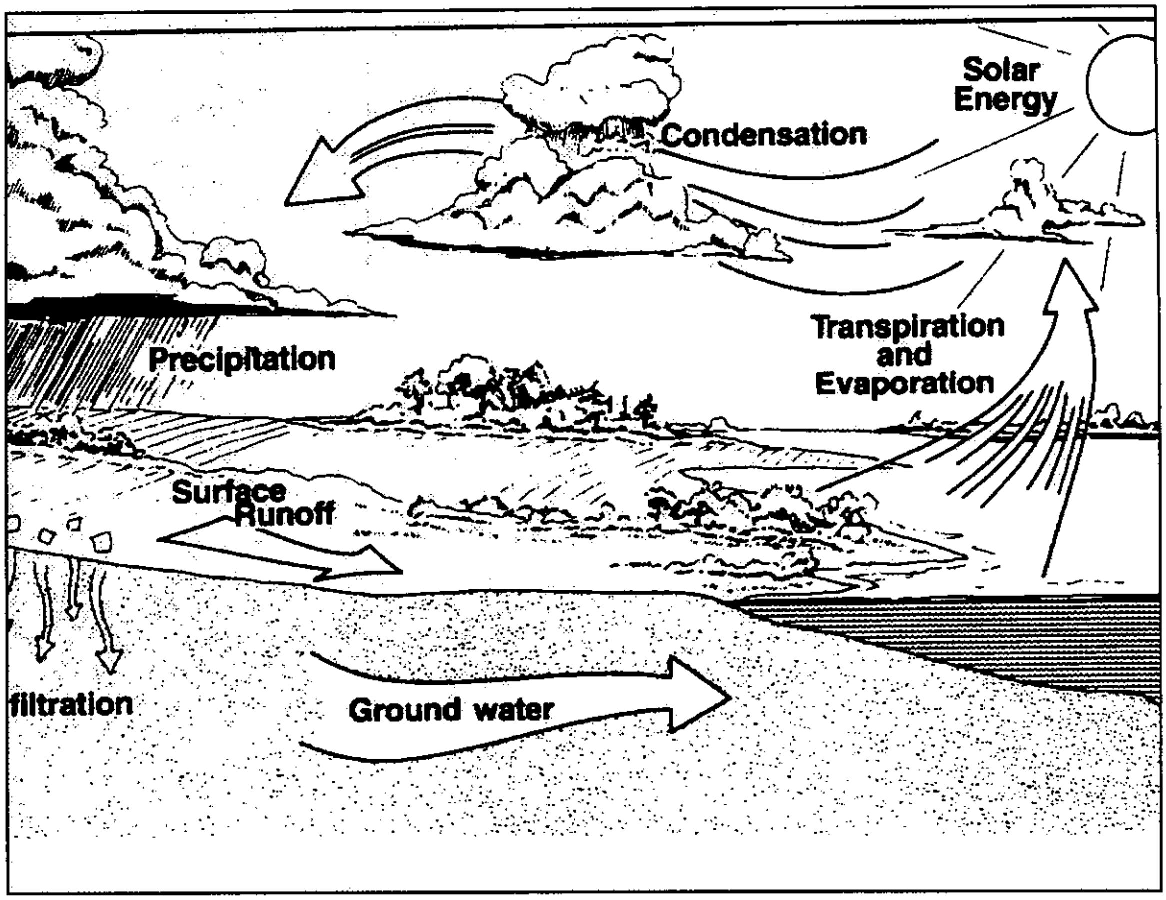


Figure 1.1 The hydrologic cycle.
State of Florida. Florida DEP. *Reuse of Reclaimed Water*. Tallahassee, 1990.

Florida's rising population and its concurrent increase in water use has significantly out paced this slow moving natural cycle. To meet the growing urban and rural demand for water, the pace of regeneration and reuse must be accelerated.

1.1.2 *Resource Contamination and Groundwater Overdraft*

Drought, contamination, and infrastructure inefficiencies all contribute to Florida's water supply problem, but the increasing demand caused by a growing population has the most significant impact. The directly proportional relationship between current and projected water demand in relation to population growth is shown in Figures 1.2 and 1.3. In addition to the increase in water demand, a similar increase in wastewater disposal demands, and contamination of groundwater will compound the problem.

The costs of expanding wastewater infrastructure for new treatment facilities presents an additional tax burden. In spite of an average rainfall of 54 inches per year and profitable efforts to optimize limited water resources, withdrawal rates in Florida continue to increase. Use of potable water in Florida has increased by a factor of 6 in the last ninety years, with 75% of the increase occurring in the last twenty-five years. Florida's population nearly doubled from 1960 to 1980, escalated 33% from 1980 to 1990, and is anticipated to increase an additional 19% from 1990 to 2000.[3] Seven counties with dense commercial and residential demographics represent almost 60% of the state's total population and nearly 70% of its domestic withdrawal and consumption.[4] Almost 79% of Florida's 13 million people reside near the coast. Furthermore, an additional 82% of the anticipated population growth will occur in coastal counties.[3] Coastal communities are primarily served by shallow aquifers that are most vulnerable to saltwater intrusion and wastewater discharge.

Broadening interpretations and increasing enforcement of legislation such as the Water Quality Act of and the National Pollution Discharge Elimination System (NPDES) are only a few of the growing mandates on waste discharge.

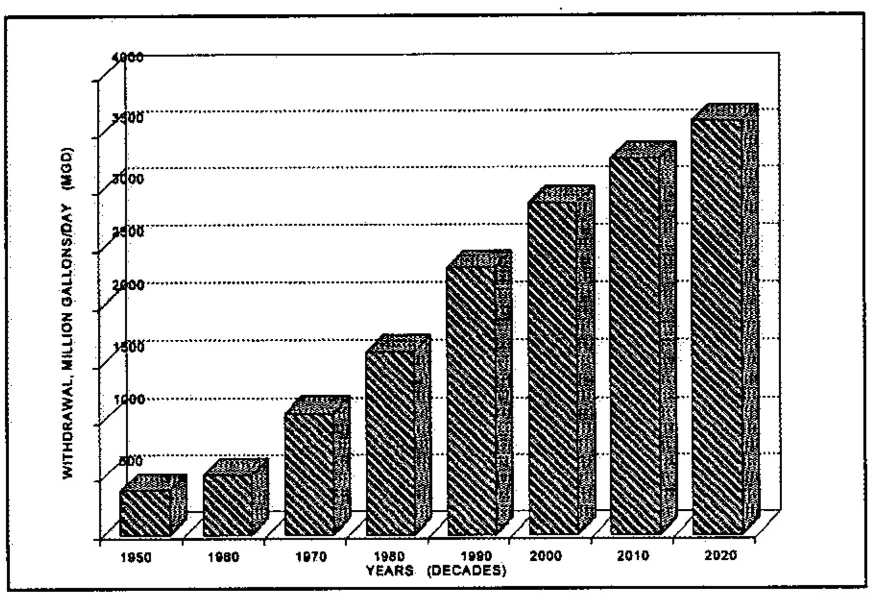


Figure 1.2 Current and projected water demand in Florida.
Chansler, James M. *The Future for Effluent Reuse.* Water Engineering and Management, 1991.

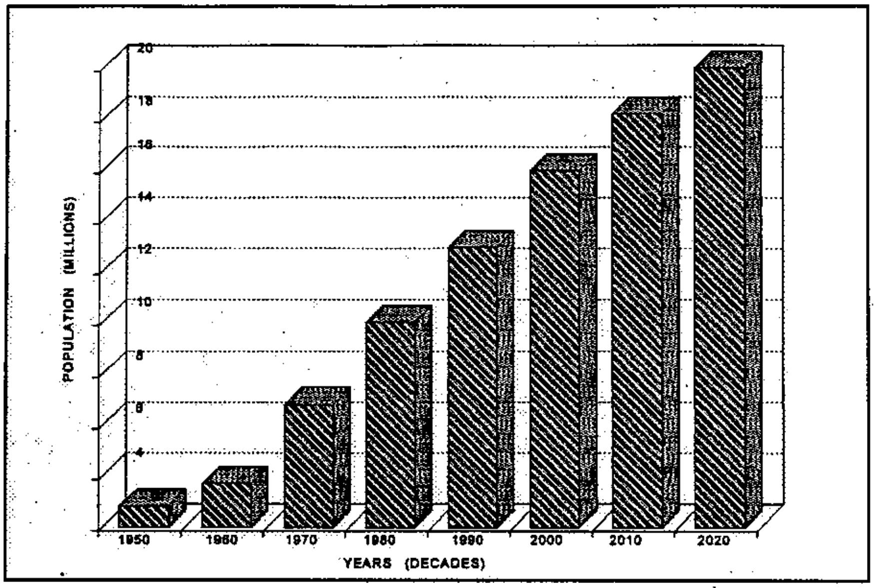


Figure 1.3 Current and projected population in Florida. Chansler, James M. *The Future for Effluent Reuse.* Water Engineering and Management, 1991.

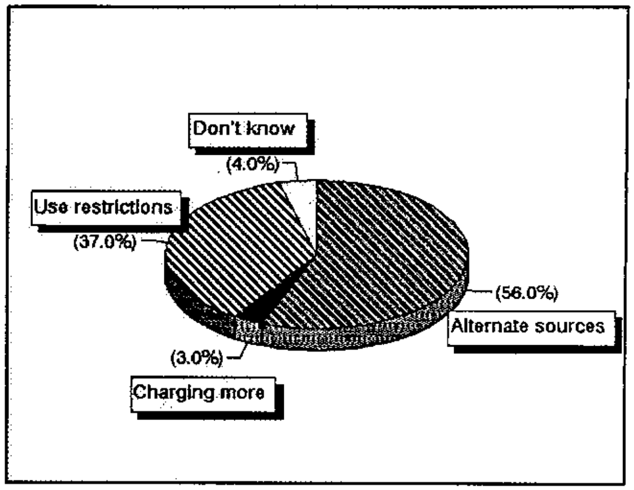
Water quality and availability issues surrounding such laws have often resulted in the complete elimination of development in a growing number of potential markets throughout Florida. An inevitable consequence of population growth and tightening environmental regulation is the inadequacy of current water resources to supply future demands. Such facts demonstrate the necessity for on-site and municipally based greywater reuse specific to urban development, especially for environmentally sensitive regions where cost effective infrastructure is neither feasible or permissible.

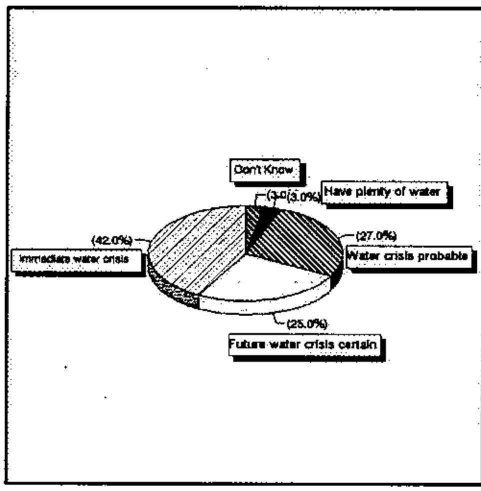
1.2 Water Resource Awareness and Perception in Florida

The average Floridian uses in excess of 100 gallons of potable water in the course of a day. This impact on the ecosystem of this usage is severe. Resource overdraft and environmental degradation requires a change in water use, conservation, reuse, and replenishment. A water resource poll conducted by the *St. Petersburg Times* in the Tampa Bay area revealed that an overwhelming census of residents were willing to pay more for water, not for continued personal use, but for environmental protection. A majority, almost 60% said they would be willing to pay 10% or more for water to help protect the environment through long term ecological sustainment such as water reclamation, bio-remediation, and wetlands restoration and enhancement. 65% percent polled further stated that they would be opposed to the price increase to be free of water restrictions which are typically viewed "quick-fix" strategies, virtually unenforceable, and at best, marginally effective.[5]

The results listed on the following page are provided from respondents throughout the Tampa Bay area in an attempt to quantify public opinion regarding water availability and its perceived impacts on regional economics, industry, growth, quality of life, and the environment.

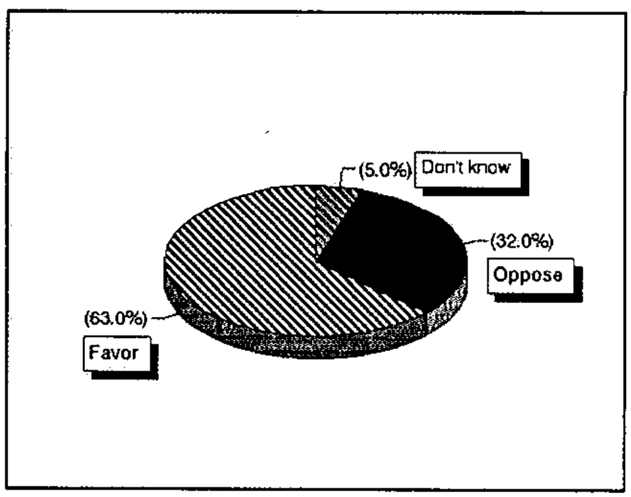
1. *Which one of these approaches do you favor most in solving a water shortage?*

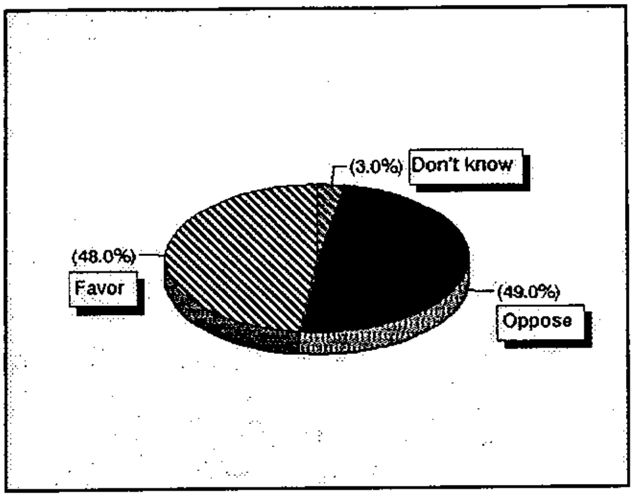




2. *Which one of the following statements do you most strongly agree with?*

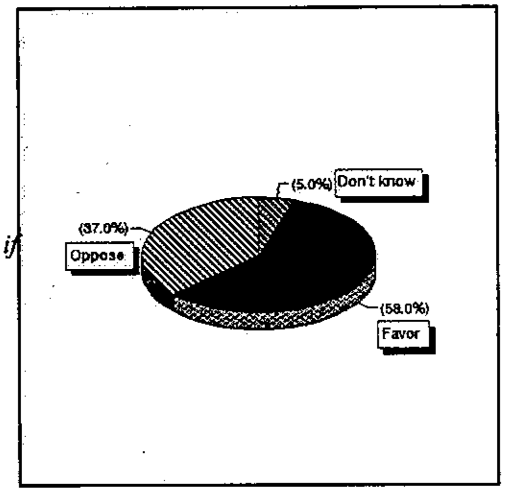
3. *Do you favor or oppose raising water rates for residences that use excessive water?*

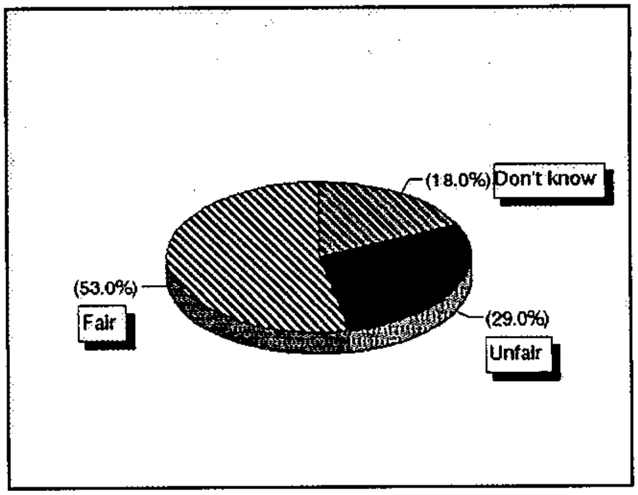




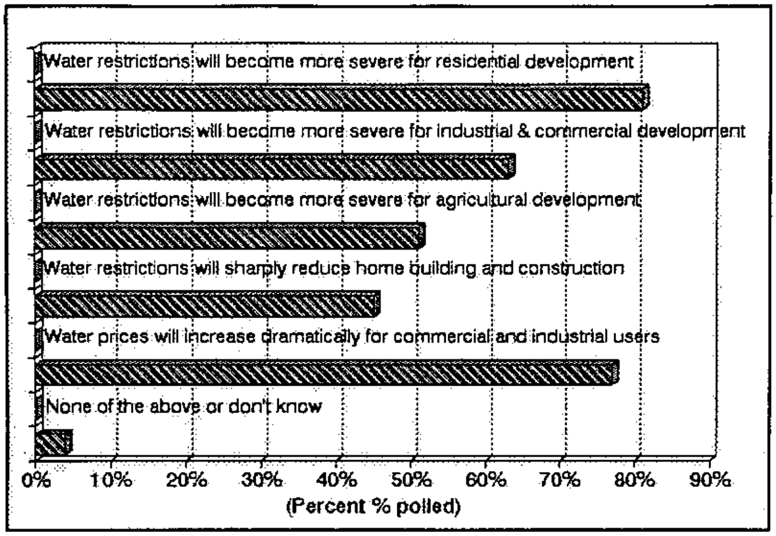
4. *Do you favor or oppose limiting new home construction and business growth?*

5. *Do you favor or oppose paying 10% more for water if it means helping the environment?*





6. *Do you feel it is fair or unfair that well fields in rural areas provide water for people in urban areas?*



7. *Which of the following events do you feel is a likely possibility during the next 5 - 10 years?*

1.3 Urban Resource Optimization and Development in Florida

The concept of wastewater reclamation and greywater recycling as resource sustainable alternatives to effectively reduce potable demand is generally well received. The coinciding idea of water conservation through reuse as a means of reducing sewage and septic discharge however, is commonly overlooked. As Florida's urban infrastructure begins to show signs of age, it is becoming painfully apparent that older systems designed for low density urban activity, cannot readily accept even gradual increases in hydraulic loading on the water distribution systems. Development of rural environments and natural habitats raises additional resource sustainability concerns.

1.3.1 *Urban Greywater Recycling and Reuse*

Potable water is defined as all water consumed for drinking, cooking, and personal hygiene. Potable water generally originates from the highest purity source and is the most rigorously treated. The commercial and residential structures that compose most urban development use in excess of 80% of their potable flow for non-potable, or "non-drinking" quality consumption, resulting in a costly, inefficient use of a limited resource. In select commercial applications, 75% or more of the domestic supply serves toiletry fixtures alone.

The central core design of most urban structures coupled with a density of occupants, would provide the greatest use of cost saving reuse water for the least "dual-plumbing" investment. The *Type A* reuse system collects *greywater*, or wastewater consisting of little or no organic matter into separate sanitary piping from non-fecal sources such as lavatories and sinks. Once this clean effluent undergoes minimal but adequate treatment, it is *dual-distributed* to all potential non-potable fixtures maintained separately of those requiring potable water. The remaining wastewater is disposed of conventionally into municipal sanitary lines. Research has concluded that Type A dual distribution/dual recovery will achieve maximum benefit in urban residential structures, where the greywater supply (approximately 40-60% of total building flow) from non-fecal fixtures balances the potential non-potable demand (40-60% of total building flow).

1.3.2 *Urban Water Reclamation and Reuse*

Public reuse of wastewater and the safe release of highly treated surplus effluent into the environment has proven the most effective method for resource optimization through reduced potable demand and contaminating discharge. Treating wastewater and distributing the reclaimed effluent for non-potable reuse as a substitute for potable water has proven to dramatically reduced demands in resource critical or environmentally sensitive regions. The hierarchy of urban wastewater recycling and reuse initiates with "direct use". Direct use applies to reclaimed greywater supplied to the user directly from municipal or on-site treatment facilities through an essentially closed-loop system. This distribution line is commonly referred to as a "third-main", sanitary and domestic mains comprising the other two. "Indirect Use" refers to reclamation systems that recharge groundwater supplies through deep well injection or surface infiltration using reclaimed wastewater or on-site septic effluent for later recovery and reuse.

Reclaimed water use can be further classified as follows:

1. **Agricultural**: wastewater that receives primary and secondary treatment for reclaimed irrigating purposes.
2. **Non-potable urban**: the use of reclaimed water in third-pipe systems for landscape and park irrigation, dual distribution, ornamental, and recreational use.
3. **Industrial**: involves the use of Ph balanced reclaimed water for uses in mechanical and industrial equipment.
4. **Indirect potable**: involves the use of highly disinfected reclaimed water for either direct injection or percolation into the groundwater supply.
5. **Direct potable**: involves the theoretical use of highly treated, disinfected reclaimed water for direct blending with existing potable supplies.

Table 1.1 Wastewater reclamation capability in the State of Florida.
York, David W. Ph.D., P.E. *Reuse in Florida*. Florida DEP.

	1986	1990
Total number of reuse facilities	118	199
Total reuse flow	206 MGD	266 MGD

Wastewater collected from organic sources such as toilets and urinals, can be recovered for reclamation and reuse. Dual distribution and single (conventional) wastewater piping systems may be used if the volume of greywater alone is insufficient to properly maintain a reuse supply balance, or if discharge flow is restricted. Commercial structures are commonly characterized by an unbalanced flow of 10-25% greywater supply and 75-90% non-potable demand. Therefore, the total recovery of wastewater for treatment and reuse is desirable through dual distribution/single recovery *Type B* greywater systems. Supply requirements for non-potable fixtures currently using potable resources such as water closets, may very from 34% in residential structures, to 75% or greater of total building flow in most commercial applications. Secondary non-potable users such as mechanical makeup and irrigation, could further reduce potable demand. Tertiary reuse applications such as fixture trap priming, aesthetic fixtures, and fire suppression accounting for less than 10% of total flow could nevertheless provide an added incentive for justifying urban reuse.

1.3.3 *Greywater Reuse Alternatives*

Primary non-potable consumers of domestic water are centered around toiletry activities, which use between 34% to nearly 75% of total building flow for residential and commercial structures respectively. Secondary non-potable applications such as HVAC make-up and irrigation will further reduce potable demand. A few of the many non-potable reuse alternatives are provided below:

Toilet and urinal flushing

As previously mentioned, toilet and urinal reuse will eliminate up to 75% of potable demand. Commercial structures are typically provided 15gpm per urinal and nearly 40gpm to flush valve toilets. Flush tank water closets most commonly used in residential structures, generally use 5-6 gal. per flush. Little or no fixture modifications are required prior to reuse.

Irrigation

The use of recycled wastewater for urban landscape irrigation is one of the fastest growing and successful reuse options in the State of Florida. Exterior residential and commercial watering can reduce nearly 40% of the total ground and potable water resources withdrawn annually. Irrigation remains however, the reuse alternative with the highest potential of human contact and ingestion. Direct contact with *spray irrigation* is among the most probable environmental pathway for exposure to airborne pathogens and viruses. Reuse *drip irrigation* allows greywater to be applied below the irrigated surface, providing a more efficient irrigation effort, reducing the exposure to humans, and subsequently reducing the levels of treatment. This subsurface leaching technique can also apply excess irrigated water to a slow rate land application medium below the irrigated strata for indirect soil infiltration to groundwater reserves.

Mechanical heat exchange and make-up

Most urban structures use potable water within building HVAC systems as a medium to absorb and expel heat. These *cooling towers* require 2.4-3.0gpm/ton of air handling capacity, amounting to 10% of total building water usage in some applications. HVAC use of recycled greywater within continuously recirculating systems would require highly treated effluent consisting of high residual disinfectants to prevent biogrowth, Ph balancing to prevent scaling or corrosion, and ultra-filtration to remove all suspended solids. Biogrowth can be controlled by the use of ammonia and nitrogen reducing NaOCl and biological nitrification. Softened reuse water free of scale forming calcium and magnesium, and acidic salts and precipitates can enhance systems performance.

Dry pipe fire suppression systems

Reuse water may be used for commercial and residential fire protection with little or no modification to the existing system. Dry pipe fire suppression systems inhibit flow to the sprinkler laterals when inactive, eliminating stagnant water which could provide a perfect environment for residual breakdown, biogrowth, and scaling between flush cycles. Although dry pipe suppression was originally designed for fire protection in unheated spaces, it will also serve to eliminate the unavoidable settle able solids in greywater from collecting within the fine orifice plates of a typical sprinkler.

1.3.4 *Urban Water Conservation*

There are currently a variety of products available on the market designed for water conservation. Since the United States has the highest per capita use of water of any country in the world, the variety of uses for water is not expected to drastically decrease as a result of continued over-development and the myth of infinite water resources. Urban reuse coupled with water saving fixtures may be more easily accepted by the public. Efficiency of water use has not previously been the hallmark of fixture design. For example, the ratio of water to waste in a conventional flush toilet is 80 to 1. It has been estimated that with the use of low cost, low water use fixtures, the amount of water used in typical residential applications can be reduced by 19 to 44 percent. Alternative flush devices will reduce the amount of water used with each flush by as much as 50%. The water efficient toilet uses 1.3 gallons per flush, and is in compliance with the National Plumbing Efficiency Act under consideration.

Flow rates of up to 4.5 gallons per minute are characteristic of conventionally engineered showerheads whereas low-flow showerheads use 1.5 to 2.5 gallons per minute and do not lower consumer preference in terms of acceptable performance. Low-flow showerheads are either aerated or non-aerated. Non-aerated showerheads pulse the water while aerated showerheads mix air with water while simultaneously maintaining pressure. It has been reported that a 16.4 % decrease in water use occurred in a pilot program with the use of low-flow shower heads in a residential development in Amherst, Massachusetts. In a Canadian study, it was found that using low-flow heads in a 719 unit apartment building reduced water use by 53%. Low-flow faucet aerators can reduce the water flow of the average kitchen or bathroom faucet's conventional rate of 3 gallons per minute by 50 % or more.

Maintaining adequate water pressure for residential areas is also important for efficiency in the system but frequently water pressure is substantially higher than is normally required. A pressure of between 50 to 60 psi for the mains and 40 psi inside a residential unit is generally appropriate. Pressures twice the appropriate amount are not uncommon, wasting water at every fixture within the distribution network. One method for conserving water is the installation of a pressure reduction valve in the main water line, providing a equalized flow and further reducing high pressure damage to fixtures and piping.

1.3.5 *Economic Analysis and Systems Selection Rationale*

Generally, the greater the volume and cost of potable supply and subsequent wastewater discharge, the more economically lucrative urban reuse becomes. By amortizing the greywater systems options based on factors such as the initial investment, environmental impact fees, life-cycle operations and maintenance costs, interest rates and inflation, and annual water and wastewater surcharges, a value engineering firm can determine the most appropriate system specific to the building designation and function. The *Type B* or total wastewater reclamation system for instance, may reduce more than twice the potable demand and resultant wastewater discharge, yet is typically twice the initial investment. The Type B system is therefore most appropriate in commercial environments where the total volume of wastewater is required to supplement the 75%-90% of the current potable demand being used for non-potable applications such as toilets and irrigation. Conversely, *Type A* or greywater only systems are most cost effective in residential settings where the 40%-60% grey waste flow from non-fecal fixtures such as sinks, lavatories, and showers nearly balances the 40%-60% non-potable demand to flush toilets that currently use potable water.

1.4 Growth Management Reuse Initiatives and Concepts

Progressive growth management dictates efficient use and reuse of Florida's water resource. The concepts of urban conservation, reclamation, and greywater reuse are not new, but full-scale reuse system implementation has been minimal. To help manage the anticipated growth, the Florida Department of Environmental Protection (DEP) has set a goal of 40% reuse of total wastewater flow by 2020. In the most populated areas of the state, water management districts are proposing 100% reuse within the next thirty years. Although the environmental benefits of water reuse are clear, greywater systems must also have inherent economic worth to achieve serious consideration and acceptability. This balance between environmental and economic concerns is necessary to enable the expansion of greywater reuse from select applications to mainstream reuse. The premise of using reclaimed effluent for non-potable use within these structures is justified by the variety of water critical solutions reclamation provides. In select applications, non-potable reuse could potentially supplement nearly 90% of total building demand. Greywater as a resource subsequently reduces the amount of wastewater disposal. Reclaimed water can be treated and sold by municipality's to the users for considerably less cost than the potable water it replaces. This creates a dual advantage that is cost effective to both the supplier and user. Inevitably, good growth managment will require the exhausted or surplus effluent returned to the surrounding ecosystem would, in most cases, be of greater quality than if it were treated solely for disposal.

1.4.1 *Reuse Markets*

Urbanized commercial and residential developments are perhaps the greatest beneficiaries of reuse technology based on the fact that such structures possess a central distribution core and a density of occupants. Such conditions result in maximum greywater consumption which optimize the minimal modifications to standard or retrofit distribution systems. This premise, coupled with the fact that Florida possesses more condominiums and residential high-rise structures than all other forty-nine states combined, presents vast potential for reclaimed water use within the interior of such structures. In addition, it is possible that nearly 25% of Florida's total water consumption is attributable to these commercial and residential buildings.

1.4.2 *Technical Overview*

Reclaimed and greywater systems can primarily be distinguished on the basis of either municipal or on-site treatment and distribution. Both achieve maximum economic value when the level of treatment is limited to its intended use. Therefore, treatment alternatives suited to specific reuse applications will be addressed in an effort to prevent the recycled effluent from approaching the costs of the potable water it is intended to supplement. Once the greywater is adequately treated and disinfected, it is provided to non-potable fixtures through a dual distribution network within the building itself. This "dual plumb" design prevents any cross connections between potable and non-potable piping. Preliminary research indicates that the life-cycled savings of using a less costly non-potable resource has almost always resulted in economic benefit in spite of the additional cost for dual distribution and maintenance.

1.4.3 *Socioeconomic Determinates*

The extent of economic, environmental, or social benefit obtainable using any greywater, reclamation, or resource conservation initiative depends heavily on the nature and function of the environment within which the system is intended to operate. Therefore, determining the most efficient reuse distribution specific to each building designation and setting is critical. A detailed economic analysis method identifying the worth of the individual system or combination of systems under a variety of reuse applications must be considered. The economics of these systems, both in a capitalization and life-cycle sense, must be factored into the overall scheme of greywater reuse. Finally, critical issues such as public health and perception must remain in perspective to understand the range of problems that can occur when reuse systems are selected as a value engineering alternative in the life-cycle productivity of the structure.

1.5 Summary

The importance of maintaining both a high quality and supply of water in the presence of increasing demands on this essential resource has prompted growing concern over the future availability of potable water. The critical issue rests with maintaining a cost effective service while extending the life of this vital resource. The matter is complicated by the fact that water has traditionally been considered a "limitless resource", further undervalued and overused. The result of this errant ideology has been an emphasis on increasing supply, instead of regulating demand. Ensuring the sustainability of water will require new techniques of water conservation and management with a new focus on optimizing water utilization through greywater reuse and wastewater reclamation.

The correlation between Florida's population, which continues to grow by about 6,000 persons each week[1], and water demands increasing exponentially, is clear. The problem of dwindling resources has been associated with the commercial and residential communities of urban Florida, responsible for over 70% of its total water consumption. It has been demonstrated that optimization of water utilization through reuse has potential benefit towards solving many of Florida's water issues.

1.6 References

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CHAPTER 2
GREYWATER RECYCLING AND ALTERNATIVE WATER RESOURCES

2.0 Introduction

A new "ecologically correct" model residence has recently been completed in Sarasota, Florida through the efforts of a public-private partnership formed by the UF/IFAS Cooperative Extension Service to illustrate the potential economic and environmental payoff of many innovative greywater and alternative water reuse techniques currently available. Sustainability concepts are integrated within the active design of this structure to conserve and recycle water and energy resources and further implement passive designs to rediscover the rewards of natural air and sound quality, lighting, and aesthetics. Rainwater for example, is harvested from two gravity fed 2,500 gallon cisterns supplied by roof runoff for domestic and landscape use. Although simplistic, rainwater harvesting has become only one of several alternative resource recycling and reuse options which minimize the embodied energy required to sustain supplemental water resources.

Although the summer months provide the most rainfall in Florida, the demand for water is surprisingly greatest during the winter months as seasonal tourism and year round agriculture deplete groundwater at a rate faster than can be replenished. The U.S. Department of Agriculture estimates that each person uses between 60-100 gallons of water per day, accumulating to more than a million gallons of water per lifetime. Furthermore, most municipal waterworks charge wastewater treatment and disposal costs per 1000 gallons of domestic water used, assuming that all domestic water will ultimately be used and discharged in its entirety as wastewater. Neglecting the *real* cost to the environment, a lifetime of water and resultant sewage charges at this conservative rate will cost most Americans the equivalent of 25%-35% of the net value of their current home.[1] Several greywater reuse and alternative water resource practices can be implemented using "off-the-shelf" dual use technologies to provide environmentally conscious and economically viable solutions to many of Florida's water availability problems. Conscious water usage does not have to be synonymous with sacrifice, as many innovative techniques actually recover capital investments in 3 years or less, reduce utility costs, reduce embodied energy, and improve the intrinsic quality of life. This section is dedicated to identifying several greywater reuse and alternative water resource options that effectively supplement increasing water demands and subsequent sustainable construction costs.

2.1 Greywater Flow Characteristics and Concepts

Greywater is a generic term that basically applies to most non-potable water other than conventional wastes that is suitable for limited treatment and reuse. Greywater systems recycle select wastewater, effluent, and several other alternative water resources consisting of little or no organic constituents. *Direct greywater* is non-fecal wastewater originating from non-fecal potable fixtures such as lavatories, sinks, and showers for limited treatment and reuse. *Septic* and *composted greywater* is extracted from conventional (black) wastewater for in most cases, substantial treatment prior to reuse. *Alternative water resources* such as rainwater harvesting, provide yet another source of greywater for non-potable reuse. Research has concluded that direct greywater reuse, the most advanced and reliable of the greywater alternatives, will generally achieve maximum benefit in urban residential structures where the greywater supply (approximately 40-60% of total building flow) from non-fecal fixtures nearly balances the non-potable demand (40-60% of total building flow) as shown in Figure 2.1 on the following page. Furthermore, recycled residential greywater provides balanced flow equalization to non-potable fixtures such as toilets and irrigation systems without the degree of treatment, and subsequent expense of recycled conventional wastewater.

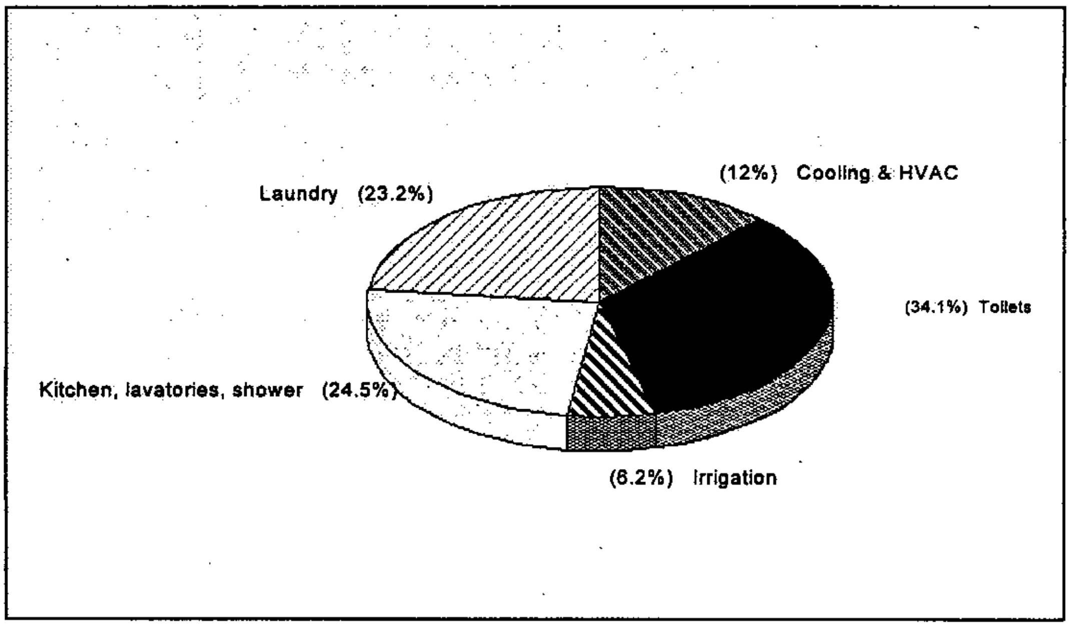

Figure 2.1 Wastewater annual average flow in typical residential structures.
Assessment of Greywater and Combined Wastewater Treatment and Recycling Systems. PHCC, 1992.

2.2 Direct Greywater Recycling

Direct greywater originates as wastewater from all non-fecal sources such as potable fixtures including bathroom basins, tubs, showers, laundry rooms and kitchen sinks discharging dilute, relatively low-organic water. Greywater from kitchen sinks is the least desirable because it frequently contains oils, fats and greases making it difficult to filter and a breeding ground for bacteria. Greywater may also include condensate or blowdown from mechanical equipment, overflow from recreational or aesthetic water impoundments, or water from any other non-toiletry, non-industrial activity. Alternative water sources such as septic or composting toilet effluent and rainwater harvesting can also be considered as grey wastes, suitable for integrated recovery, treatment , and re-distribution. Another benefit of greywater recycling in addition to reducing 50% or more potable water demand, is a proportional reduction in sewage loads and a more concentrated and therefore more efficiently treated influent.

2.2.1 *Direct Greywater Treatment and Water Quality Objectives*

Direct greywater treatment is fast becoming a viable alternative in many developing commercial and residential communities throughout Florida where water and wastewater infrastructure is marginal and the environmental capacity to manage wastes is severely limited. Due to the lack of long range municipal planning, sewer moratoriums are increasingly being imposed on high value commercial and residential properties restricting discharge volume. Potential development areas remain undervalued in the absence of sanitary infrastructure and the presence of poor septic leaching soil. Other areas are further susceptible to water table draw-down from over active well point pumping.

The State of Florida currently mandates in FAC 17-610.451 that water reclamation facilities capable of supplying reuse effluent for on-site applications must achieve a minimum 0.1 MGD flow for systems control and reliability. This is well above the flow rate for most light commercial and residential developments considering greywater reclamation and reuse. Special interest lobbies from the wastewater treatment industry have further been suspect in limiting on-site water recycling for fear of dwindling control and market shares. However, since realizing the potential of greywater recycling to reduce water resource consumption, an increasing number of on-site treatment facilities are being approved on a case by case basis by DEP.

As with any water reuse alternative, adequate treatment remains critical. The central feature of the greywater system is the on-site capability to condition a "clean" wastewater for dual distribution to non-potable fixtures. The economic principal governing greywater recycling is to treat the water to the degree of quality required for its intended reuse. This varies with both the intended use and the original source of the effluent. The simplest system for greywater treatment involves media filtration followed by chlorination. Yet, research has indicated that select residential greywater fixtures often contain such a high amount of detergent that defoaming agents are required for the removal of aqueous foams from laundry and washing fixtures in the recovery network.

Direct greywater treatment processes range from simple filtration and disinfection similar to residential pool maintenance, to multiple barrier systems such as septic sedimentation, biological clarification, sand filtration, and reverse osmosis. Greywater treatment processes are generally dictated by the quality of greywater influent and the level of anticipated human exposure to its treated, non-potable reuse. Greywater from drinking fountains and lavatories can be reused with little treatment and disinfection. Greywater containing detergents and organics from kitchen sinks and dishwashers requires more advanced treatment and is generally less desirable. Figures 2.2 and 2.3 provide a complete listing of potential contaminates per residential greywater source as well as several reuse water treatment options to remove such contaminates. Three different disinfection schemes, tablet chlorine, iodine crystals, and ultraviolet irradiation, are particularly useful for preparing filtrated greywater for either on-site surface discharge, or interior reuse in non-potable fixtures such as HVAC make-up and toilet/urinal flushing.

	CHARACTERISTIC														
REUSE WATER SOURCE	BACTERIA	BLEACH	CHLORINE	pH	NITRATE	ODOR AND COLOR	OIL AND GREASE	ORGANIC MATTER	OXYGEN DEMAND	PHOSPHATE	SALINITY	SOAPS AND FOAMS	SODIUM	SUSPENDED SOLIDS	TURBIDITY
AUTOMATIC CLOTHES WASHER		O			O					O	O	O	O	O	O
AUTOMATIC DISH WASHER	O					O	O	O	O			O		O	O
BATH TUB AND SHOWER	O					O			O			O			O
EVAPORATIVE COOLER			O												
HVAC BLOWDOWN CONDENSATE				O											
BATHROOM LAVATORY	O					O			O			O			O
KITCHEN SINK	O					O	O	O	O			O		O	O

Figure 2.2 Water quality characteristics of domestic greywater.
Popkin, Barney P. *Recycled greywater for home irrigation.* Water & Wastes Engineering, September 1989, p 62-64.

REUSE WATER TREATMENT	BACTERIA	BLEACH	CHLORINE	pH	NITRATE	ODOR AND COLOR	OIL AND GREASE	ORGANIC MATTER	OXYGEN DEMAND	PHOSPHATE	SALINITY	SOAPS AND FOAMS	SODIUM	SUSPENDED SOLIDS	TURBIDITY
STORAGE				O				O	O			O		O	
CARBON FILTRATION	O					O									
CHLORINATION	O					O									
PLANT FILTRATION	O							O						O	O
PLANT UPTAKE					O					O		O	O		
DILUTION				O	O					O	O		O		
FLOTATION							O								
HYDROGEN PEROXIDE	O					O									
LIME	O					O							O		
SEDIMENTATION								O	O			O		O	
SOIL FILTRATION					O					O		O	O		
SOIL UPTAKE	O	O	O					O	O					O	O

Figure 2.3 Treatment for water quality variables.
Popkin, Barney P. *Recycled greywater for home irrigation.* Water & Wastes Engineering, September 1989, p 62-64.

2.2.2 *Direct*

Greywater Mechanics

Direct recycling systems have the option of either collecting non-fecal greywater separately using dual recovery stacks, or collecting both grey and black wastewater together using a conventional single waste stack and venting. Greywater collected separately using the *Type A* system (Figure 2.4) is recovered from non-sanitary fixtures such as sinks and showers and is recycled. Sanitary wastes or blackwater from urinals and toilets is directed to the municipal sewer or septic tank disposal system (for minimal flow applications only). The primary benefit of the Type A *dual stack* system is lower treatment and reuse of a "clean" wastewater.

Although the Type A alternative concedes a higher initial cost, the dual stack concept provides greywater recovery using a pre-existing *vent stack,* allowing proper system flow and venting. The enlarged vent stack now used as a *wet vent* to collect 50% or more of the total wastewater flow, could result in a proportional reduction in the size of the blackwater *soil stack.* Though the volume of greywater recovered from low consumption fixtures is insufficient in commercial environments, Type A greywater recovery systems are viewed as most appropriate in residential structures where the recycled greywater flow from showers and lavatories balances the non-potable demand to toilets and irrigation systems.

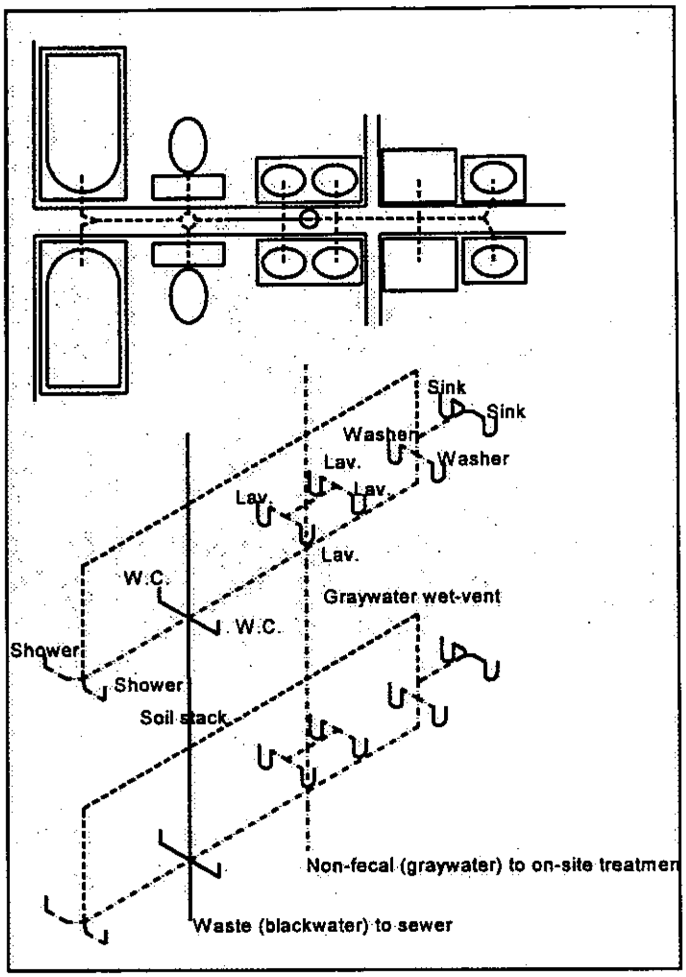

Figure 2.4 Central core greywater (Type A) recovery system.
Grosskopf, Kevin R. *Water Reclamation and Reuse Within Multi-Level Structures.* University of Florida, 1993.

2.3 Septic Greywater Recycling

The most common subsurface disposal system for treatment of domestic wastewater is a septic tank for primary treatment and biological clarification, and a leaching bed for the disposal of septic effluent. The quality of the septic effluent depends greatly on the duration of the biological and chemical treatment, and the detention time (in days) relative to the volume of the septic tank and the volume of wastewater discharged from the residence. The efficiency of the septic process can be improved substantially by separating greywater from the conventional waste stream, reducing 40%-60% of the volumetric influent load, and thus lengthening detention time. The septic tank effluent is a primary treated product carrying potential pollutants and contaminates to the surrounding soil strata, groundwater, or even to adjacent surface waters. Therefore, an enhanced effluent reduces environmental degradation and the destruction of potential potable water resources. The resultant greywater can then be disposed for indirect infiltrated groundwater recharge, used as direct subsurface irrigation, or recycled for non-potable surface reuse.[7]

2.3.1 *Septic Greywater Denitrification*

As Florida's rural and semi-urban populations continue to outpace the wastewater infrastructure required to support them, a greater emphasis may soon be placed once again on the very septic systems identified as being one of the greatest contributors to groundwater contamination in the state. The continued proliferation of phenols and chemical surfactants into uncontrolled septic systems has too often resulted in the destruction of the biological treatment processes required to remove anaerobic contaminates, primarily nitrogen (N). Denitrification, or the effective removal of nitrogen from the wastewater, is largely predicted on the increase of carbon © and Oxygen (O) relative to nitrogen. Laboratory results and trial field systems using septic denitrification, have demonstrated an effective nitrogen removal nearly 95% when OC/N is greater than 1.35 as opposed to 20% or less when OC/N is 0.6, common to most septic systems. Greywater recovered separately as an effluent, aerated, filtered and reintroduced to the influent wastewater stream provides an exceptional organic carbon source required for denitrification. Typical flow volumes needed to achieve acceptable organic carbon concentrations for denitrification are 35%-50% greywater to 50%-65% conventional wastes (blackwater).[2] The resultant septic effluent may then be used for slow rate land application using conventional leach fields for irrigation and indirect aquifer recharge without nitrogen induced contamination to groundwater sheds. Residential structures consisting of a nearly balanced greywater to blackwater flow are considered the greatest beneficiaries of this process.

2.3.2 *Septic Greywater Treatment and Water Quality Objectives*

Advanced systems that collect, treat, and redistribute greywater and septic effluent are increasingly gaining popularity as the second generation septic systems successor. Septic effluent and greywater discharge qualities of *biochemical oxygen demand* (BOD) 100 mg/l can be reduced to BOD 20 mg/l, achieving a dissolved organics removal efficiency of 80% or more.[4] This septic replacement or supplement system requires only $0.76m^3$ for installation, employing a treatment train using submerged biofilters. The basic configuration of this system is illustrated below and is described as follows:

1. A 300 liter controlling tank with a screen for removing large solid matter.

2. A submerged biofilter concentrated with artificial porous stones and activated carbon to efficiently decompose polluting substances by biological clarification.

3. A blower to aerate the submerged filter tank.

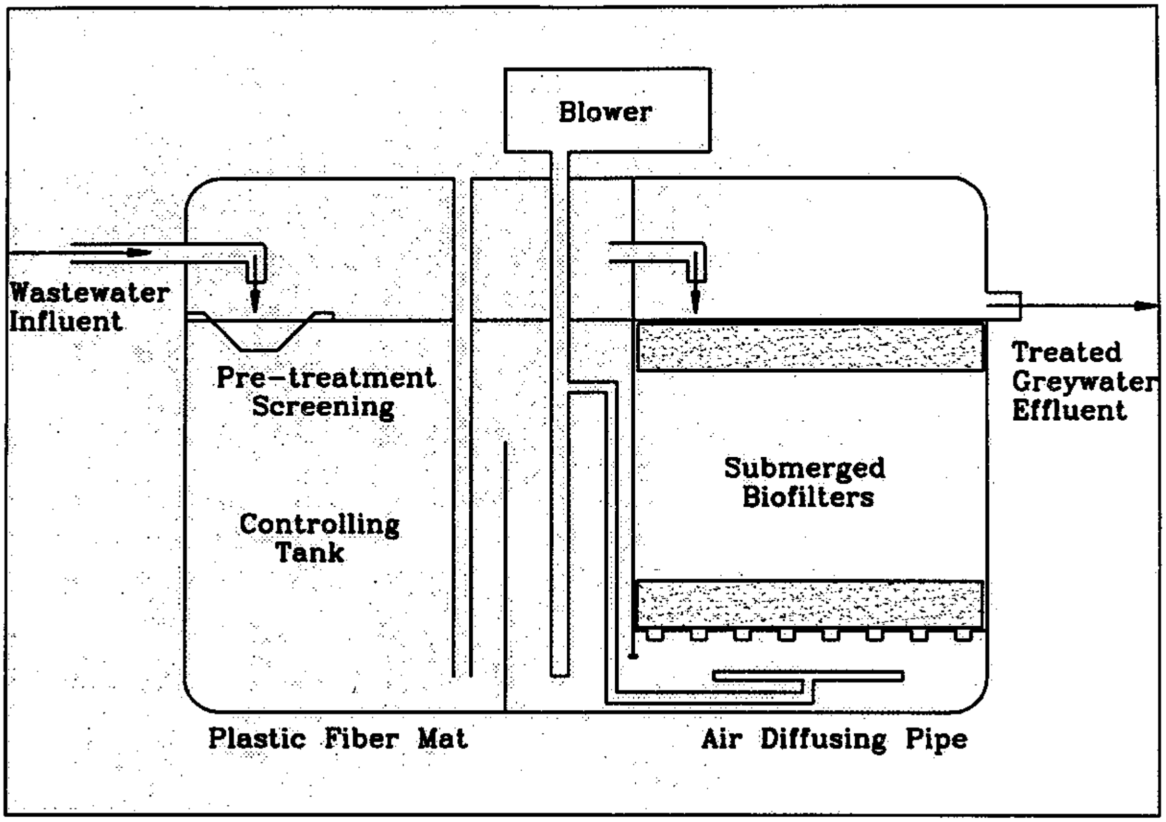

Figure 2.5 Cross-section of Kanagawa Perfecture greywater treatment system.
Fujiwara, Masahiro. *Present State and Future Direction of Countermeasures for Pollution*. Tokyo, 1986.

This system described in figure 2.5 achieves a design influent capacity of 1000 l/d and a design BOD loading rate of 150 g/d. Sludge in the submerged filter is allowed to flow out with discharging water as simplification of maintenance is emphasized.

2.3.3 *Septic Greywater Characterization*

Studies conducted on two separate septic tanks used by the same residence for treatment of greywater and domestic wastewater from sanitary fixtures have yielded the following results:

1. The use of a separate greywater septic tank for treatment of non-sanitary wastes has dramatically extended the detention time, treatment efficiency, and subsequent effluent quality of the sanitary septic tank.

2. The use of phosphorous-free detergents reduced the total soluble phosphorous in the greywater effluent from 1.4 mg/l to less than 0.17 mg/l.

3. The average total Kjeldahl nitrogen (TKN) in the greywater effluent was 11.3 mg/l, or approximately 7% of that in the sanitary effluent.

4. Surprisingly high levels of coliform organisms in the greywater effluent were almost exclusively attributable to kitchen wastes containing little breakdown in relation to sanitary wastewater, which is largely composed of material that has undergone considerable microbial and enzymatic catalyzation during its passage through the human digestive track. Elimination of kitchen greywater will reduce reusable greywater volume slightly, yet reducing organic loading substantially.

5. The observed sludge accumulation rate per person in the greywater septic system was approximately 8.3 l/y in relation to the sanitary sludge accumulation rate of 65.7 l/y.

6. Sludge removal and septic cleaning intervals are 8-10 times longer than the respective time intervals recommended for normal domestic septic tanks.[7]

2.4 Composting Greywater Recycling

The use of compost technology, employed extensively in Scandinavian countries, has received sparse acceptance in the United States. The primary issue inhibiting this water conservation scheme is the lack of control for managing greywater separation, treatment, and reuse. Until recently, the general public's aversion in a technology which contains and treats wastes in the household has resulted in a reluctance to incorporate this water saving concept. Nevertheless, segregating conventional wastes from greywater remains lucrative for reducing ground and surface water pollution as well as reducing potable demand more than 40%.[3] American interest in the use of compost toilets as a waste management technique has since grown in light of increased environmental awareness, wastewater management problems, excessive conventional treatment costs, and population growth. Wastewater management systems play a crucial role in land use. Compost technology and greywater reuse systems have the potential to make unbuildable land buildable, therefore playing a significant role in land use planning. Segregating conventional wastes and greywater eliminates 70% of the nitrogen load, 45% of the phosphorous load, and the bulk of the biodegradable organic load in the resultant effluent. Three basic compost toilets exist, ranging from *large* and *small* units, and *owner built* models. Larger units may be installed in below ground vaults for single story slab construction, or in basements or mechanical rooms for multi-level construction. Smaller units may be installed within the bathroom itself. Advantages of larger units include passive composting with minimal energy requirements and the ability to assimilate excessive peak demands. Smaller units benefit from minimal space requirements, minimal retrofit in existing structures, and lower initial costs. Disadvantages with larger units include effluent build-up, lack of optimal compost aeration, and excessive ventilation requirements that could impact HVAC efficiency. Solar assisted composting toilets are currently being developed to allow passive solar energy to heat and evaporate excess effluent. Composted matter can be reused as effective organic fertilizer, containing less than 30 fecal coliform bacteria per gram, or approximately 15% of the 200/g coliform limit established by the National Sanitation Foundation (NSF), and 0.03% of the 100,000/g coliform concentration in standard septic sludge. Similarly, composted effluent has been repeatedly tested and found to contain less than 40 coliform per 100ml of water. The EPA standard for swimming quality water is 200/ml, while typical septic effluent commonly exceeds a half million coliform per 100ml sample.[6]

2.4.1 *Compost Greywater Treatment and Water Quality Objectives*

Septic Tank
Septic tanks provide for the retention of the solids portion of the greywater and anaerobic liquid treatment generally for three to five days. The septic tank allows solids from influent (incoming) greywater to settle to the bottom of the tank, forming a sludge layer. Lesser dense materials such as soaps and oils, form a floating layer. The floating layer is held by baffles, allowing the liquid effluent (outgoing) to flow into a absorption field or into another treatment system for non-potable reuse.

Sand Filter
The sand filter treatment system consists of a sand and rock filled tank with an underdrain component. Greywater originating as wastewater from non-fecal fixtures such as sinks and lavatories or as sedimentated effluent from a septic system is placed onto splash plates. The greywater then permeates the sand filter media, allowing both physical and biological treatment. Biological clarification occurs by bacterial growth within the sand that extracts organic nutrients from the water and uses carbonaceous material for growth. Physical treatment occurs by the filtering of non-organics.[5]

Rack Filter
The rack filter component is used to pre-treat greywater. The primary function of this unit is to remove particulate matter from the greywater. The construction of this device consists of a large column (0.5m+ diameter x 1.5m length) and one or more screen racks (varying from #200 to #40 mesh) supporting small gravel or sand. Greywater is passed through the filter media and collected within the tank for further treatment or direct reuse.

Biological Treatment
Biological treatment of greywater is a means of reducing both soluble and insoluble organic contaminates. These units usually consist of three chambers: (1) pre-settling, (2) aeration, and (3) final settling with sludge return. Greywater first flows into a pre-settling chamber where gross solids settle. The effluent then passes to the aeration chamber where biological action removes soluble organics. The effluent then flows into the final settling chamber where biologically active solids settle out.

Physical and Chemical Treatment
In this process, greywater flows through a rapid mix tank where polymer and activated carbon are added. The mixture of greywater, polymer, and carbon flow into a clarifier where a sludge conditioner is added. After settling, the effluent is disinfected and passed through a diatomaceous earth filter. The greywater is then suitable for direct reuse, irrigation, or non-potable interior reuse as flush water.

Sedimentation and Filtration
Sedimentation and filtration units basically consist of a conically shaped storage/settling chamber and a filter. The shape of the chamber along with the drain simplifies the sludge removal process. The storage tank must be equipped with an overflow fitting and a low level control to assure an adequate water supply at all times. Cartridge filters are commonly used because they can be conveniently disposed of once spent. Diatomaceous earth filters and activated charcoal filters can also be used.

Chlorine Disinfection
Chlorine disinfection is the most commonly used method of disinfection. Chlorine tablets are often dissolved within the greywater storage tank after treatment. A nominal contact time of 30 minutes is usually adequate for most domestic greywater. Gravity fed chlorination columns and dosing pumps can be used as well for greater disinfection reliability, yet with substantially higher operating costs.

Iodine Disinfection
Iodine disinfection units operate in the same general manner as chlorination units. Due to the limited solubility of iodine however, forced fed columns are required to assure adequate pressure and flow of wastewater for

iodine dissolution.

Ultraviolet Irradiation

Ultraviolet (UV) irradiation is a very effective method to reduce bacterial concentrations in a very short contact period and with very little embodied energy. This process involves passing the greywater over a lamp which emits a UV spectrum light that effectively destroys pathogenic microorganisms. The reliability of UV disinfection is largely predicated on the level of suspended solids, which act as a barrier to UV irradiation of bacteria coliforms. Greywater treated by UV disinfection cannot maintain a residual disinfectant as can chlorine and iodine dissolution. Therefore, UV disinfected greywater cannot be stored or continuously cycled for long periods of time for risk of system biofouling.[5]

2.4.2 *Compost Greywater Disposal and Reuse Alternatives*

Soil Absorption Fields

Greywater represents 40%-60% of normal domestic wastewater flow, so a separate system for greywater permits reductions in system size and costs.

Irrigation

Greywater can be disposed of by using it for commercial and residential irrigation. The following provisions apply to direct or minimal treated greywater when used for irrigation:

1. Disperse greywater to avoid concentrated amounts of potentially adverse greywater constituents, such as chlorides.

2. Apply greywater directly to soil using subsurface leaching or surface drip irrigation. Do not spray.

3. Dilute greywater or alternate it with potable water or harvested rainwater when applying to sensitive foliage.

4. Avoid using undiluted greywater on root and leaf crops to be eaten or those requiring acidic conditions due to the potential of high chlorides and direct uptake.[5]

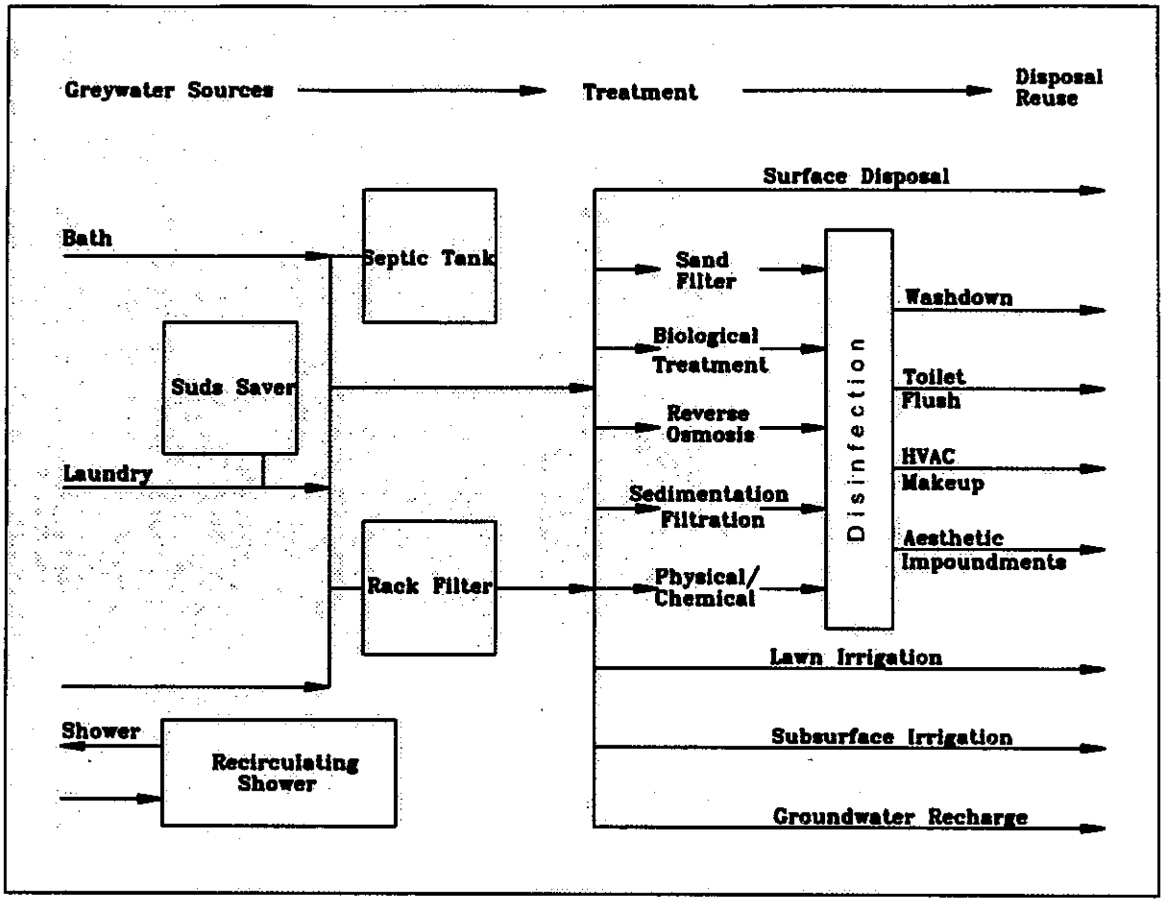

Figure 2.6 Range of greywater treatment, disposal, and reuse alternatives. Lombardo, Pio. *Expanding options for greywater treatment.* Biocycle, 1982.

Recirculating Shower

The recirculating shower is a direct means of recycling greywater. This device, as the name implies, collects used washwater and uses a lift pump to transport the washwater through a filtration system and back to the showerhead. This device is portable and can be relocated easily. Other than filtration, little treatment is provided prior to reuse.

Suds-Saver

The suds-saver washer is another direct alternative to recycle greywater. This device allows a savings of 20 gallons of water with every 2 loads of laundry. This system consists of a 20 gallon tank located adjacent to the washer. The two are connected by drain and return lines. Settle able solids are allowed to filter out and the resultant effluent is diluted with potable water and returned to the next wash cycle.[5]

> ...Is greywater reuse something new and dangerous? The *suds-saver* is a greywater recycling system long used and accepted in the U.S., even though thousands of housewives can come in physical contact with the greywater everyday.[8]

Removal of toilet and kitchen wastes from domestic wastewater and composting them dramatically lessens the extent of treatment for the remaining greywater (as it looks and is frequently called). *Dry* toilets and other composting measures reduce nearly two-thirds the volume of water used and subsequently treated. Such reductions lower treatment requirements below the threshold where expensive contractor installed septic or sewer systems are necessary and where simple owner installed and maintained systems are adequate. Such systems may cost $100 or less, or roughly 5%-10% of the costs of a septic/leach system, and only 1% of the costs of a sewer installation.[8]

Simple compost greywater recycling is necessary to provide an alternative to a centralized, conventional sewage system. Composting technologies and dry toilet usage possess the following advantages:

1. Composting systems can cost only a fraction of central systems and lessen the massive financial burden central systems place on individuals and communities.

2. Composting systems avoid the environmental and infrastructural stress of land development.

3. Water is typically returned to the *local* groundwater table by slow rate land application for purification and filtration through soil strata in small volumes.

4. The estimated cost benefit with dry toilets is a potable water, and in most cases an equivalent wastewater discharge reduction of between 4,000 - 6,000 gallons of water per year.

5. Increased development potential in areas where there are limited potable resources or limits on wastewater discharge due to unsuitable geoclimatic conditions, lot size, or inadequate infrastructure.

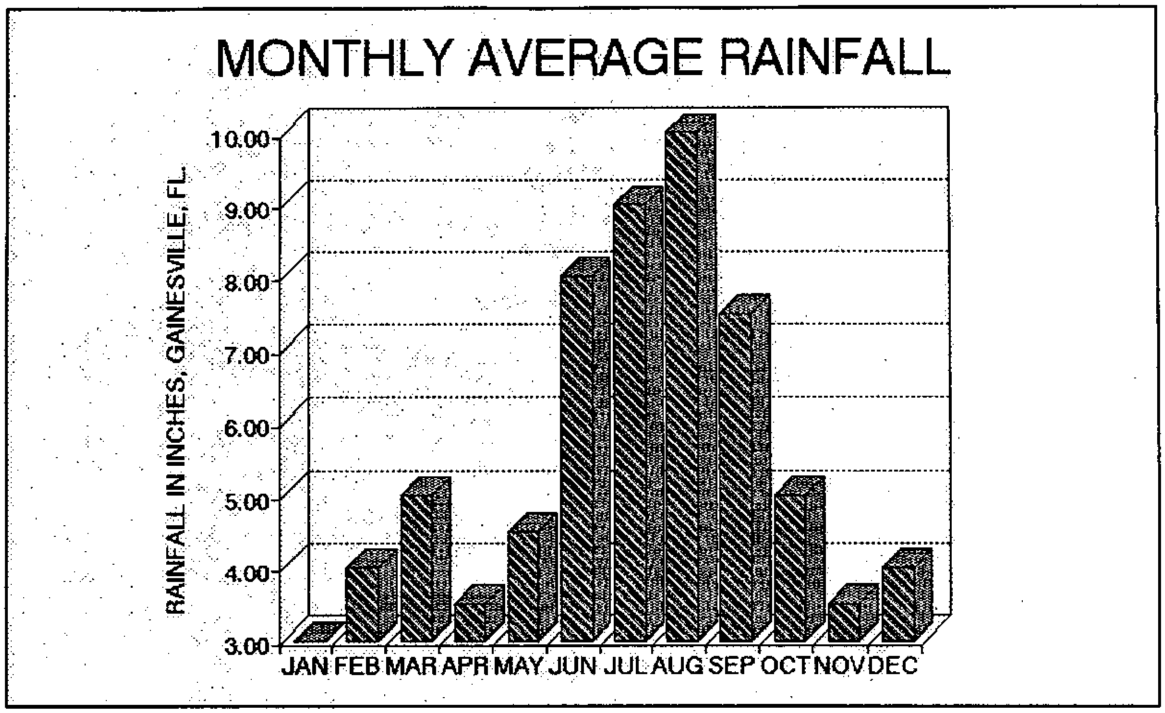

Figure 2.7 Monthly average rainfall, Gainesville, Florida.
Atlas of Florida. *Water Resources.* Florida State University, 1985.

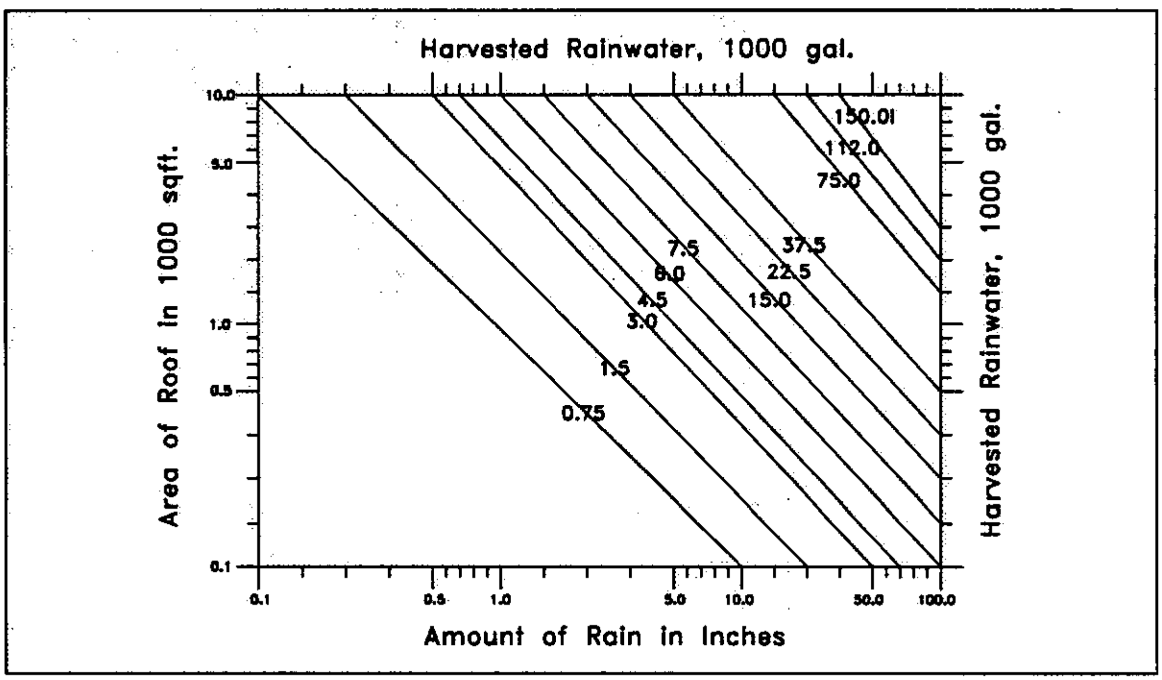

Figure 2.8 Rainwater available for irrigation from roof runoff (1000 gal.)
Popkin, Barney P. *Recycled greywater for home irrigation.* Water & Wastes Engineering, September 1989, p.62-64.

2.5 Alternative Water Resources

Greywater effluent from non-fecal fixtures, or less than 10% of the total commercial wastewater flow, is in many instances inadequate to meet the non-potable irrigation demands of many commercial users. Rainwater harvesting is therefore commonly used to provide the balance required. A significant reduction in both user and municipal costs are possible with grey and alternative water irrigation.

Non-potable reuse irrigation and toilet flushing alone may reduce residential potable demands as much as 80%. Rainwater harvesting may also reduce stormwater loads an additional 60%.

2.6 Summary

The average American uses between 60-100 gallons of water each day, resulting in a proportional quantity of wastewater to be treated and assimilated by the environment. Conservative estimates place the amortized net worth of this lifelong resource and energy intensive process to roughly 25%-35% of the net worth of a typical homeowner's current residence. Several commercially available systems have effectively proven to reduce water demands and subsequent wastewater discharges up to 50% or more. Greywater reuse, or the use of non-fecal wastewater or alternative non-organic, non-potable resources, have been shown to readily harvest and reuse "clean wastewater" for a variety of non-potable applications without the extensive treatment and dual-distribution associated with municipal reclamation efforts.

Residential structures provide the greatest potential for greywater reuse as result of a nearly balanced supply and demand (40%-60% of total building domestic water and wastewater flow) from greywater sources such as sinks, lavatories, and showers to non-potable applications such as toilets and irrigation. Constituents and contaminates in domestic wastewater are also easier to quantify and remove. Treatment processes consisting of sedimentation, clarification, filtration, and disinfection may be employed with a minimum of expense prior to reuse. *Direct greywater reuse* is non-fecal wastewater treated and reused for interior and exterior applications. *Septic and composted greywater reuse* utilizes effluent resulting from biological action and settling within the clarification chamber of a standard septic operation that is filtered and applied to subsurface irrigation systems and indirect ground water recharge. *Alternative water resources* such as rain and storm water runoff may be harvested for non-potable reuse, or to provide clarification or makeup to a conventional greywater system. This may enable greywater systems to be more amenable in commercial environments where greywater alone from sinks and lavatories is insufficient to meet the non-potable demand to toilets, urinals, and irrigation systems.

2.7 References

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4. Fujiwara, Masahiro. *Present State and Future Direction of Countermeasures for Pollution from Domestic Wastewater in Japan.* Water Pollution Control Division, Environment Agency, Tokyo, 1986.

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6. Riggle, David. *Composting Toilets Reach the 90's.* BioCycle: August, 1990.

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8. Warshall, Peter. *Wasting Water.* RAIN: December, 1977, p.4-5.

CHAPTER 3
WASTEWATER RECLAMATION

...Water which, as a result of treatment of domestic wastewater, is suitable for a direct beneficial use or a controlled use that would not otherwise occur.[1]

3.0 Introduction

The concept of reclaiming wastewater for non-potable use within urban development is strengthened by the variety of water critical solutions reclamation provides. The reuse of treated effluent for non-potable fixtures currently using potable water satisfies the primary objective of directly reducing potable demand. In select applications, non-potable use of domestic water has accounted for nearly 90% of total building flow. Reusing treated wastewater likewise reduces the amount of wastewater to be disposed of. Wastewater can be recycled and sold by the municipality for substantially less cost than potable water, providing cost savings to both supplier and user. Finally, the exhausted or surplus effluent assimilated by the environment would, in most cases, be of greater quality than if it were treated for disposal alone.

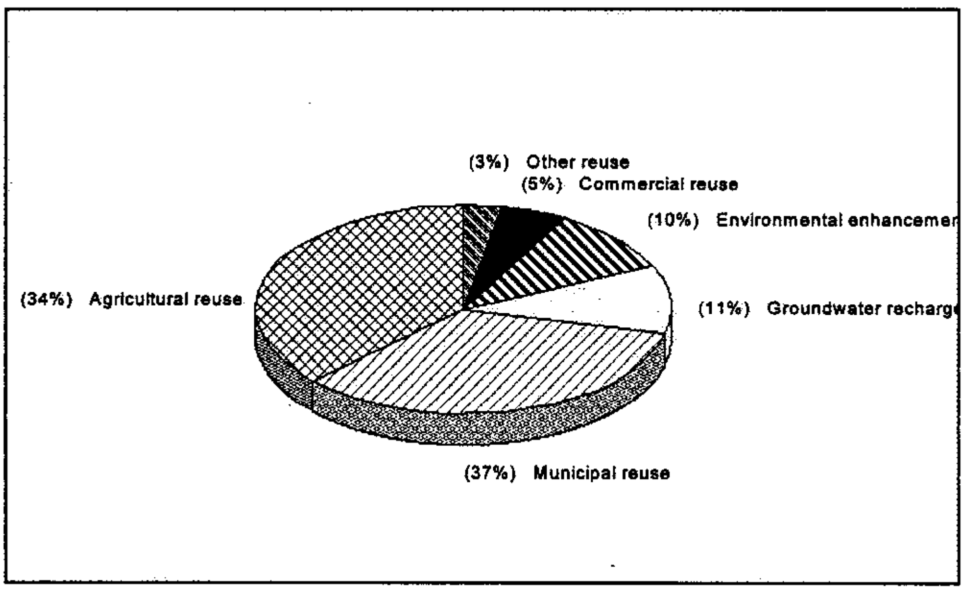


Figure 3.1 1990 Reuse water allocations in the State of Florida.
York, David W. *Reuse in Florida.* Florida Department of Environmental Protection (DEP), 1991.

3.1 Wastewater Flow Mechanics and Recovery

Conventional wastewater collected from both non-fecal and fecal sources alike, such as toilets and urinals, can also be recovered for reuse. Conventional wastewater piping can be implemented for both grey and blackwater recovery if the volume of greywater alone is insufficient to properly maintain a reuse supply and demand balance, or if discharge flow is limited. Commercial structures are commonly characterized by an unbalanced flow of 10-15% greywater supply and 85-90% non-potable demand as demonstrated in Figure 3.2 Therefore recovery of both grey and conventional wastewater for treatment and reuse is required through *Type B* single-stack recovery systems as illustrated in Figure 3.3

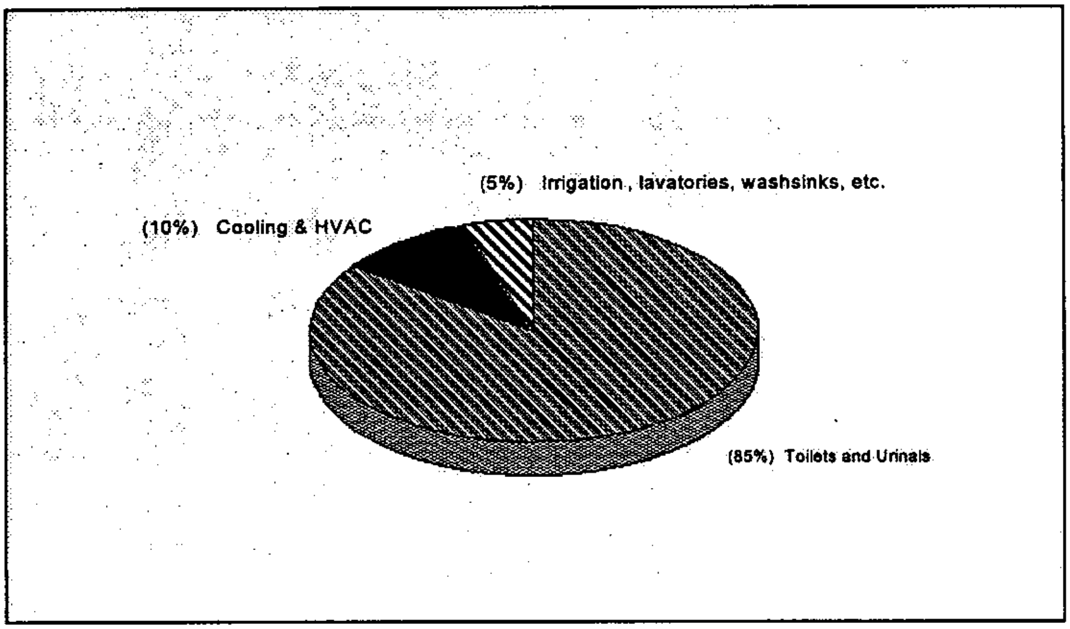


Figure 3.2 Wastewater annual average flow in typical commercial structures.
Assessment of Greywater and Combined Wastewater Treatment and Recycling Systems. PHCC, 1992.

Type B systems as illustrated in Figure 3.3, provide wastewater for recycling and *dual distribution*, yet utilize only a single soil and vent stack. Wastewater from toiletry and greywater fixtures are collected together using a conventional soil stack. The collected wastewater is disposed of into sanitary mains for municipal reclamation and reuse, or diverted to on-site treatment infrastructure. Although the Type B approach requires very little modification and initial cost increase, it requires a substantially greater degree of wastewater treatment.

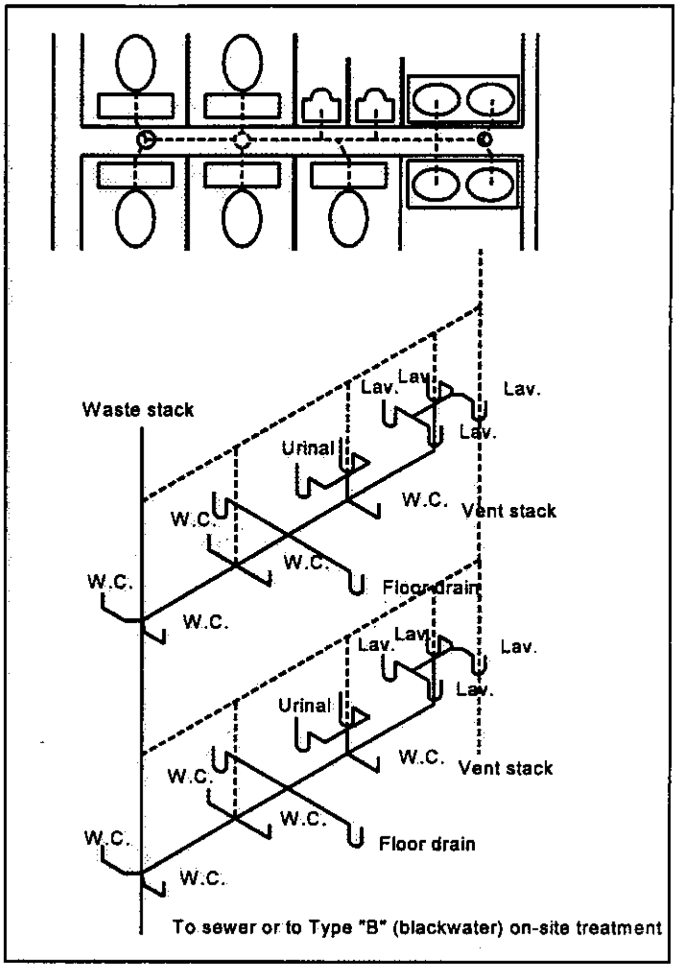


Figure 3.3 Conventional (Type B) wastewater recovery system.
Grosskopf, Kevin R. *Water Reclamation and Reuse Within Multi-Level Structures.* University of Florida, 1993.

The benefits of this approach include lower initial construction costs and the ability to provide adequate non-potable supply equal to the non-potable demand in commercial environments where the balance of greywater alone is far insufficient. A Type "B" system should always require a complete tertiary treatment by either municipal services or on-site treatment. Chemical treatment, filtration, carbon adsorption, and high-level disinfection may be used due to the high level of *biochemical oxygen demand* (BOD) and *Chemical Oxygen Demand* (COD) resulting from the presence of fecal matter.

3.2 Wastewater Treatment and Water Quality Objectives

Two critical elements of reclaimed water quality are treatment and service reliability. Reclaimed water used for unrestricted urban reuse must adhere to *public access quality*, which recognizes the inevitability of direct human contact and possible consumption. Reclaimed water must therefore be safely treated to reduce the potential for bacterial and viral infections as a result of such contact. Reclaimed water of public access quality has been categorized by the American Water Works Association (AWWA) Standard 5531 *Advanced Wastewater Treatment (AWT)*. AWT is characterized by the addition of *tertiary* treatment processes beyond *primary* sedimentation and *secondary* biological treatment.

The primary differences between AWWA 5531 AWT and reclaimed water for restricted or controlled reuse are the concentrations of suspended solids and the level of residual disinfectants. *Total suspended solids (TSS)* are to remain below 5 parts per 1,000,000 (5 ppm). Although *carbon adsorption* is an effective method of solids removal in potable treatment, *sand media filtration* has proven to be a far more cost effective alternative in high volume, non-potable treatment. Pursuant to the *Florida Administrative Code (F.A.C.)* 17-610.460, the application rate of chlorine must be sufficient to maintain 1 mg/L (0.5 ppm) residual at the non-potable fixture, ensuring lasting disinfection under inevitable breakdown from extended storage or continuous cycling.[2]

Reclaimed water for interior and unrestricted exterior applications requires a DEP classified *Class 1 Reliability*. F.A.C. Section 17-610.300 stipulates that class 1 reliability can only be achieved with duplicate units, standby power sources, and continuous on-line monitoring of turbidity and residual disinfectant within the municipal reclamation and *third-main* system.[2] The specification for class 1 reliability accounts for the potential health and safety infrastructure that will most likely function using non-potable water if available. Infrastructure such as sanitary, fire suppression, and HVAC systems require an uninterrupted supply of water for operation. Class 1 reclamation systems must therefore be designed as two separate systems capable of maintaining at least 50% of the daily peak flow each. This *process redundancy* provides duplicate unit systems to maintain treatment reliability in the event that one unit incurs complete failure. Calculated peak demands are supported by a 10-20% *factor of safety (FOS)* for the design of the "twin" treatment and distribution system. Each therefore, maintains the capability to supply 60-70% of peak effluent demand as well as to receive 60-70% of peak influent.

Water failing the suspended solids criteria of AWWA 5531 AWT must be discharged to reject storage for later blending. Pursuant to F.A.C. 17-610.464, the reject water storage capacity must exceed peak wastewater flow for one day.[2] Acceptable effluent is allowed to be circulated back into reuse distribution at the reuse water tank, capable of supplying 3 day peak reuse demand. The only interface between reclamation and potable distribution involves air gap cross-connections that provide potable make-up for evaporation loss or peak demand. The air gap is the only acceptable cross-connection to provide potable make-up without the risk of back flow or siphonage.

3.2.1 *Multiple Barrier Treatment and Processes*

The distinction between potable water and AWT is that potable treatment must provide protection against contaminants that **may** be present while AWT treatment ensures the removal of contaminants that **are** present. This distinction is dictated by economics and safety. Reclaimed water is determined to be safe when used for its intended purpose. To reclaim effluent to levels approaching those of potable treatment would result in a situation whereby reclaimed water, intended to be an economical alternative to potable resources, would cost considerably more.

Multiple barrier designs provide cost effective treatment for unchlorinated secondary effluent. Using redundant pathogen barriers such as lime treatment, ozonation, reverse osmosis, and chlorine disinfection, no one unit process is wholly responsible for the removal of a single physical, chemical, or microbiological contaminant. The multiple barrier system concept as illustrated in Figure 3.7, is consistent with many reuse regulations mandating tertiary or advanced wastewater treatment reliability for on-site non-potable usage. Multiple contaminant barriers provide treatment reliability because failure of one unit process to effectively remove one contaminant of concern does not preclude effective overall treatment. Fortunately, many unit processes act as barriers to remove more than one contaminant category, so the number of unit processes within the treatment train does not become costly.

Table 3.1 Contaminate characterization.
Metcalf & Eddy, Inc. *Wastewater Engineering.* New York: Mc Graw-Hill, 1991.

Contaminates	Reason for importance
Suspended solids	Suspended solids can lead to the development of sludge deposits and anaerobic conditions.
Biodegradable organics	Biodegradable organics are measured primarily in terms of BOD and COD. If distributed within reclaimed water, their biological stabilization can lead to the development of septic conditions.
Pathogens	Communicable diseases can be transmitted by pathogenic organisms in untreated wastewater.
Priority pollutants	Organic and inorganic compounds selected on the basis of their known or suspected carcinogenity or acute toxicity.
Refractory organics	These organics tend to resist conventional methods of reclamation. Typical examples include surfactants, phenols, and agricultural pesticides.

Secondary treatment standards for wastewater are concerned with the removal of biodegradable organics, suspended solids, and pathogens. Many of the more stringent standards that have been developed for unrestricted urban reuse include the additional removal of priority pollutants. Such standards normally include requirements for the removal of refractory organics, heavy metals, and in some cases, dissolved inorganic solids. Table 3.1 identifies important contaminants of concern for wastewater reuse. Untreated wastewater first entering a reclamation system is typically subjected to pre-treatment process that involve the screening of large matter and the settling of heavy grit. *primary* clarification is achieved by adding flocculents to the pre-treated wastewater to suspend smaller particles. Coagulants, coagulant aids or polyelectrolytes can be added prior to primary treatment to bond these particles into clusters for easier particle removal. Filtration, a tertiary process, is used for TSS control. According to F.A.C. Section 17-610, Part III:

> Reclaimed water shall not contain more than 5.0 mg/L of suspended solids prior to the application of the disinfectant.[2]

Secondary treatment is commonly referred to as biological clarification, and involves the removal of organics passing primary clarification. Secondary wastewater treatment, possibly involving grit removal, aeration, and clarification, can result in a 90% reduction in *biochemical oxygen demand (BOD)* and TSS. In this process, the wastewater first enters the resettling chamber where gross solids settle out. The effluent may then flow into an oxygen rich aeration chamber where biological action reduces soluble organics. The BOD identifies the quantity of oxygen required for bacteria to metabolize the degradable organic matter present in the wastewater. Test samples are "loaded" with oxygen and nutrients to create a perfect environment for maximum bacterial metabolization. The amount of oxygen consumed determines the amount of degradable organic matter in the water prior to bacterial enzyme oxidation. *Chemical Oxygen Demand (COD)* tests measure oxygen demands at an accelerated rate by artificially oxidizing the organic matter in the water. This chemical process will oxidize virtually all organic compounds. Often, a BOD to COD ratio is calculated. This allows wastewater reclamation facilities to determine the biodegradability of the organic compounds present. A high ratio approaching "1" indicates a very degradable solute where as a very low ratio approaching "0" indicates less enzyme degradable compounds or compounds foreign to that particular species of bacteria.

Reclaimed water clarity for most reuse applications generally must remain below 2-5 nephelometric turbidity units (NTUs). Turbidity measurement was established as a surrogate for effective removal of pathogenic organisms, including viruses. Direct filtration processes, with the aid of chemical coagulants have proven most effective when the secondary effluent turbidity is 10 NTU or less, as is typical for activated sludge secondary effluents. The EPA maintains that reclaiming trickling filter effluent should involve full flocculation and sedimentation prior to filtration, whereas the activated sludge process mentioned previously, may require only direct filtration for target TSS and turbidity.[3]

Carbon adsorption

Carbon adsorption is a common process often associated with AWT. This tertiary process allows the adsorption of organic and some inorganic compounds associated with undesirable water color and odor which could limit reuse acceptability. The loading capability of the carbon is proportionate to the surface area in relation to its mass. It is estimated that the extremely porous internal structure of granulated and powdered carbon can provide up to several hundred square meters of loading area per gram of mass. Fifteen minutes of "true contact time" with this carbon in gravity fed or pressurized columns is sufficient for fine particle removal. At a given time interval, the granular activated carbon (GAC) and powdered carbon will become exhausted. The granular carbon can either be disposed of in the sludge process (as is powdered carbon) or it can be recharged. Carbon adsorption may be used in place or in combination with filtration and chemical treatment due to the high BOD and COD of fecal matter in most wastewater. The benefit of GAC is the removal of organic chemicals, whether biodegradable, synthetic, or volatile by adsorption. Yet, because the degree of adsorption depends greatly on the nature of the compound, its molecular weight, and its polarity, exact removals cannot be predicted.

Reverse osmosis

Reverse osmosis is characterized by the use of spiral wound polyamide membranes that act as a physical barrier to the passage of pathogens and other extremely fine particles. In addition, this process removes toxic metals, some nitrogen forms, and certain organic compounds. Osmosis allows pure water to move with tremendous hydrodynamic force through a membrane to dilute a contaminated source. The reverse osmotic process is initiated by forcing the solution back through the membrane with sufficient force to overcome the natural osmotic pressure. This process is commonly required to remove chlorides for Ph and salinity control. For example, brackish water requires approximately 400 psi of osmotic pressure to achieve reverse osmosis whereas undiluted saltwater may require pressures in excess of 1000 psi.

Ion exchange

Ion exchangers commonly used in water softeners can be adapted into on-site and municipal service as well if anion and cation pollutants are present. The polymer structure of the basic resin in the exchanger may be positively or negatively charged during fabrication. This process is induced by adding the required opposite charged solution to create a stable loading surface. When the effluent passes through the ion exchanger, the less favored ion is exchanged for the more favored. The less favored ion is then allowed to intercede with the outflow effluent. An ideal example of this process occurs when positively charged hydrogen ions are introduced to the negatively charged polymer resin. Influent wastewater is gravity or forced fed through the exchanging unit. If the water consists of other ions of greater positive charge, the hydrogen is replaced on the polymer resin with that ion. The hydrogen is then allowed to flow out into the effluent.

A common element extracted by ion exchange is calcium. In addition, this process can be reversed by creating a positive polymer field resulting in the extraction of undesirable negative ions. A commonly displaced negative compound by this reversed process is hydroxide. If the positive and negative systems work in tandem, the hydrogen and hydroxide will theoretically bond to yield pure water. Coincidentally, the loading on the resin during ion exchange is similar in concept to that of carbon absorption. Therefore, the resin may also be removed by settling and is subsequently recharged or replaced.

Ozonation

Ozonation is a highly rigorous oxidation process to further alter organic compounds for carbon adsorption and disinfection. Ozone, a highly reactive form of oxygen, can be produced by forcing pure oxygen gas through a strong electromagnetic field called a corona, energized just short of arcing. This process creates the ozone along with very unstable oxygen radicals. This poor bonding possesses a constant tendency to revert back to pure oxygen. Because of this situation, ozone cannot be stored or used as a lasting residual disinfectant. However, ozone is nevertheless a very powerful initial disinfectant. When mixed with water entering the ozonation chamber, the ozone can rapidly disinfect and dissipate. When combined with ultraviolet (UV) light, ozone forms hydroxyl radicals, which have even higher oxidation power. Chemical oxidation with ozone and hydroxyl promoters conditions organics to a state more amenable to removal in subsequent unit processes such as GAC adsorption.

Chlorination

Another popular disinfection processes is the use of chlorine dioxide. Chlorine reacts with water to form hydrochloric and hypochlorous acid. Chlorine disinfectants in reclaimed water could have limitations as well. Chlorine as a residual may deteriorate in as few as seven days, leaving an ideal environment for biological growth. The addition of ammonia into the chlorination process however, allows further oxidation, yielding monochloromine. This compound could provide a very long lasting residual for high recycling applications such as cooling towers and heat exchangers. Yet, concern regarding ammonia's corrosiveness to common piping materials such as true copper and copper alloys, may severely limit this practice. Where chlorine is used for disinfection, a total residual of at least 1.0 mg/L must be maintained after at least 15 minutes contact time at maximum daily flow, or after at least 30 minutes contact time at average daily flow, whichever provides for the higher level of public health protection under F.A.C 17-600.440(5)(f).

Ultraviolet irradiation

Irradiant ultraviolet disinfection has also been in limited use to destroy pathogenic organisms remaining in secondary effluent. This irradiation process uses lamps which emit light waves in the ultraviolet spectrum that effectively destroys any microorganisms in reclaimed wastewater. Although radiation is an effective disinfectant, it is assumed that it could not be implemented alone due to the fact that it cannot provide a residual presence. Irradiation may be used as an economical alternative to reduce contact chlorination time or other more costly antipathogenic processes. Disinfection is normally the final barrier to microbiological organisms. It is most effective at the end of the treatment process where very little suspended solids remain, and oxidant demand has been greatly reduced.

Table 3.2 Florida DEP approved treatment alternatives.
State of Florida. Florida DEP. *1992 Reuse Database.* Tallahassee: 1992.

DEP approved secondary treatment processes:

1)	Anoxic/oxic treatment	2)	Activated sludge
3)	Contact stabilization	4)	Extended aeration
5)	Oxidation ditch	6)	Trickling filter

DEP approved tertiary treatment processes (beyond secondary):

1)	Adsorption	2)	Ammonia stripping
3)	Aluminum precipitation	4)	Air stripping
5)	Breakpoint chlorination	6)	Denitrification
7)	Filtration	8)	Ion exchange
9)	Iron precipitation	10)	Lime precipitation
11)	Metal salt addition	12)	Nitrification-denitrification
13)	Ozone	14)	Precipitation

DEP approved disinfection processes:

1)	Chlorination	2)	Ozonation
3)	Ultraviolet radiation		

Other factors such as constituent nutrients, salinity, and unbalanced pH levels are directly related to scaling, corrosion, biological growth, and fouling of sensitive mechanical equipment and aesthetic impoundments. Excessive nutrient concentrations can cause accelerations in plant and algae growth. Such nutrients important to commercial and residential landscape management include N, P, and occasionally K, Zn, B, and S. The most beneficial and the most frequently excessive nutrient in reclaimed municipal wastewater is nitrogen. However, when such nutrients are present in excess of plant or turf needs, problems associated with delayed or uneven maturity, sporadic growth, and reduced plant quality often occur.

Salinity levels originating or infiltrating into the reclamation system can severely damage landscaping and mechanical equipment using reclaimed water. Sources for wastewater salinity include piping infiltration and inflow (I/I) from underlain salt water, discharges from industrial brine sources, and discharges from regenerative water softeners (RWS). The generally accepted norm for chloride concentrations in domestic wastewater varies from 100-140 mg/L although salinity readings along Florida's coastline may reach 2400 mg/L. The costs for effective chloride removal can exceed $800.00/lb. A more cost effective approach is to remove brine discharge sources and incorporate slip or inversion lining to reduce 90% of the chlorides from entering the system.

The following summarizes reliability requirements (below) and suggested treatment processes (Table 3.3)

Table 3.3 Summary of reclamation processes for varying reuse water quality objectives.
Grosskopf, Kevin R. *Water Reclamation and Reuse Within Multi-Level Structures. University of Florida: 1993*

Water Quality Objective	Potential Reclamation Process
Oxidation of BOD	Biological processes: biotowers and activated sludge. Activated sludge is more versatile for varying reclamation objectives.
Removal of turbidity in suspended solids (SS)	Coagulation, flocculation, and filtration. Aluminum and polymer addition is mandatory.
Removal of coliforms (and therefore pathogens)	Disinfection using chlorine. Detention time may vary based on desired coliform count.
Oxidation of ammonia	Biological processes: biotowers, and activated sludge. BOD and ammonia oxidation can be combined in one process.
Removal of magnesium, silica, carbonate hardness, organics, and disinfection	Lime treatment, pH of 11.0+. Enhanced efficiency in HVAC units by reduced scaling.
Removal of non-carbonate hardness	Lime soda ash treatment.
Removal of additional calcium carbonate or pH adjustment	Recarbonation. Increased cycle efficiency in cooling towers by removing calcium scale.
Removal of organics, TDS and bacteria	Reverse osmosis. Increases the acceptability of commercial and residential reuse by further reducing biofouling and chloride corrosion.
Nutrient removal (N & P)	Reverse osmosis in conjunction with chemical precipitation. Required for urban

necessary to achieve American Water Works Association (AWWA) Standard 5531 water quality objectives.

1. Minimum secondary treatment level with filtration and chemical feed, maximum TSS of 5 mg/L.

2. High level disinfection, with no fecal coliforms exceeding 25 ppm.

3.4 References

1. State of California. Irvine Ranch Water Management District. *Rules and Regulations for Water, Sewer, and Reclaimed Water Service.* Irvine: 1988.

2. State of Florida. Florida Department of Environmental Protection. *Florida Administrative Code Section 17-610, Part III.* Tallahassee: 1990.

3. United States. Environmental Protection Agency. *Municipal Wastewater Reuse.* Washington D.C.:1991.

or 30 minutes at average daily flow be provided to ensure an adequate chlorine residual of 0.5 ppm at the point of reuse. In the event of a malfunction within the on-site process, it is proposed that the waste effluent to be treated could be disposed of into the sanitary sewer or leach field. Potable water using an air gap cross-connection would be implemented for make-up, provided that sufficient non-potable reserves had not been stored prior. Typical water quality achieved is *biochemical oxygen demand* BOD and *total suspended solids* TSS less than or equal to 5mg/L, turbidity under 0.5 NTU, and total coliform less than 2.2/100mL.

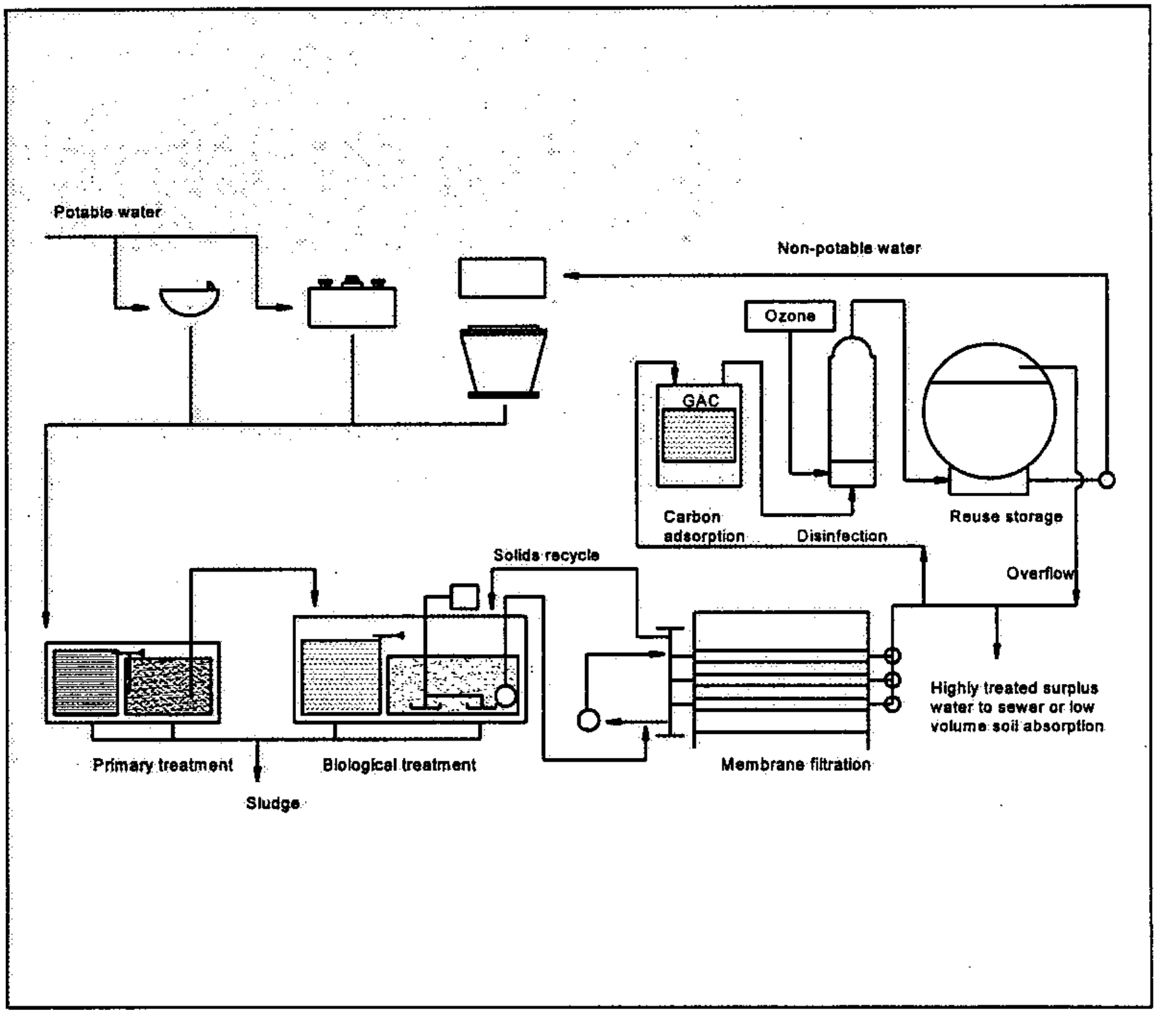


Figure 3.4 On-site reclamation schematic for conventional wastewater treatment and non-potable reuse.
Thetford Systems, Inc. *Cycle-Let Greywater Treatment*. Thetford Systems, 1986.

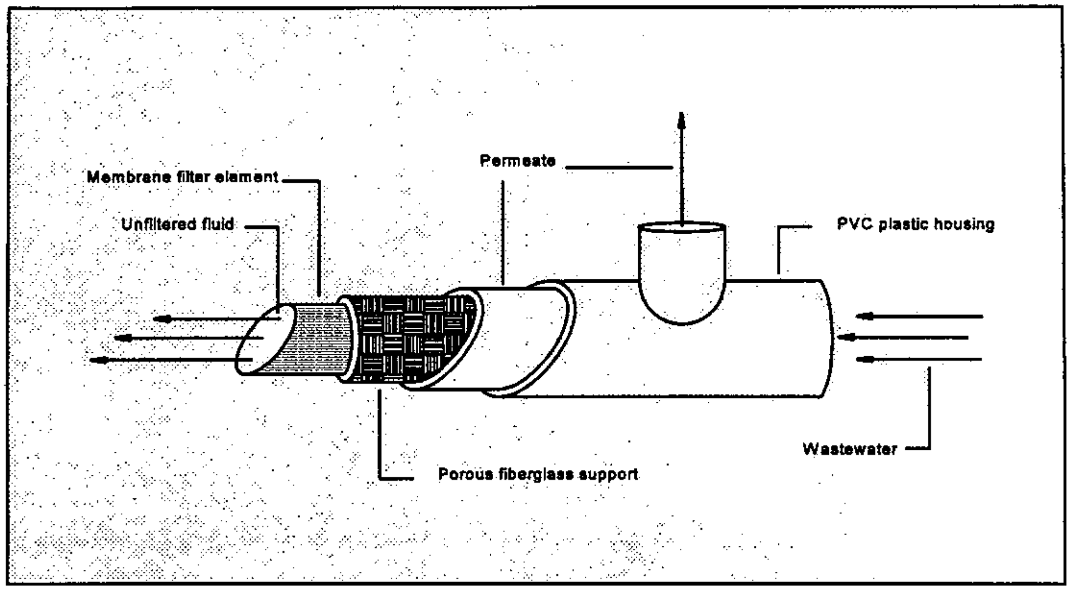


Figure 3.5 Thetford Cyclet-Let ultra-filtration process.
Tilley, Ray D. *Reclaimed Resources.* Architecture: December 1990.

Due to their location, odor control and visual aesthetics require design integration for on-site reclamation. Color and odor may also be apparent in reclaimed water as a result of its initial source, the quality of blending water, or the presence of constituents caused by infiltration and inflow. Because of this, continuous monitoring and maintenance should be provided on-site to treat the discolorment and odor that may be associated with reuse effluent. Reclaimed water for non-potable use is often heavily chlorinated to provide an extended residual disinfectant for possible storage or continuous cycling. Therefore, an effluent chlorinated to 10+ ppm retains a slight chlorine odor. Odor control may be accomplished in both liquid and vapor phases. Ferrous chloride fed to the influent sewer precipitates hydrogen sulfide. Caustic impregnated activated carbon is used to adsorb odorous elements from the enclosed primary aeration basins.

The normal range of effluent clarity is quantified between 15 and 25 color units. However, emergency borrow reserves for municipally supplied effluent in times of drought can elevate the color unit count to 114+ and above, resulting in an undesirable appearance. The installation of a GAC filtration system, similar to those used for potable clarity, may reduce color units to approximately 8 or less. Dying the reclaimed effluent an aesthetically pleasing shade of blue may also provide added user acceptability as well as serving as an additional safety measure to help distinguish non-potable water from potable water in the event of accidental cross-connection.

The following are calculations which are used to determine commercial building flows with the *Thetford Cycle-Let System*™ using 6.0 gpm and 4.0 gpm toiletry and urinal flush valve fixtures respectively. The example provided applies to a 100,000 square foot office building consisting of 50% males and 50% females.

Occupancy:	100,000 sf / 200 sf/person = 500 occupants
Usage:	500 x 3 toilet/urinal uses/day/person = 1,500 flushes
Toilet/Urinal Flow:	Males use urinal 76% of usage
	Males use toilets 24% of usage
	Females use toilets 100% of usage
Blackwater flow:	
	(76% of use) x (50% males) x (4 g/flush) urinal x (1,500 total flushes) = 2,340 gpd
	(24% of use) x (50% males) x (6 g/flush) toilet x (1,500 total flushes) = 2,160 gpd
	(100% of use) x (50% females) x (6 g/flush) toilet x (1,500 total flushes) = 4,500 gpd
Blackwater flow:	= 9,000 gpd
Greywater flow:	Lavatories, sinks, washdown (2 gpd/person) = 1,000 gpd
Combined conventional wastewater flow:	= 10,000 gpd
Blackwater conserved with Cycle-Let:	9,000 gpd
Greywater conserved with Cycle-Let:	500 gpd
Total:	9,500 gpd
Total wastewater discharge using Cycle-Let:	500 gpd
Maximum domestic water savings per year:	1,443,870 gpd
Maximum wastewater reduction per year:	2,470,000 gal
Cycle-Let discharge quality:	BOD < 5mg/L
	TSS < 5mg/L
	Total coliform < 2.2/100 ml
Treatment fee per month:	$1,900.00/ month at start-up
Space requirement:	1000 SF
Estimated power usage:	77,000 KWH/YR
Estimated sludge volume:	7,000 GAL/YR

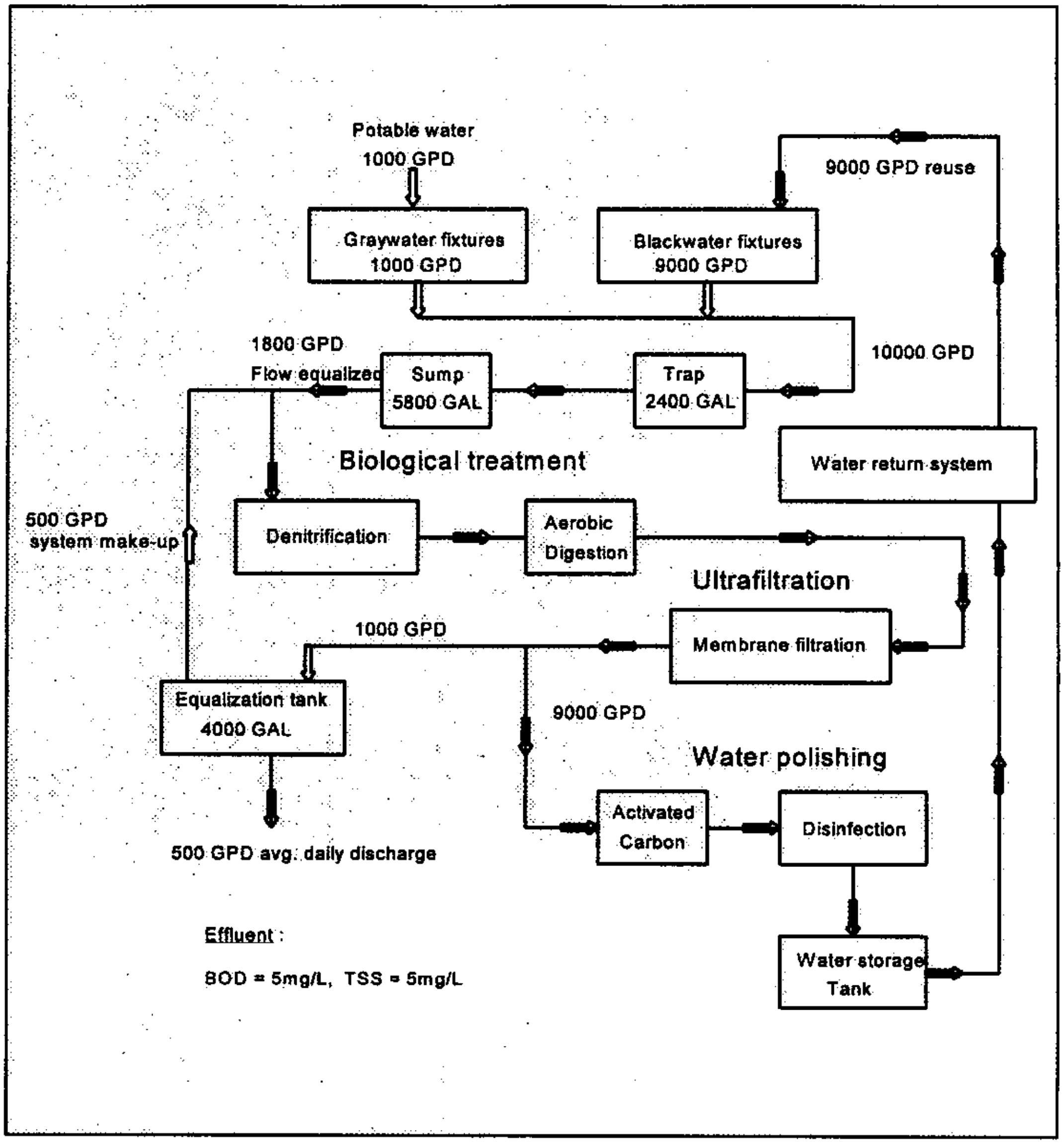


Figure 3.6 Cycle-Let wastewater flow diagram.
Thetford Systems, Inc. *Cycle-Let Greywater Treatment*. Thetford Systems, 1986.

The following data has been compiled based on commercial applications using a fixed variable of 200 square feet per person (SF/PP). The analysis considers commercial structures 20,000 SF to 500,000 SF of gross floor area, implementing blackwater treatment and achieving less than 5% discharge balance.

Table 3.4 Cycle-Let on-site wastewater reclamation flow diagram.
Thetford Systems, Inc. *Cycle-Let Greywater Treatment*. Thetford Systems, 1986.

Building size SF	Population served 200 SF/PP	Conventional discharge GPD	Cycle-Let discharge GPD	Wastewater recycling $/month	Space Req. SF
20,000	100	2,000	86	$1,300	600
40,000	200	4,000	172	$1,400	800
60,000	300	6,000	257	$1,600	800
100,000	500	10,000	500	$1,900	1,000
200,000	1,000	20,000	858	$2,500	1,200
300,000	1,500	30,000	1,287	$3,900	1,600
400,000	2,000	40,000	1,716	$4,800	2,000
500,000	2,500	50,000	2,145	$6,000	2,000

3.2.3 *Municipal Wastewater Reclamation*

Reclamation plants may differ from typical treatment facilities, which are primarily designed for minimal cost treatment and discharge. First, the location of the reclamation plant should be situated within the proximity of potential markets rather than the area's service topography and discharge site. The sludge or surplus influent received or produced at a reclamation plant may be returned to the sewer for treatment and discharge or composting at another facility. The amount of influent wastewater treated at the reclamation facility should balance the demand for reclaimed water. The effluent is a marketable resource and should be treated as such. Reclamation facilities should maintain the flexibility to modify wastewater recovery, treatment, and distribution processes in response to future changes in raw water quality, demographics, and regulatory requirements.

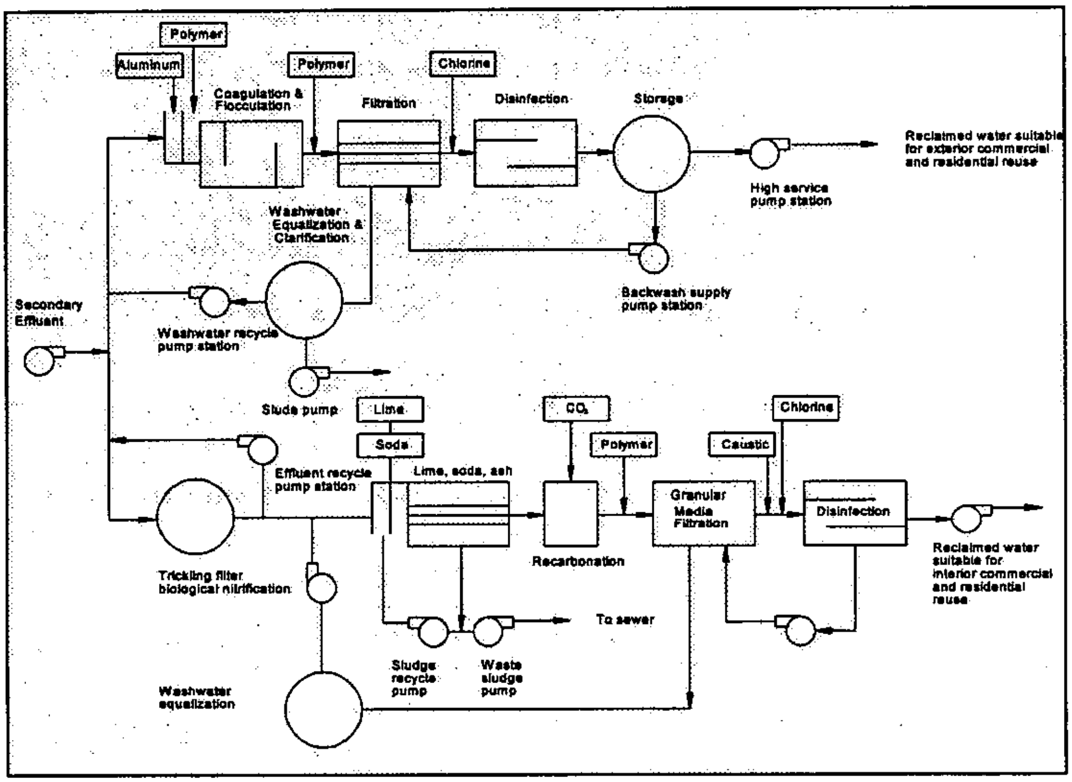


Figure 3.7 Full-scale municipal reclamation facility using multiple pathogen barrier design.
Grosskopf, Kevin R. *Water Reclamation and Reuse Within Multi-Level Structures*. University of Florida, 1993.

3.3 Summary

The reuse of reclaimed domestic wastewater for non-potable applications in urban environments has accounted for nearly 70%-90% water and wastewater flow reductions in limited situations. *Direct use* of reclaimed water applies to the reuse of recycled domestic wastewater through an enclosed loop or municipal *third-main* system. *Indirect use* of reclaimed resources consists of environmental enhancements, groundwater infiltration, and deep well injection for groundwater recharge and reuse. Unlike greywater recycling, reclamation benefits from high volume discharges, total wastewater recovery and a centralized treatment and re-distribution network serving several users. In commercial buildings, the total reclamation of wastewater is necessary to meet the peak demands of sanitary fixtures and other mechanical systems. Wastewater reclamation implements conventional sanitary systems without the need for separate or *dual-recovery* piping arrangement commonly associated with greywater reuse.

Although more energy intensive than greywater recycling, wastewater reclamation allows much greater control utilizing *multiple barrier treatment* in which several contaminate and pathogen barriers are in place so that failure of one unit process does not preclude the systems from providing effective overall reclamation. This process redundancy allows the reclamation effort to reclaim secondary wastewater to *advanced wastewater treatment (AWT)* quality for safe and reliable interior non-potable demands. The balance of reclaimed water may be used for lower priority applications such as irrigation, indirect groundwater recharge, or environmental enhancement. AWT processes also are effective for the removal of excessive nutrients and refractory organics, chlorides, suspended solids, heavy metals, and dissolved inorganics which may foul fixtures or systems implementing non-potable resources. Reclaimed wastewater is a far more environmentally amenable discharge solution that simultaneously reduces potable demands and further resource overdraft and waste assimilation.

Reclaimed water is a marketable resource. Public reuse of reclaimed wastewater and its inevitable release of highly treated effluent safely into the environment has proven the most effective method for sustaining domestic water resources.

3.4 References

1. State of California. Irvine Ranch Water Management District. *Rules and Regulations for Water, Sewer, and Reclaimed Water Service.* Irvine: 1988.

2. State of Florida. Florida Department of Environmental Protection. *Florida Administrative Code Section 17-610, Part III.* Tallahassee: 1990.

3. United States. Environmental Protection Agency. *Municipal Wastewater Reuse.* Washington D.C.:1991.

CHAPTER 4
DUAL DISTRIBUTION MECHANICS AND GUIDELINES

4.0 Introduction

Dual distribution refers to the simultaneous water supply to both potable and non-potable fixtures alike. For greywater recycling and re-distribution, this process is simplified by a limited number and variety of on-site reuse applications. Municipal systems serving urbanized regions employ a far more sophisticated and immense infrastructure providing 100 MGD or more.

4.1 Infrastructure

Wastewater treated at a municipal reclamation facility is distributed by what is commonly referred to as a *third-main*, in addition to domestic and sanitary mains. Municipal third-main infrastructure consisting of at least 1.0 MGD capacity, accounts for over 96% of the total 320 MGD reuse flow in the State of Florida.[1] Third-mains consist of color coded ductile iron usually 2.5"-36" of inner diameter depending on flow designations. Mains supplying reclaimed water are commonly tagged a standardized color of purple. In addition to material differences and signatured labels, this color coding avoids confusion between potable (blue) and sanitary (green) mains. The pressure in the third-main is maintained at least 10 psi lower than domestic mains to prevent backflow and siphonage in the event of accidental *cross-connections*. By definition, non-potable water is not safe for human consumption. Therefore, it is imperative that third-main infrastructure minimize, if not eliminate, the potential for uncontrolled access and misuse. If potable water make-up or emergency pressure is required for non-potable mains, an American Water Works Association (AWWA) air gap type cross-connection should be employed at either the reclamation facility or at the individual pumping stations. Such direct cross-connections should provide a minimum *air gap* (AG) separation equivalent to double the diameter of the supply pipe, measured vertically from the flood rim of the receiving vessel to the supply pipe. AWWA approved air gaps should maintain a minimum 1" separation and should be entirely visible, providing reasonable clearance from obstructions. Although direct cross-connections have proven effective by using pressure differentials and back flow prevention devices, it is the expressed opinion of this investigation that no direct cross-connections other than AWWA approved air gap connections shall exist.

A typical reclamation network must establish pumping stations along the third-main to provide a constant controlled pressure of approximately 70 psi, or at least 10 psi lower than the parallel potable supply. It is proposed that such reuse mains and service laterals should be constructed at a minimum of 36 inches below finished street grade, and should consist of ductile iron, polybutylene or polyvinylchloride (PVC) in minimal pressure applications. A typical reuse service to the commercial or residential user may consist of a color coded 2.5"-8" sub-main, depending on building flow requirements and the TDL. The minimum separation between potable water mains and non-potable water mains should be no less than three feet horizontally and no less than one foot vertically.

> Maximum obtainable separation of reclaimed water lines and domestic water lines should be practiced. A minimum horizontal separation of five feet (center to center) or three feet (outside to outside), shall be maintained between reclaimed lines and either potable water mains or sewage collection lines.[2]

Water services containing meter pits must allow for minimum piping and *maximum obtainable separation distances* between potable and non-potable sub-mains. No reclaimed service may be placed within the same meter pit or above grade enclosure as the potable service. Therefore, a *double meter separation layout* is recommended for third-main distribution at the user connection. This concept as illustrated in Figure 4.1, provides efficient dual distribution while maintaining maximum obtainable separation distances as specified by FAC 17-610.470.3. Meter pits or enclosures containing reclaimed water service must additionally be identified with warning signatures stating "Reclaimed Water" or "Reuse Water: Do Not Drink".

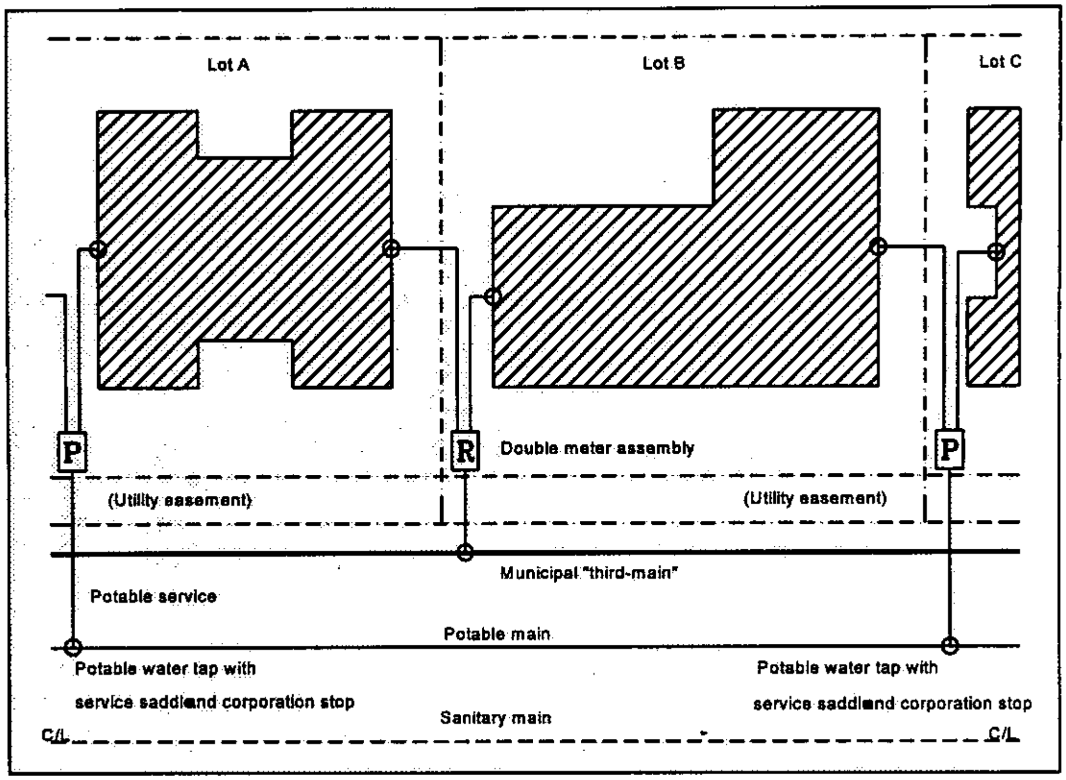


Figure 4.1 Typical site plan for double meter separation layout. Grosskopf, Kevin R. *Water Reclamation and Reuse Within Multi-Level Structures.* University of Florida, 1993.

To eliminate the possibility of back siphonage of reclaimed effluent into domestic lines, back-flow prevention devices must be located on each potable service to the individual user. The service integration between the municipal supply and on-site user is identified as the most probable location for accidental cross-connections to occur. It is therefore recommended that a *double check valve assembly* (DC) separated by a positive shut-off key coupling valve within the meter assembly be implemented on all potable water sources in accordance with F.A.C 17-640. A double check valve assembly or reduced pressure principle backflow prevention device (RP) should as a minimum, fully conform to AWWA Standard C506-78 (R83).

A double check valve assembly should be located as close to the user's connection and should be installed above grade if possible, and in a manner readily accessible for testing and maintenance. It is recommended that check valves and backflow prevention devices be excluded from non-potable mains in an effort to further reduce similarities between the two, unless on-site exposures would impact the quality of the non-potable supply. Quick coupling valves used on reclaimed water services should be operated only by a key with an ACME thread. This thread should only be implemented on reclaimed lines, providing further differentiation. It is recommended that *pressure relief valves* (PRV) and flow regulating globe valves be implemented on all non-potable services to adequately reduce the incoming pressure and regulate flow to the commercial or residential user. Many existing and proposed third-mains are currently designed for wash-down, irrigation and other low priority, low reliability reuse alternatives. For this reason, there exists the potential for pressure fluctuations and flow irregularities during systems start-up.

A fixed pressure indication device should be employed on the non-potable line to register the maximum pressure exerted on the user's dual distribution system by the municipal third-main. Such a device should be installed down-line from the meter assembly to provide untampered indications resulting from the supply side pressure, and not from the user or the meter assembly itself. Strainers should be required at the point of connection or at the user's meter. Strainers may be installed either before or after the meter and are generally the same size as the service line. Strainers installed before the meter will protect the meter assembly as well as the on-site distribution system. Wye strainers are generally accepted for above ground applications and basket strainers may be suitable for both grade and subgrade use. Filter strainers may be applied for specialty applications such drip irrigation and should be located at grade or above. Strainers of 20 to 80 mesh may be considered adequate. Either an in-line type or end-of-line type blow-off or drain assembly should be installed for removing water or sediment from the pipe. The line tap for the assembly should be no closer than 18 inches to a valve, coupling, joint, or fitting unless it is at the end of the line. If there are restrictions on discharge runoff, the regulatory agency should be consulted to find a suitable alternative.[3]

The following third-main distribution and backflow prevention requirements are summarized below and in Table 4.1.

1. The minimum depth for the top of the pipe should be not less than 36 inches below finished street grade.

2. The minimum horizontal separation between non-potable water lines and potable water lines should be no less than five feet (center to center) and three feet (outside to outside). Vertical separation should be one foot.

3. Strainers are required at the point of connection and/or user's meter. Strainers of 20 to 80 grid per square inch are deemed acceptable. Strainers may be installed either before or after the meter and are generally the same size as the non-potable line.

4. All reclaimed water lines, valves, pumps, and appurtenances are to be painted a standardized color of purple and are to be properly identified as "Reclaimed Water" or "Reuse Water: Do Not Drink".

5. Cross-connections between potable supplies are prohibited unless air-gap separation is provided. Back flow prevention devices such as an approved dual check valve assembly are to be required on all potable water sources.

Table 4.1 Backflow prevention per degree of hazard.
State of California. *Regulations for Reclaimed Water*. Irvine: 1988.

Degree of Hazard	Minimum Type of Backflow Prevention
1) Premises where the domestic water system is used to supplement the reclaimed water supply.	AG
2) Premises where there are wastewater pumping and/or on-site treatment plants and there is no inter-connection with the potable water system.	AG/RP
3) Premises where there are subsurface or spray irrigation systems into which fertilizers, herbicides or pesticides are, or can be, injected.	RP
4) Premises where interior non-potable systems are directly supplied from the domestic reserves and not interconnected with on-site reclaimed distribution.	DC
5) Premises where interior non-potable systems are directly supplied by reclaimed effluent, using domestic supplies for make-up.	AG/RP
6) Premises where entry is restricted so that inspections for cross-connections cannot be made with sufficient frequency, or premises where a repeated history cross-connections has been established or re-established.	RP

4.2 Dual Distribution

Building developments in urban environments offer the preferred characteristics for *dual distribution.* Dual distribution can be characterized as plumbing systems supplying both potable and non-potable water to a variety of fixtures throughout the building. Quantitatively, non-potable reuse results in an equivalent reduction in potable consumption. Given its properties, year round demand, and its relative independence from climatic influences, urban reuse is a more dependable and consistent form of resource optimization than other water conservation alternatives. Urban structures offer vast potential for dual distribution construction, given that these structures all possess similar base characteristics. One such characteristic, is the concept of *back-to-back* plumbing design. This concept achieves required potable flow and wastewater collection by eliminating unnecessary, costly piping. Serviced by central utility cores, plumb-walls, and high occupant densities, the TDLs of water and wastewater piping are greatly reduced.

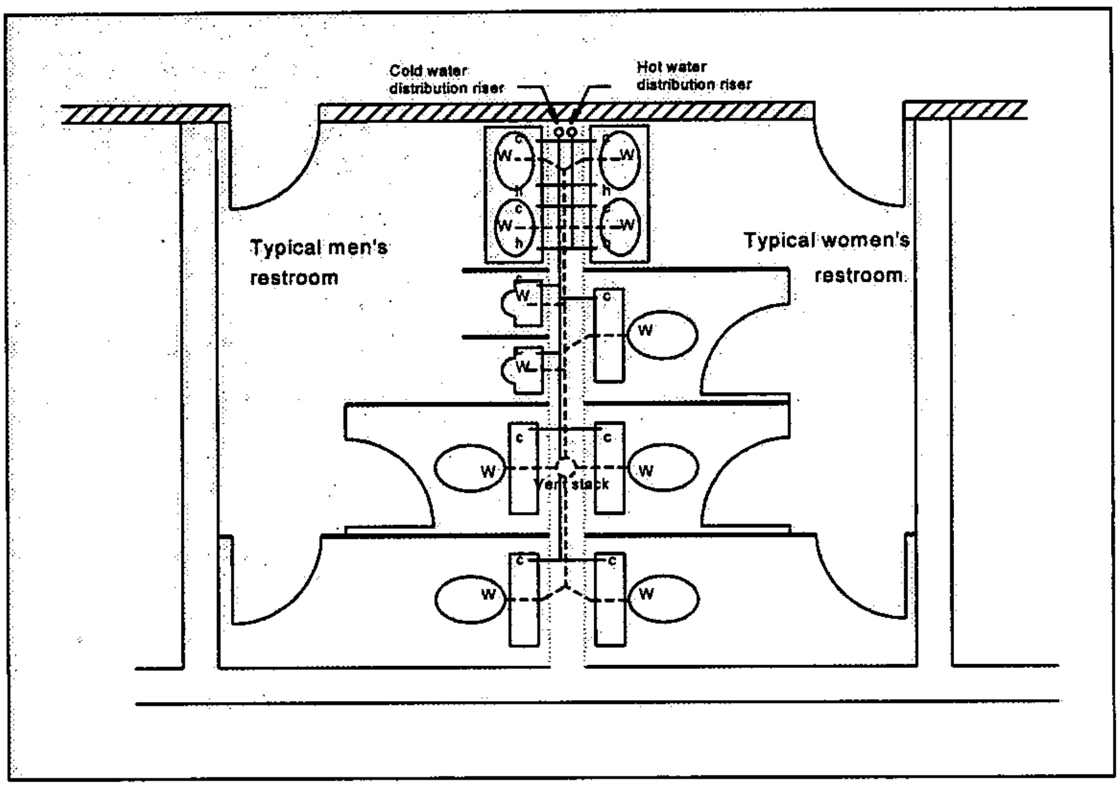


Figure 4.2 Proposed back-to-back structural and piping layout. Grosskopf, Kevin R. *Water Reclamation and Reuse Within Multi-Level Structures.* University of Florida: 1993

If excessive building height restricts direct piping to each non-potable fixture or single reuse zone, reclaimed water must then be pumped at intermittent elevations to a series of gravity fed distribution reserves or to tankless pumping systems at each zone (Figure 4.3). Such reuse distribution pumps most commonly would be located following the municipal supply entrance on the user's side of the non-potable meter assembly. A combination of types and sizes of dual distribution pumping and non-potable zoning may be implemented depending on peak demand, type of zoning, and building designation. Reuse water systems would likewise be required to handle the peak demands, static head, and frictional resistance of vertical, densely occupied buildings common in urban environments. The *Standard Plumbing Code* requires water service to provide at least 15 psi to the farthest fixture within each zone. Considering a pressure gain of 0.433 psi per foot head neglecting pipe friction, volumes of reuse water could be stored at predetermined elevations or zones to accommodate 15 psi pressure and 3-40 gpm flow (Table 4.2).

Table 4.2 Minimum requirements for fixtures using reclaimed water. Grosskopf, Kevin R. *Water Reclamation and Reuse Within Multi-Level Structures.* University of Florida, 1993.

Type of non-potable fixture	Pipe size (inches)	Pressure (psi)	Flow rate (gpm)
Urinal (flush tank)	½	15	3
Urinal (direct flush valve)	3/4	15	15
Water closet (flush tank)	½	15	3
Water closet (direct flush valve)	1	10-20	15-40

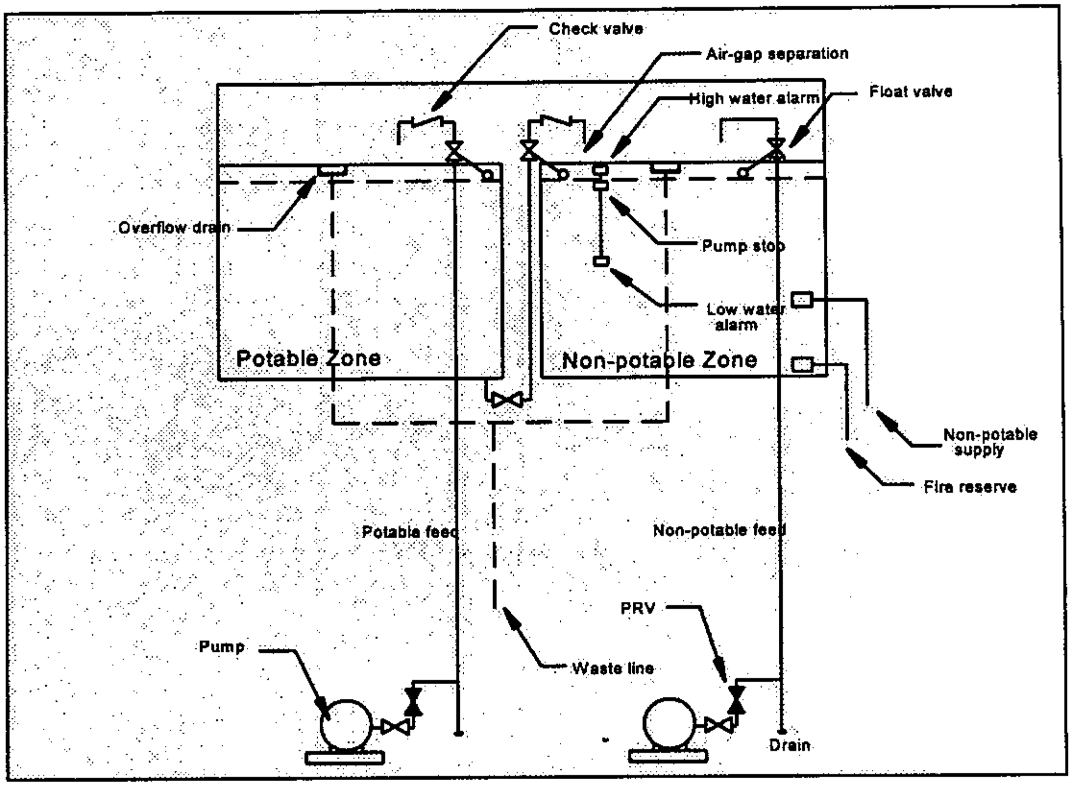


Figure 4.3 Gravity fed dual distribution schematic.
Grosskopf, Kevin R. *Water Reclamation and Reuse Within Multi-Level Structures.* University of Florida, 1993.

Special provisions should be incorporated for pumping facilities distributing non-potable water to identify the type of water handled, provide back-flow protection, provide for appropriate drainage of packing seal water, and prevent the release of non-potable water in an uncontrolled manner. When using potable water as seal water for non-potable water pumps, seals should be adequately protected from back-flow. To prevent damage such as broken pipes resulting from water hammer and pressure surges, all pumping systems should have appropriate surge protection. AWWA approved air gaps must be provided to protect the potable zone from back siphonage if such potable supply is required for emergency make-up to the non-potable zone.

Non-potable distribution, as potable distribution, must achieve general design requirements for both flow and pressure to operate respective fixtures within commercial and multi-tenant residential design. In accordance with the Standard Plumbing Code, the following data is provided for the safe and efficient use of standard non-potable fixtures implementing reclaimed effluent:

1. A group of not more than two fixtures shall be connected to a ½" reuse water supply.

2. A minimum service pressure at the point of discharge shall not be less than 8 psi for all fixtures except direct flush valves, for which it shall not be less than 15 psi.

3. When a booster pump is used and the possibility exists that a pressure of less than 5 psi or less may occur on the suction side of the pump, a low pressure cut-off shall be installed to prevent the creation of negative pressures on the suction side of the distribution system.

4. When the municipal supply has a wide fluctuation in pressure, the distribution system shall be designed for minimum pressure available.

5. Pipe installations shall be adequately protected from water hammer by use of air chambers or other approved devices.[4]

4.3 Permitting and Approval

DEP is primarily responsible for enforcing the Florida Statute (F.S.) and Florida Administrative Code (F.A.C.) regarding environmental issues, including water reuse and dual distribution provisions. Although DEP reserves the right to permit reclaimed water treatment, reliability, and dual distribution under F.A.C. 17-600 and 17-610 respectively, the continued monitoring and cross-connection control is delegated to the individual Water Management Districts. According to F.A.C. 17-610.490 (Appendix III), DEP will normally issue a single permit for the potential reuse system to either the wastewater management facility or the individual water management district. Regulation and management of the reuse consumer will be the principal responsibility of such management entities through binding agreements with the individual user or by local building ordinance. DEP will not issue individual permits for the use of reclaimed effluent to individual property owners.[5] Once the district permit is issued, a "case by case" determination is conducted by the municipality to ensure that all proposed reuse applications meet DEP and Health and Rehabilitative Services (HRS) requirements.

4.4 Testing and Maintenance

Prior to building occupancy, the on-site dual distribution system must be filled, pressurized, and operated with potable water using the air-gap potable make-up system employed at each gravity fed zone or pumping station. Both the potable and reclaimed risers within the building should be equipped with a manual drain and an air/vacuum check valve (Figure 4.4) which will allow both backflow protection under normal operations and riser drainage for inspection and maintenance.

For cross-connection and tamper protection, the reclaimed water riser should be drained annually in the presence of both the building superintendent and the water management official. Once the reclaimed water riser has been completely drained, the official should check each non-potable fixture using reclaimed effluent by flushing toilets and opening reuse valves to verify that potable cross-connections do not supply such non-potable fixtures within the dual distribution system. The potable system should likewise be drained and checked for flow. After both systems are completely drained and no cross-connection have proven to exist, the dual distribution system may be returned to normal operation.

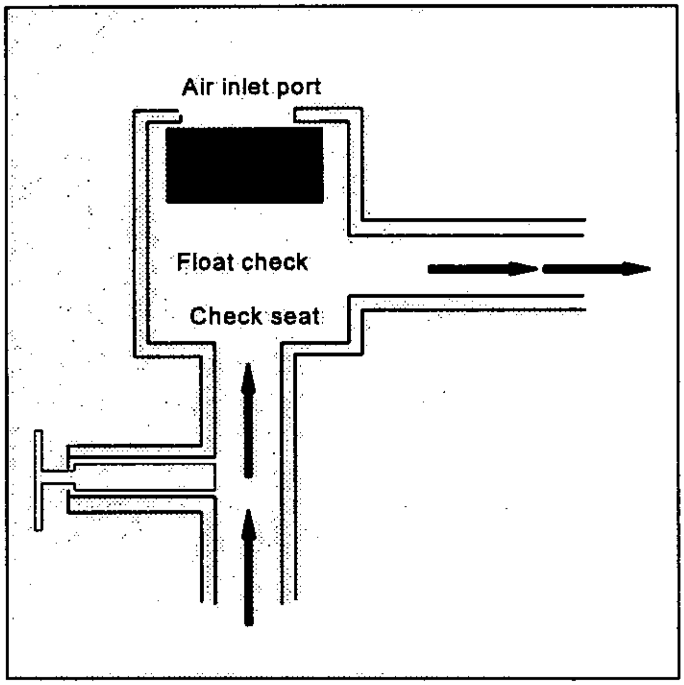


Figure 4.4 Typical air-vacuum check valve. Mueller, Jerome F. *Plumbing Design and Installation Details*. Mc Graw-Hill, 1987.

If any flow is detected from a fixture while that system is depressurized, a cross-connection should be presumed to exist. A predetermined water management plan should then be implemented to immediately remove the dual distribution system from service until the cross-connection or other source of flow is offline and the potable lines are adequately flushed and tested. The course of action listed on the following page is suggested in the event of accidental cross-connection.

1. Shut down the reclaimed water to the building at the meter and drain the reclaimed water riser.

2. Shut down the potable water to the building at the meter.

3. Notify of both state and county health officials immediately, followed by a written notice within 24 hours.

4. Uncover and disconnect cross-connection(s).

5. Shock the potable water system with 50 ppm of chlorine for a minimum of 24 hours.

6. Flush the potable system after 24 hours to perform standard bacteriological testing. If test results are acceptable, recharge the potable water system in accordance with water management standards.

7. Re-test the dual distribution systems by depressurizing both potable and non-potable risers to ensure all cross-connections have been removed.

8. Obtain final approval from state and county health officials to put the dual distribution system back on line.

Backflow prevention devices should also be tested annually, or more frequently if deemed necessary by the health agency or water supplier. Backflow preventers should be tested immediately after they are installed, relocated or repaired, and not placed in service until fully functional. Reports of cross-connection control and backflow testing should be maintained by the water supplier for a minimum of three years (Appendix III). In addition to the detailed annual cross-connection and backflow control inspections described herein, periodic monitoring of all buildings implementing dual distribution is recommended. This should consist of, as a minimum, visual inspection of pump rooms, pressure reducing stations, all bathrooms, signs, tags, valves, and any other reuse appurtenances. Other elements of the periodic monitoring program may consist of, but are not limited to:

1. Random water sample tests on both the reclaimed and potable supply.

2 Visual repairs which may indicate unauthorized alterations of the dual distribution system.

3. Presence of broken seals or unauthorized access into central utility cores, chases, or other interstitial spaces that may indicate unauthorized alterations of the dual distribution system.

4. Questioning on-site maintenance personnel to verify the existence of "routine" operations or maintenance on the dual distribution system.

4.5 Summary

Dual distribution mechanics are most suitable under the following conditions:

Large point loads
Buildings supporting a vertical density of occupants can benefit from reuse distribution serving the most potential users with the least retrofit and dual distribution.

Central utility cores
In a high-rise building utilities arenormally placed in a central utility core. This allows reclaimed water fixtures to be supplied by a common riser while separating potable water from the non-potable supply.

Primarily occupied by adults
Because the user of reclaimed water for non-potable applications is required to be aware of the use of reclaimed water, a building which is primarily occupied by adults is desirable so that warning signs and user directions may be facilitated.

Controlled access to plumbing
Accidental cross connections occur most frequently where unrestricted access is given to a user who is uneducated or unfamiliar with the system.

Designated maintenance staff
Normally, high-rise buildings have centralized maintenance staffs representing a single point of control of the system by building management for inspections and repairs.

Table 4.3 Type "A" and Type "B" dual distribution systems analysis.
Lehr, Valentine. *Greywater Systems.* Heating, Piping, Air Conditioning. January: 1987.

System	Piping	Treatment	Reuse applications	Water savings	Sewage Reduction
Conventional Base	None	N/A	0		0
Type A	Dual distribution Dual waste recovery	Filtration Adsorption Chlorination	Water closets 10,000 GPD Irrigation	 17% * 22%	20,000 GPD 26%
Type B	Dual distribution Single waste recovery	Biological/chemical Filtration Adsorption Chlorination	Water closets 35,000 GPD Cooling/HVAC Irrigation	 30% * 38%	35,000 GPD 46%

* With irrigation

Table 4.3 above identifies the results of comparisons between both *Type A* greywater recovery and *Type B* conventional wastewater recovery using on-site reclamation and dual-distribution in identical urban residential buildings. Although the Type B approach generally would be better suited in a commercial environment where the reclamation of the total wastewater flow would be required to equalize the non-potable demand, it nevertheless provides a 46% sewage reduction and a 38% domestic water savings compared to 26% and 22% for the Type A system respectively.

4.6 References

1. York, W. Ph.D., P.E. Florida Department of Environmental Protection. *Reuse in Florida.* Tallahassee: 1991.

2. State of Florida. Florida Department of Environmental Protection. *Florida Administrative Code: Section 17-610, Part III.* Tallahassee: 1990.

3. American Water Works Association. *Guidelines for the Distribution of Non-potable Water.* Denver: AWWA 1991.

4. Shannon, Daniel J. *Multipurpose Wastewater Reuse.* Journal WPCF Vol. 3, p.58: 1991.

5. State of Florida. Florida Department of Environmental Regulation. *Florida Administrative Code.* Section 17-610, Part III. Tallahassee: 1990.

CHAPTER 5
WATER REUSE ALTERNATIVES

5.0 Introduction

Water reuse is any activity which utilizes otherwise unused waste or disposed water for either a new or existing purpose which then reduces water demand. Thus, water reuse is a form of the broader concept of water conservation. *Structural* water reuse strategies are those which consist of engineering, hardware, and systems. *Nonstructural* water reuse strategies are those which consist primarily of software, policies, and operations. Examples of structural water reuse strategies include municipal wastewater and domestic greywater reuse irrigation, toilet flushing, and other infrastructural elements using reclaimed wastewater or alternative water resources. Examples of nonstructural water reuse strategies include high minimum potable and sewer fees, tax credits for reuse activities, and legislation which *permits* and *promotes* wastewater reuse.[5]

Developments in urban environments have been proven to use between 40 and 95 percent of potable flow for non-potable activities. *Primary* non-potable consumers of total building flow involve toiletry activities, varying from 34% in residential structures to nearly 85% in most commercial buildings. *Secondary* non-potable consumers such as mechanical systems makeup and irrigation, could further reduce potable demand. *Tertiary* non-potable consumers could include ornamental or aesthetic fountains, fire suppression, and floor trap priming. Although such potential reuse applications generally would not account for more than 5% of total flow, they nevertheless could benefit from on-site dual distribution and provide an added incentive to justify such a reuse program. The focus of this chapter is to provide alternative applications for both interior and exterior non-potable reuse of recycled greywater and reclaimed wastewater. A condensed analysis involving water quality objectives and dual distribution requirements specific to each reuse application will be provided herein.

5.1 Construction Use of Greywater Water

Reclaimed and grey water resources could perform a variety of reuse alternatives on-site during the building construction phase. Secondary effluent may be tapped from the municipal reuse supply for soil compaction, pile and pipe jetting, and dust control. If available, tertiary effluent could be implemented for limited contact construction roles such as equipment washdown, temporary fire suppression, concrete batching, and temporary toilet flushing. Such construction phase reuse would be most economical if the building design incorporated dual distribution within the final design scheme.

5.1.1 *Recycled Sludge for High Compressive Strength Fly Ash*

As a by-product of virtually all wastewater treatment, reclamation, and reuse, sludge is an inevitable part of waste solid suspension, coagulation, sedimentation, and filtration. Generally, dewatered sludge is disposed of by surface spreading or landfill. However, strengthening DEP regulations and spacial constraints in many urban communities throughout Florida have severely limited this process. As a consequence, new concepts for recycling the former waste by-product for use in building and construction materials are being developed. Incinerated sludge produces a very light weight, high compressive strength fly ash that can be introduced into concrete batching.

5.1.2 *Use of Reclaimed Water for Concrete Mixing*

Reclaimed wastewater and greywater effluent may also be harvested for industrial and construction applications. Based on results obtained from laboratory analysis on the quality of reclaimed wastewater from the Jurong Industrial Water Works and compared with the tolerable limits establish by various researchers, reclaimed wastewater could be used as mixing water in concrete without any adverse effects. In fact, results obtained from the laboratory study on the various concrete mixes demonstrated that when compared to concrete batched from 100% potable water, increases in compressive strength were observed in concrete cast with increasing percentages of reclaimed wastewater after 28 day yields. Concrete cast with both potable and reclaimed wastewater also demonstrated higher 28 day yields when cured with greywater as opposed to 100% potable water.[1]

5.2 Toilet and Urinal Flushing

Pursuant to F.A.C. 17-610.476, reclaimed water may be used for toilet and urinal flush in commercial structures and multi-unit residential buildings such as motels, hotels, apartment buildings, and condominiums where the occupants do not have access to the plumbing system for repairs or modifications.[6] As previously mentioned, flush water has proven to account for nearly 35% of total potable flow within residential environments. Commercial buildings may use 90% of total potable flow for such activities. Therefore, toilet and urinal reuse may be considered the single greatest reuse alternative for reduced potable flow.

Commercial and residential buildings occupied by the general public such as motels are often required to supply flush water through direct head pressure flush valves ranging in pipe diameter from 3/4" for urinals, to 1" for water closets. Such conventional fittings are required to supply a minimum of 15 psi and 15 gpm to direct flush urinals, and 10-20 psi and 15-40 gpm to direct flush water closets (Table 4.2). Although flush valve toiletry fixtures cannot achieve the resource efficiency equivalent to flush tank fixtures, such direct flush accessories limit access to internal plumbing. Reduced flush volume is being achieved in similar "low-flow" direct flush fixtures by using aerator fittings, turbulent flow devices, and pressure inducing valves. Such accessories have proven reduce flow volume 8L/flush (2 gal) in direct flush water closets, resulting in an estimated unit water savings of 30.8L/d (8 gal/d) per capita.

Flush tank water closets are common to most residential structures where access to fixture plumbing is generally restricted to the public. Common residential flush tanks operate using ½" accessories, providing a minimum of 15 psi and 3 gpm of flow to the gravity fed flush tank. Reduced flush volume is also being achieved using low-flow flush tanks. New construction using dual distribution for water closet reuse may implement 6L/flush (1.5 gal) low-flow tanks. Such fixtures have proven to reduce water demand by 61L/d (16 gal/d) per capita. Existing buildings having flush tanks can either retrofit to similar low-flow non-potable fixtures, or may opt to use tank "dams" that displace unnecessary flush water, thereby reducing flow per flush.

5.3 Irrigation

Residential irrigation throughout densely populated, salt intrusive areas of Florida remains a major water resource depleter, amounting to 5-10% of all potable water consumed per capita. However, in the Southwestern U.S., low rainfall and humidity, coupled with high evapo-transpiration make irrigation essential for plant growth, amounting to nearly 65% of all water consumed per capita. Similar to Florida, a large percentage of its water resources are used for home irrigation and another substantial amount is returned to sewers. As water fees increase due to urban sprawl and increased water quality standards, supplemental residential watering sources are becoming more attractive.

The use of reclaimed wastewater for irrigation of urban landscape is one of the fastest growing reuse options in the State of Florida. Exterior residential and commercial watering on a yearly basis can average more than 40% of the total water use.[7] Irrigation however, possesses the highest potential for human contact than any other reuse option. As the level of human contact progressively increases, so must the degree of effective treatment and use. Table 5.1 on the following page outlines the recommended water quality objectives for reuse irrigation.

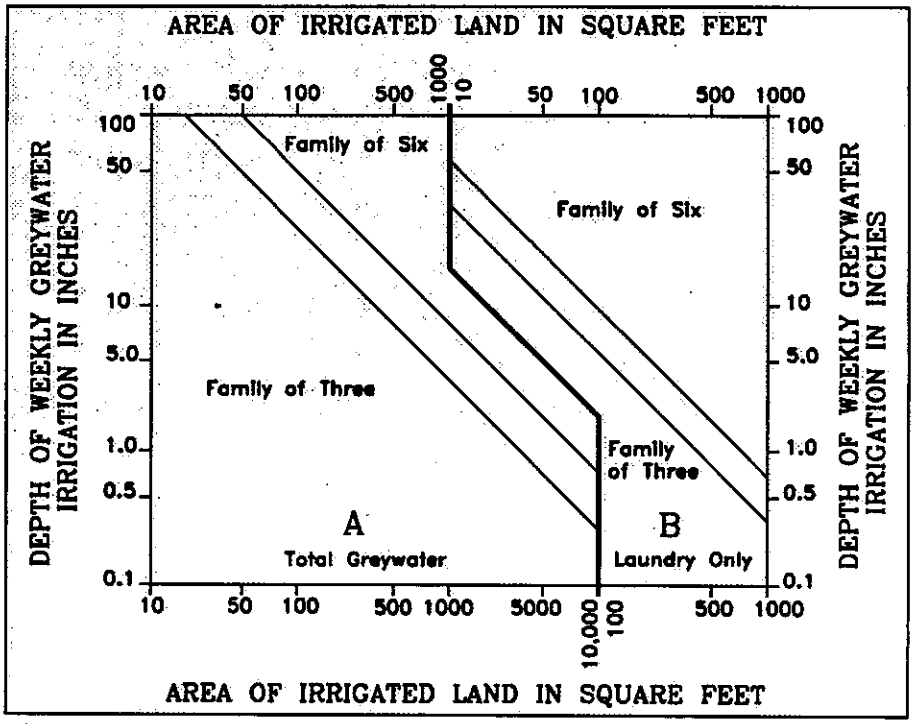


Figure 5.1 Irrigation with recycled greywater.
Popkin, Barney P. *Recycled greywater for home irrigation.* Water and Wastes Engineering, September 1989, p62-64.

5.3.1 *Greywater Irrigation*

Application of selected home wastewater, or greywater for domestic irrigation is considered favorable where high sewage-treatment and potable water costs exist and loamy, well drained soils are present. Sewage treatment and disposal rates are most often based on the net volume of potable water used due to the fact that wastewater flow cannot be economically or efficiently metered. Domestic applications such as irrigation are therefore dual-penalized for wastewater disposal costs even though the domestic flow never reaches the sewer system. Greywater irrigation techniques common to the arid climates of the southwest are now surfacing as viable options in Florida's urban communities where high cost domestic water is currently used as well as in salt intrusive coastal locations unable to provide acceptable ground water for irrigation.

Table 5.1 Recommended water quality objectives for reuse irrigation.
United States. Environmental Protection Agency. *Municipal Wastewater Reuse*. Washington D.C.: 1991.

Contaminant	Levels for controlled access
Biochemical oxygen demand (BOD), mg/L	20.0
Total suspended solids (TSS), mg/L	20.0
Chlorine residual, mg/L	1.0
Fecal Coliform, per 100 mL	<2.2
Total coliform, per 100 mL	2.2
Turbidity, NTU	2.0

In-Line Flow Irrigation

Greywater reuse separation can be accomplished through in-line wastewater flow diversion. This design concept utilizes a flow spitting connection similar to a hybrid 30° "y" fitting and a check valve assembly placed downstream from gravity flow greywater (non-fecal) fixtures such as lavatories, sinks, and showers; and up stream from blackwater (fecal) fixtures such as urinals and water closets.

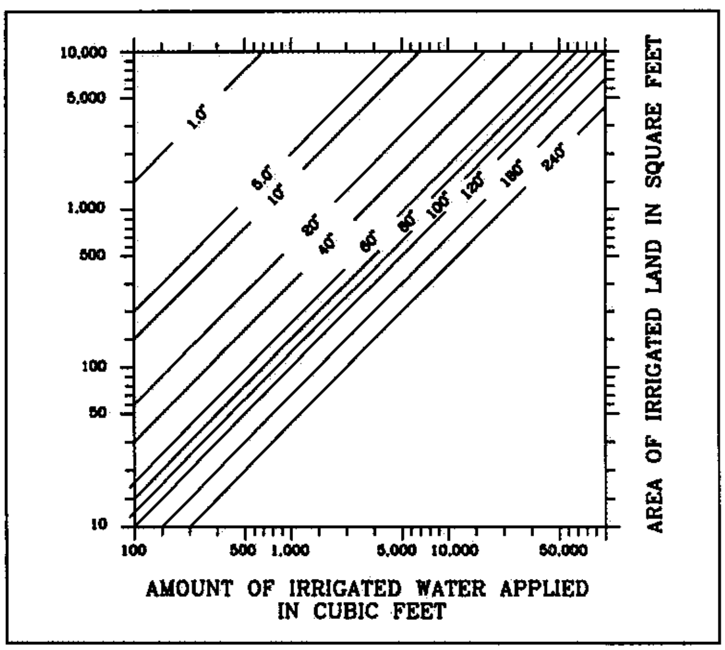


Figure 5.2 Quantity of irrigation available in inches of depth.
Popkin, Barney P. *Recycled greywater for home irrigation*. Water & Wastes Engineering, September 1989, p 62-64.

Conventional wastes excluded from in-line flow diversion are directly disposed of under adequate hydraulic flow conditions and the resultant greywater is separated for sub-surface drip irrigation and infiltration recharge where geologic conditions permit. The connection provides venting of septic gases and ensures adequate atmospheric pressures to eliminate siphonage or backflow. The in-line flow diversion device uses a minimum of parts to down-cycle used water resources to a lower priority application, thus reducing the costs and embodied energy requirements associated with potable consumption or on-site reclamation. Unlike a dual recovery system, this simplistic approach would amount to only a fraction of the construction or retrofit costs, while maintaining 100% and 90% flow efficiencies under normal and peak flow rates respectively.[2] In-line diversion also maintains the flexibility to assume conventional operation by closing the greywater diversion valve and restoring both grey and blackwater flow to the sewer system in the event of soil saturation or systems failure.

In-line Flow Irrigation Design and Specifications

Referring to Figure 5.3, a typical building is illustrated having a conventional supply of wastewater provided to a common disposal line (1). The disposal line (1) is connected to non-fecal, greywater source lines such as (2) sinks/lavatories, (3) showers/tubs, (4) washing machines, and (5) dishwashers. A connecting line (7) discharges fecal blackwater downstream of fixtures (2-5) for conventional disposal into the municipal sewage lateral (8). Positioned between greywater fixtures (2-5) and blackwater fixture (6), the in-line flow diversion device (9) provides greywater flow recovery and reuse via collection lateral (10) and backflow prevention from blackwater fixture (6) downstream. Collection lateral (10) is designed to conduct greywater from disposal line (1) to a sub-surface cistern (11) for gravity fed irrigation/recharge through a subsurface lateral leach-line (12). Figure 5.3 provides a respective view of both opened and closed cross-sections of the in-line flow diversion device (diverter seat [13], diverter hinge [14], flow diverter [15], and shut-off valve [16]).

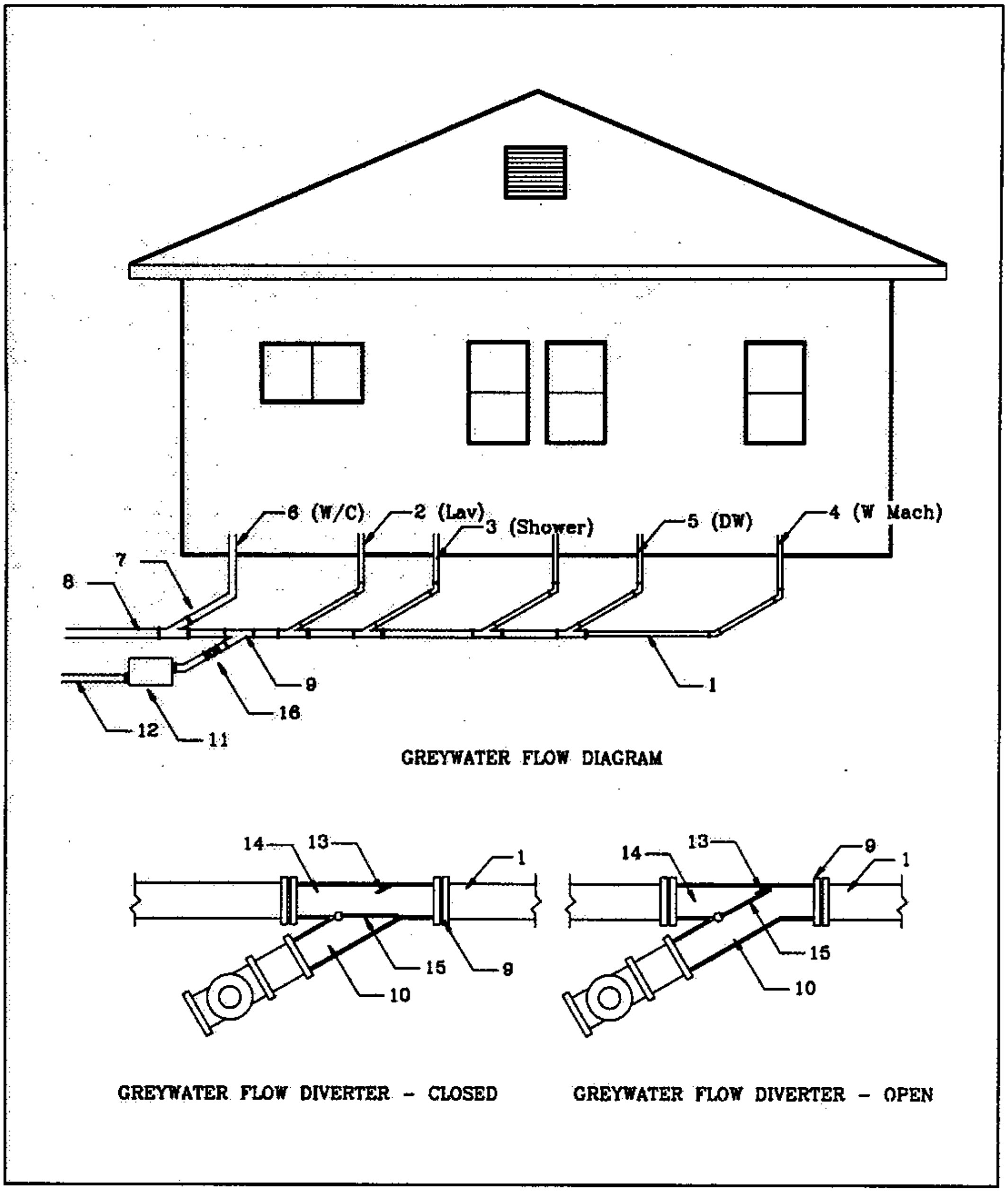


Figure 5.3 In-line flow diversion for sub-surface drip irrigation. *Land Application of Selected Home Wastewater.* American Society of Agricultural Engineers, ASAE No. 78-2062, 1988.

Restricted to sub-surface irrigation and recharge, in-line flow diversion is recommended for both commercial and small-scale residential structures where greywater flow would be insufficient for non-potable demands beyond subsurface irrigation.

5.3.2 *Spray Irrigation*

Sprinkler or spray irrigation may involve a potential risk of human infection from exposure from potentially pathogenic microorganisms in the sprayed effluent. Direct contact with insufficiently treated wastewater and associated mist are among the most probable environmental pathways for exposure to viruses and pathogenic bacteria. The microorganism density in air, **C**, in colony forming units (cfu/m^3), derived from a electrostatic precipitator sampler (LVS) is calculated as:

$$C = AV/FRD$$

Where,

- **A** = Microorganism density, BHI fluid, cfu/mL
- **V** = Final BHI volume, 100 mL
- **F** = Correction factor for LVS operating voltage
- **R** = Air sampling rate, 1.0m^3/min
- **D** = Sampling duration, 30 min

BHI is referred to as the collection medium used to recover airborne pathogens in a polyoxyethelenesorbitan monooleate solution. Although microorganism density in air is subject to municipal regulation, a common value of **C** = 4 cfu/m^3 is generally the accepted norm.

5.3.3 *Slow Rate Infiltration and Subsurface Drip Irrigation*

Reuse drip irrigation using treated wastewater effluent or potentially direct (untreated) greywater, may be pumped from the reuse storage tank, through a mesh screen filter, control valve, and pressure regulator. The header line (manifold) may have a flush valve/vacuum breaker that would in turn feed the drip lines. Conventional drip lines are usually inserted 4 to 12 inches below grade. An automatic flushing valve/vacuum breaker is placed at the end of the flush line and is commonly embedded in gravel to prevent soil scour during clean out. To minimize the problem of emitter clogging associated with reuse subsurface irrigation, it is recommended that drip lines be provided turbulent flow of 1 to 2 gph using 0.06" to 0.07" orifices constructed of PVC or PP (polypropylene) to resist most acidic constituents of domestic wastewater and Florida's "aggressive" soil characteristics.

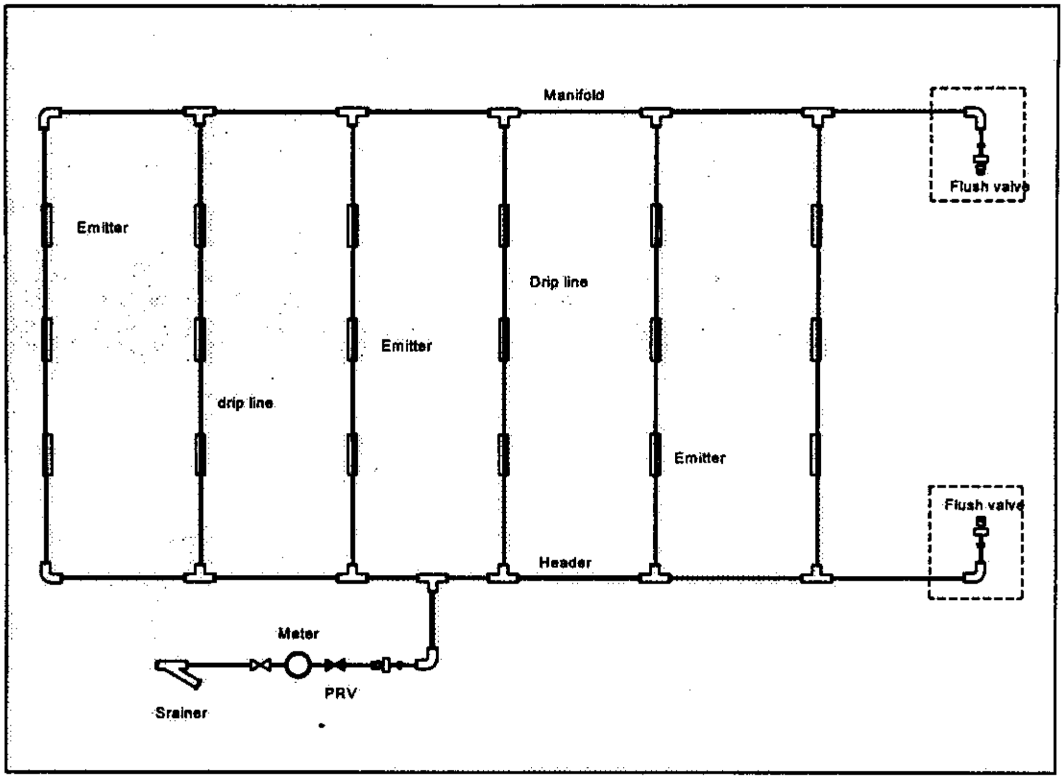


Figure 5.4 Subsurface drip irrigation and aquifer recharge systems layout.
Assessment of Greywater and Combined Wastewater Treatment and Recycling Systems. PHCC, 1992.

Direct leaching for subsurface irrigation using untreated residential and commercial greywater is becoming a reality in California. Legislation effective July 1, 1993, will permit the direct reuse of water from showers, bathtubs, lavatories, and drinking fountains for landscape irrigation via subsurface distribution. However, to reduce the possibility of collected greywater containing excessive organic matter or pathogens, it is recommended that grease producing sources such as kitchen sinks and dishwashers be omitted from the Type "A" dual recovery system. Direct leaching using collected greywater may reduce costly treatment, contact with the public, surface runoff, and evaporation loss. Figure 5.4 illustrates a potential subsurface drip irrigation layout using reclaimed effluent.

Table 5.2 Drip irrigation construction criteria. *Assessment of Greywater and Combined Wastewater Treatment and Recycling Systems.* PHCC.

Construction item	Minimum	Maximum
Number of drain lines per valved zone	1	N/A
Length of each perforated line	N/A	100 ft
Bottom width of trench	12 in	18 in
Spacing of lines, center to center	4 ft	N/A
Depth of cover lines	10 in	N/A
Depth of filter material cover of lines	2 in	N/A
Depth of filter material beneath lines	3 in	N/A
Grade of perforated lines	level	3 in/100 ft

Irrigation Criteria

Because of the nature of greywater or lesser treated effluents, its unsafe, indiscriminate application can be hazardous. Several factors should be considered in applying reclaimed wastewater for irrigation purposes. These factors include (1) soil absorption capacity and criteria, (2) greywater salinity, and (3) minimum setback distances. Tables 5.2 and 5.3 outline several construction techniques and soil absorption capacities proposed for safe and efficient use of subsurface drip irrigation in connection with Figure 5.4.

Prior to implementing commercial and residential reuse irrigation, a soil evaluation study must be conducted. The soil evaluation study may consist of the following:

1. The quality and quantity of organic matter and its affect on the fertility of the soil and the amount of water that can be retained.
2. Soil texture and particle size and its affect on removing potential contaminates in the wastewater effluent.
3. Soil structure, which affects the permeability of the soil.
4. Topography, which affects surface runoff and erosion.
5. Infiltration rate, which indicates how much runoff may occur.
6. Subsurface geology and underground water movement.
7. Impermeable layers of clay strata, which can impede percolation.
8. Fractured areas which could allow treated wastewater to reach groundwater prior to the natural filtration of potential contaminates.

Table 5.3 Soil capacity and criteria for subsurface drip irrigation.
Assessment of Greywater and Combined Wastewater Treatment and Recycling Systems. PHCC.

Type of soil	Min. ft2 drip area /100 gal. discharge	Max. absorption capacity/ft2/day
Course sand or gravel	20	5
Fine sand	25	4
Sandy loam	40	2.5
Sandy clay	60	1.66

For irrigation purposes, it is necessary to determine which landscape foliage is to be irrigated with reuse water. While many plants are suitable for both spray and subsurface drip irrigation using reclaimed effluent or direct greywater, foliage requiring shaded, acidic soil conditions are not. Salinity levels common to greywater and reclaimed wastewater frequently fall within the range 100-400 mg/L, especially in coastal regions experiencing salt or brackish water infiltration and inflow. Although the resultant chlorides in the reclaimed effluent can be tolerated by most native species, others have little or no tolerance to chlorides. Table 5.4 provides chloride tolerances of landscape species native to the State of Florida.

Table 5.4 Chloride tolerance of selected reuse irrigated species.
Riek, George C. *Using Effective Salinity Control to Expand Opportunities for Reclamation.* 1992.

High tolerance (>400 mg/L)

Australian pine	Dahoon holly	Oleander
Hibiscus	Cabbage palm	Live oak
Sea grape	Bougainvillea	Lantana
Bermuda grass		

Moderate tolerance (100 - 400 mg/L)

Banana	Carambola	Grapefruit
Orange	Slash pine Rubber tree	
Canna lily	Bromelaids	Iris
Pampas grass		

Low tolerance (<100 mg/L)

Avocado	Crape myrtle	Rose
Camphor tree	Mango	Persimmon
Poinsettia	Jacaranda	

No tolerance

Chinese privet	Dwarf azalea	Formosa azalea·

Pursuant to F.A.C. 17-610.471, it is required that there is a minimum setback distance of 75 feet from the edge of wetted area of public access land application area to potable supply wells that are existing or have been approved by DEP or HRS, but have not yet been constructed. Within 100 feet from public eating, drinking and bathing facilities, low trajectory nozzles or other means to minimize aerosol formation should be used. No setback distances are required for private swimming pools, hot tubs, or eating facilities. No setback distance is required to any non-potable water supply well.

5.4 Mechanical and HVAC Greywater Reuse

Water is an essential element for many of the HVAC and mechanical systems used in urban building construction today. Cooling towers for example, require 2.4-3.0 gpm/ton of air handling capacity, using in excess of 10% total potable flow for such heating and cooling operations.[9] Potential non-potable applications for reclaimed effluent in mechanical systems include heat exchange and recirculation makeup. In this elementary process, reuse water could be used in place of potable water in typical commercial and residential recirculating cooling systems (Figure 5.5).

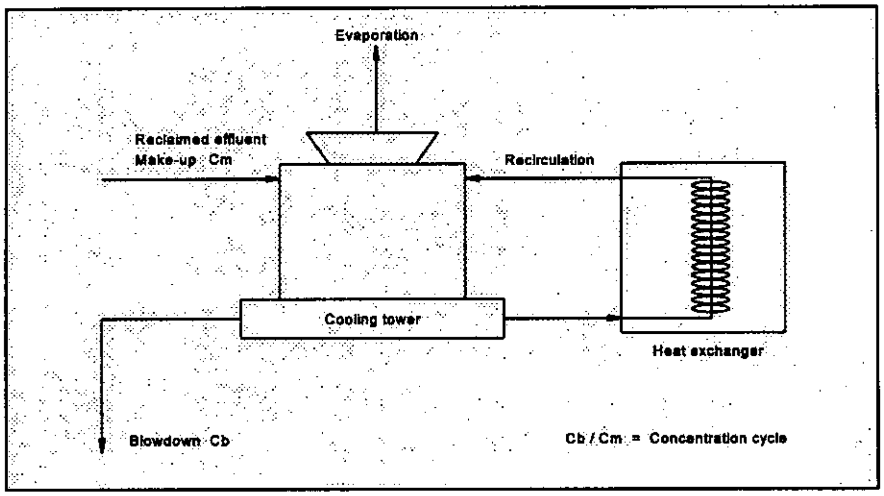


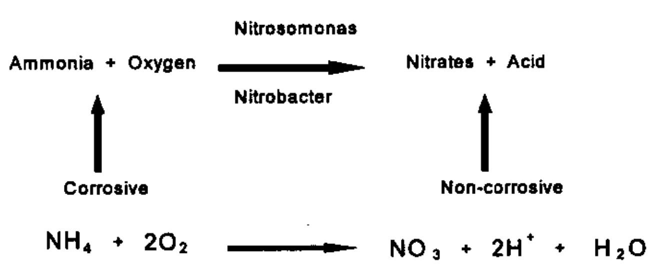
Figure 5.5 Recirculation HVAC schematic using greywater makeup.
Grosskopf, Kevin R. *Water Reclamation and Reuse in Multi-Level Structures*. University of Florida, 1993.

Reuse water recirculated in cooling towers and heat exchanging units would require optimal levels of treated effluent. Closed loop systems such as these would cycle continuously, thus retaining the reuse water for extended periods of time.

Once the residual disinfectant in the treated effluent deteriorates, intricate mechanical systems can provide an excellent environment for biogrowth. Scaling and corrosion resulting from wastewater constituents and pH imbalances can likewise increase inner pipe friction, restrict flow, and reduce blowdown rates. Suspended solids accumulation from evaporation can further reduce operating efficiency. Most mechanical systems are constructed of iron or carbon metals which are capable of accepting galvanized (zinc) coatings or creating a self-protecting surface film of oxidation which tends to reduce the rate of corrosion. However, with the constant flow of water and evaporation of vapor common to heat exchange elements, such barriers could be subjected to a highly concentrated, aggressive effluent bath which could in turn accelerate corrosion within an already susceptible system.

Calcium carbonate scale formers are present in both fresh water and reuse water, however they are more numerous in the later. Calcium phosphate scale formers are specific to reclaimed effluent because of its inherent phosphate content. This situation alone could become a strong scaling factor, especially on the surface of heat exchangers and similar units. Corrosion factors specific to treated wastewater often include ammonia, which has proven to be corrosive to copper alloys frequently used in heat exchange systems. Due to the high concentrations of nutrient rich elements such as nitrogen, biogrowth may be enhanced in recirculating cooling systems by the residual organic substrates remaining in the reclaimed wastewater. Most secondary treatment processes have proven inadequate to remove or sufficiently reduce ammonia, phosphates, alkalinity, calcium, and suspended solids responsible for potential scaling and corroding. Therefore tertiary AWT may generally be required for the removal of damaging wastewater compounds such as ammonia.

However, research has indicated that when a significant level of nitrate is present, the result is a substantial reduction in corrosive ammonia. The nitrification reaction equation illustrated below provides evidence that the reduction in pH levels from 10.5 in the reuse makeup water to 7.8 in the recirculating cooling water without any additional acid, confirms that ammonia reducing nitrification has taken place within the system. The actual nitrification is accomplished by an activated sludge process that utilizes autotrophic bacteria which utilize carbon dioxide as their carbon source and obtain energy from the oxidation of ammonia to nitrate. The activated sludge system may enhance the reliability of the AWT process substantially and may reduce operation and maintenance (O & M) costs.



In this process, ammonia is first converted to nitrite, which is then oxidized to nitrate. Nitrifiers are strict aerobes and therefore require dissolved oxygen. Nitrifiers do not compete with other bacteria for basic nutrients, but do compete for oxygen. Since nitrifiers do not obtain as much energy from oxidizing ammonia as other bacteria obtain from oxidizing carbon, they grow much slower than bacteria utilizing organic substrates. Therefore, oxygen-limiting conditions may greatly hamper nitrification as a consequence of the system's inability to sustain a large enough population of nitrifying bacteria.

Nitrates produced as a result of nitrification are generally not corrosive to copper alloys and may even go as far to act as a corrosive inhibitor to many similar metals. In addition, the acid produced through nitrification may act to balance or neutralize the potentially alkaline pH associated with recirculated reuse water. The alkaline carbonates and hydroxides present in the effluent are therefore balanced and the nitrification process may additionally serves as a "self-regulating" pH control mechanism without the need of external acid addition. Further developments suggest that reverse osmosis may accomplish the same overall objective as the biological nitrification towers through an ability to remove corrosive ammonia, alkaline carbonates, and non-carbonate hardness in one unit process. This substitution will significantly reduce the quantity of sludge produced. Ion exchange may become another alternative for mechanical reuse treatment. The ion exchange media clinoptilolite, exchanges sodium ions for ammonium ions. The exhausted media beds can be regenerated by purging the ammonia with a concentrated sodium chloride solution. Ammonium may then be removed from the regenerate solution in an ammonia removal and recovery process (ARRP).

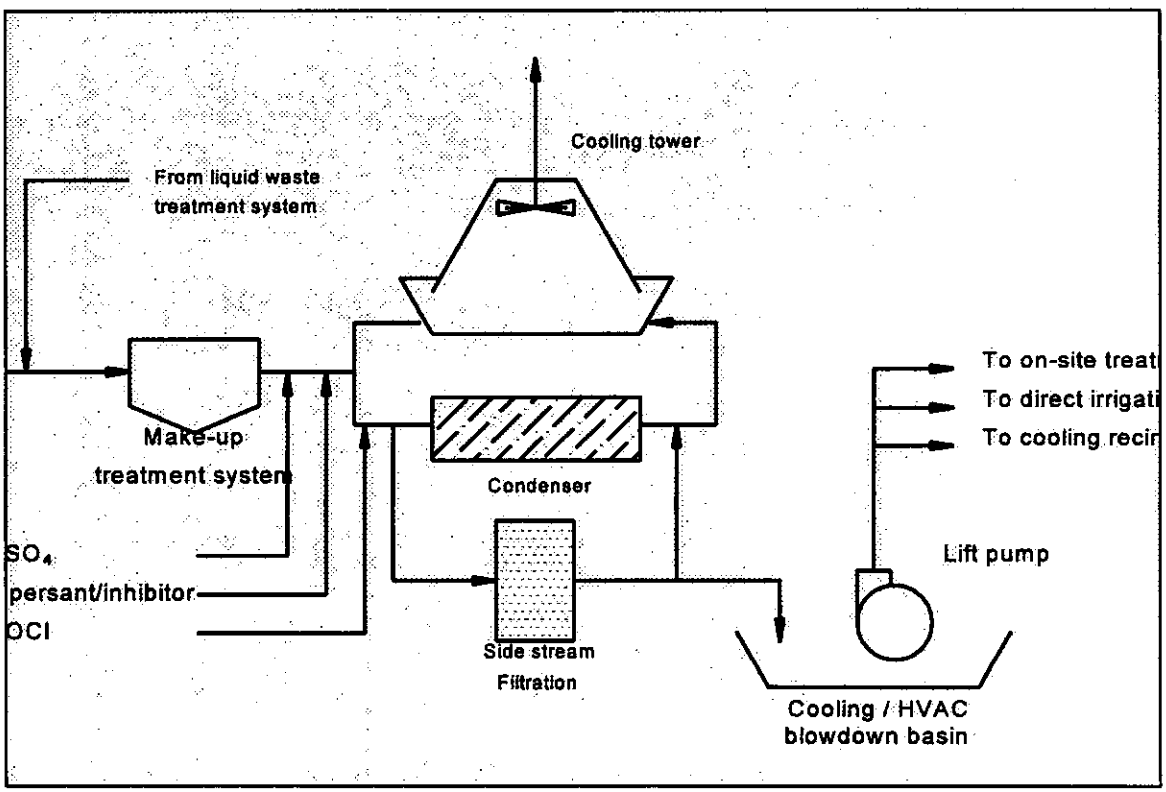


Figure 5.6 Sodium hypochlorite fed and side-stream filtration system. Grosskopf, Kevin R. *Water Reclamation and Reuse Within Multi-Level Structures*. University of Florida, 1993.

Biofouling can be controlled by using biocides such as chlorine. However, where nitrification is economical and beneficial, this process should not be added in order reduce a corrosive acidity imbalance within the reuse makeup system. Instead, more frequent cleaning operations of heat exchangers and a higher initial reuse quality should be achieved. Ammonia concentrations as well as phosphorous provide excellent nutrients for several biological species. Control of biogrowth can be controlled by ammonia reducing chemical and biological nitrification as previously mentioned or through chlorination using a sodium hypochlorite (NaOCl) within the on-site reuse makeup system at the mechanical zone(s). The disinfection system illustrated in Figure 5.6 could provide continuous "shock treatment" lasting between 30-60 minutes contact time and maintaining a chlorine concentration of 0.5-1.0 mg/L from the condenser. In addition to sodium hypochlorination, a supplemental biological dispersant should be added every 2-3 months to remove any accumulated biogrowth on the condenser tubes. This process may involve direct electrolytic conversion of sodium chloride brine to a dilute hypochloritic solution. Softened reuse water free of scale forming calcium or magnesium, and free of corrosive salts can additionally reduce precipitates that could potentially foul the system. The chemical feed program may include sulfuric acid for control of alkalinity and may act as another chemical dispersant or inhibitor in place of nitrification. This method may only be required if cooling water consisting of reclaimed effluent is found to have significant alkalinity. The Langlier Saturation Index (LSI) indicates however, that reclaimed water with a slightly greater tendency to scale rather than corrode is generally preferred for makeup water cycles in heat exchanging and cooling tower operations. The optimum target value therefore falls within the range of 8.0 to 8.3 on the LSI scale.

Table 5.5 Recommended criteria for circulated cooling water.
Grosskopf, Kevin R. *Water Reclamation and Reuse in Multi-Level Structures.* University of Florida, 1993.

Component	Unit	Raw wastewater	Secondary effluent	Tertiary effluent	Cooling water
pH	LSI		7.2	10.5	7.9
Alkalinity	mg/L		620	250	300
Hardness	mg/L		450	150	250
Chlorides	mg/L		350	350	500
Suspended solids	mg/L	400	60	15	30
BOD	mg/L	450	50	10	<5
COD	mg/L	950	240	80	110
Ammonia	mg/L	60	35	25	<1
Nitrate	mg/L	N/A	2.2	2.2	13.6
Phosphate	mg/L	30	20	0.2	0.1

Side stream filtration can be use to control the TSS in circulating reuse water. Most of the filtered water can be returned to the circulation system and the balance can be deposited into blowdown storage tanks for other non-potable applications. Filtration processes should be designed to allow high flow rates with relatively low pressure drops and high TSS removal capacity. The final disposal of untreated, exhausted cooling water can be considered environmentally sound considering that in most cases, the resultant tertiary blowdown, may still achieve water quality well above disposable secondary wastewater. Since mechanical reuse is not in contact with building occupants and is generally independent from climatic or seasonal influences, reuse water should be considered for this non-potable application.

5.5 Fire Suppression

> Reclaimed water may be used to provide water for fire protection. Reclaimed water may be supplied to fire hydrants. Hydrants shall be color coded, shall have tamper-proof hold-down nuts, and shall be capable of being operated only with a special wrench. Hydrants supplied by reclaimed water shall have no connection to the potable supply.[6]

Pursuant to F.A.C. 17-610.477, reclaimed water may be used to provide water for fire protection in sprinkler systems located in commercial facilities and buildings. Reclaimed water may also be used for water to provide fire protection in sprinkler systems located in motels, hotels, apartments, and condominiums where the individual occupants do not have access to the reuse distribution system for repairs and modifications. The essence of fire protection is the preservation of human life and property in the event of a fire regardless of source or cause. In systems in which water in some form is the source of fire protection, the fundamental design must provide both a sufficient pressure and an adequately supply.

5.5.1 *Reuse Fire Suppression Standpipes*

The National Fire Protection Association (NFPA) requires pressures of 65 psig at the topmost outlet, and a minimum 30 minute flow duration of at least 500 gpm for central supply standpipes. Such standpipes, or supply risers extending from the source of the grey or reclaimed water to the point of fire suppression, are limited to a maximum 275 ft in height and limited to 100 psig unless pressure reducing appurtenances are provided at the sprinkler zone or fixture outlet (hose cabinet). The 65 psig pressure and 500 gpm flow requirement may present design challenges in lieu of the fact that reclaimed lines are to be maintained at approximately 70 psi, 10 psi lower than potable mains.

As structures increase in height, the pressure in the lower portion of the standpipe may be well over 100 psig in order to provide 65 psig to the farthest non-potable fire suppression fixture. Non-potable fire suppression fixtures at the base of the riser must therefore be provided a non-adjustable pressure reducing valve (PRV) or pressure reducing orifice plate at each sprinkler or hose cabinet outlet. Orifice plates when used in conventional fire suppression implementing potable water are less subject to failure and unauthorized "adjustments". Such tamper-proof, reliable appurtenances should be inherent within any non-potable reuse alternative.

5.5.2 *Reuse Fire Suppression Zones*

Reuse fire suppression zones implementing gravity induced storage tanks should be separate from the dual distribution system, or for spatial and economic purposes, may be incorporated within each non-potable fire reserve as illustrated in Figure 4.3. To maintain emergency pressure and flow, such non-potable fire reserves within each reuse zone would be required to provide 15,000 gal (500 gpm x 30 minutes), using a factor of safety (F.O.S.) of 10-15% (1,500-2,250 gal) in addition to non-potable distribution loads. Potential advantages of gravity feed zoning over direct pumping involve lower rated lift equipment and supply piping. In addition, reuse storage tanks are readily capable of receiving emergency makeup from potable supplies using an approved air-gap (AG) cross-connection. Finally, in order for reuse water to travel 480 ft vertically (40 stories), requires gravity resisting pressures approaching 250 psig (480 ft x 0.433 + frictional resistance). This figure represents the ceiling for all direct non-potable supply risers and standpipes.

5.5.3 *Wet and Dry Pipe Fire Suppression Systems*

The most common conventional method for fire suppression using water is the wet pipe sprinkler system. A single system can achieve adequate fire suppression if the area served by a sprinkler system is a space on one floor for which ordinary or light hazardous installation equals 52,000 sf or less regardless of building height.[11] NFPA guidelines also stipulate that sprinkler orifice spacing at 13'-0" maximum in accordance with the 130 sq ft per head limit ($3.14r^2$ or $3.14(13/2)^2 = 130$ sq ft).

Dry pipe fire suppression systems inhibit flow from the supply riser or standpipe, allowing a water-free sprinkler system when inactive. Traditional benefits of this system involved using cost efficient sprinkler systems in unheated spaces where water filled pipes would readily freeze and burst. In lieu of the fact that reuse water contains a higher concentration of scale forming and corrosive constituents, a dry pipe system could eliminate damage to sensitive piping and orifice plates. Furthermore, dry pipe configurations eliminate the stagnant holding durations between flushing intervals, which would provide an excellent environment for biogrowth and scaling in wet pipe layouts. It is therefore recommended that the dry pipe be implemented in all sprinkler systems implementing grey or reclaimed water resources.

The dry pipe system can implement reclaimed water under pressure from compressed air or inert nitrogen. If a sprinkler orifice within the dry pipe zone is activated by heat or smoke, the rupture disc would release the compressed gas and depressurize the fire suppression pipe, releasing the reuse water from supply zone or standpipe. The sizing of the piping for a "dry system" is the same as that for the wet system previously described, as is the location and spacing of the orifice heads. At a point farthest from the reuse supply riser or standpipe, it is recommended that a test valve and drain connection to the test water receptacle be provided. This assembly must serve as the inspector's test tee to assure that minimal response time be provided to supply adequate reuse flow and pressure to the farthest orifice from the control source, in addition to testing for potential cross-connections and residual disinfectant.

5.6 Aquifer Recharge and Wetlands Restoration

Southwest Florida water resource officials are drafting a plan that involves pumping reclaimed water from domestic sewage treatment plants back into wetlands and into slow rate land application drain fields in an indirect effort to restore and recharge the state's co-dependent ecosystems. Saltwater could intrude as far as eight miles inland over the next 50 years if pumping freshwater along the aquifer spanning Florida's central west coast continues at projected rates, which could reach 1.6 billion gallons per day by the year 2020.[3]

Currently, the three most populous of the districts 16 counties generate 200 MGD of treated wastewater, with as much as 100 MGD of reclaimed water being used for agricultural, residential, and municipal irrigation. The balance of the effluent supplied to wetlands and slow rate land application drain fields would provide indirect aquifer recharge through soil strata infiltration, a natural purification process. The goal of the proposed plan is restore 1 gallon of extracted groundwater with a gallon of highly treated, highly disinfected reuse water. The concept of reclaimed water for indirect potable use began when the first civilizations began disposing wastes into bodies of water upstream of other civilizations. In the State of Florida, the majority of potable water originates in underground aquifers. Therefore, *groundwater recharge* using reclaimed effluent is one of the only practical methods of indirect potable reuse. Groundwater recharge using reclaimed grey and domestic wastewater has proven to achieve several of the following:

1. To prevent and even displace salt water intrusion in fresh water aquifers;
2. To store reclaimed water for future use;
3. To control or prevent ground subsidence;
4. To augment non-potable or potable groundwater aquifers.

Recharge can occur by *direct injection* or by *surface spreading*. In surface spreading, reclaimed water percolates from basins through an unsaturated zone into groundwater. This filtration process through permeable layers of strata cleanses the recharge water further until finally reaching non-permeable bedrock. Direct injection involves pumping reclaimed water directly into a confined aquifer. Although this method involves considerably less time for recharge, it requires greater treatment, embodied energy, and subsequent expense. Direct injection systems are generally used as an immediate restoration process to save a diminishing aquifer from salt water intrusion.

Defined, *wetlands* are transitions between terrestrial and aquatic regions. In addition to surficial recharge basins, wetlands provide an excellent source of flood control, pollutant removal, temperature moderation, wildlife habitat, and public recreation. Therefore, the innovative concept of using reclaimed water for wetlands restoration has had widespread acceptability. However, in the fierce competition for a dwindling water supply, the economic and political influences of the agricultural, commercial, and industrial communities have often taken precedence. The level of treatment for wetland reuse depends greatly on the level of human exposure. Health concerns consist of the pathogenic and pollutant contamination potential in reclaimed water. Human health risks are classified within the potentiality of direct contact with the water, and through indirect contact such as disease transmission by parasitic organisms. Parasites such as mosquitoes, are notorious disease carriers in such habitats. These wetland parasites are often in close proximity to urban areas large enough to provide the volume of secondary effluent necessary to sustain the ecosystem. However, the conditions necessary to transmit diseases associated with highly organic water are very complex. Thus the possibility of indirect exposure to organic contaminates is "remote". The risk of direct or indirect contamination from pathogenic organisms such as bacteria, viruses, and protozoans, as well as the risk posed by non-biological pollutants can be controlled by three wetlands activities including (1) sufficient wastewater treatment for wetlands use, (2) natural wetlands processes, and (3) adequate wetlands design and operation.

Wastewater treatment for wetlands use includes an initial pretreatment involving the screening of large solids and the settling of heavy grit. The following primary treatment involves the physical clarification of the waste water in a tank. A primary clarifier is used to allow solids to settle and be removed. Few treatment plants discharge primary effluent into surface waters. Secondary treatment is often used to clarify primary water through biological treatment. Secondary water is commonly used for wetlands enhancement and surface water discharge. Tertiary treatment involves fine filtration of suspended solids and is commonly used for municipal irrigation where direct public contact may occur. Wetlands enhancement rarely involves this level of treatment due to the high cost of the advanced treatment. Additional nutrient removal may be required for discharges into sensitive receiving waters because of the potential for harmful algae growth. Disinfection can additionally reduce the pathogenic content of treated wastewater by a factor of 1,000,000 through the use of chlorine, ozone, and ultraviolet radiation as discussed previously. Therefore, disinfected secondary water is the most common effluent discharged into reclaimed wetlands.

Natural wetland processes consist of the physical, chemical, and biological characteristics of the wetland. These natural properties can greatly reduce the pollutants and pathogens in the reclaimed effluent, thus reducing the costs of additional treatment. The following wetland features that enhance this process are slow moving water, aerobic and anaerobic zones, water with high and low light transmittance, porous soils, and a diversity of aquatic and terrestrial organisms. The presence of these conditions allows the natural settling of solids, permeation of water through soils, chemical conversion and fixation of many materials, and predation of adult parasites and larvae. This process not only allows for the development and enhancement of wetlands and wildlife renewal, it also provides additional treatment for wastewater effluent in a very economical and environmentally sound process.

Wetlands design and operation primarily concerns itself with overall risk reduction. This is accomplished by carefully adhering to the checks and balances of the natural wetland cycles. These characteristics are evident through the following wetlands
enhancement criteria:

1. Cultivate a diversity of plant and animal life;
2. Allow for water level and flow rate changes incurred through natural periods of drought and flooding;
3. Allow isolation ponds for wetlands maintenance;
4. Manage for deep and shallow areas;
5. Harvest vegetation to remove pollutants if needed.

Artificial wetlands are also a very inexpensive alternative to revitalize Florida's diminishing aquifer supply. Although direct injection of *advanced wastewater* is a viable option for immediate salinity barriers, it is nevertheless a very costly alternative in terms of treatment and application. As previously mentioned, this practice is often reserved for critical intervention to restore severely diminished groundwater. Reclaimed wetlands are not only an economically and ecologically sound method of nitrogen and phosphorous removal, they additionally provide a natural alternative to safe groundwater recharge.

5.7 Other Reuse Alternatives

Ornamental and architectural reuse is yet another low flow, low consumption alternative that could benefit from the supply of reclaimed water. Pursuant to F.A.C. 17-610.479, reclaimed water may be used for aesthetic purposes. Such uses include, but are not necessarily limited to decorative fountains, ponds, lagoons, and pools.[6] Such water however, must be treated with carbon adsorption to remove any unpleasant odor or color causing constituents. Such water may additionally be dyed an aesthetically pleasing color of blue, which may serve as a further means of differentiation with potable impoundments.

Trap priming is another low consumption, non-potable alternative that could potentially benefit from reuse. In structures where toiletry units may be left unused or in need of periodic flushing, reuse could provide non-potable water ideal for clean-out activities or trap priming. This potential potable supplement would enhance wastewater flow efficiency and prevent the extrusion of septic gases into the dwelling unit from evaporated trap seals. Non-potable washdown has found widespread acceptance in the industrial sect where public contact is virtually eliminated. Although multi-level, multi-unit commercial and residential washdown could be economically achieved using only locked below grade vaults or limited access valves as previously described, such reuse may only be implemented under strict operating management. It is recommended that this potential alternative be restricted until satisfactory experience with other more feasible applications be obtained.

5.8 Summary

The added provisions for the use of reclaimed grey and domestic wastewater for non-potable reuse are in most cases, minimal. Research has demonstrated that reclaimed water that has been treated and distributed within the conditions stated herein, can be used with little or no modifications to existing non-potable fixtures, and little or no modifications in the manner in which they are used. Reuse hypothetically will earn the advantage of shifting the non-potable demand to reuse supply, thereby reducing the demand and subsequent dimension of the potable water system. *Primary* non-potable consumers such as toilet and urinal flushing account for 70% or more of commercial potable demand, yet require little, if any *fixture* modification prior to reuse. Drip irrigation using direct greywater or reclaimed wastewater results in lesser initial construction costs through the elimination of costly groundwater well points and pumping equipment, in addition to a more effective irrigation effort free of water restrictions, significant evaporation, and public contact. *Tertiary* non-potable alternatives such as fire suppression, trap priming, and limited washdown may not in themselves provide economic nor environmental justification for dual distribution, yet should be implemented if reuse distribution is planned for primary and secondary applications.

5.9 References

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CHAPTER 6
URBAN WATER CONSERVATION

6.0 Introduction

Water conservation is any activity which reduces water demand, either by engineering or social practice. A variety of programs currently exist in the United States which lower the consumptive use of domestic water. *Structural* water conservation strategies are those which consist of engineering, hardware, and systems. *Nonstructural* water conservation strategies are those which consist primarily of software, policies, and operations. Examples of devices used in structural water conservation include lawn irrigation timers, swimming pool covers, low-flow fixtures, fixture aerators, toilet dams, and pressure restrictors. Nonstructural strategies can incorporate water supply rationing, low minimum water use charges with increasing unit price rates for increasing total water use, seasonal water fees, and penalties for excessive or select water uses. Water reuse strategies such as wastewater reclamation and greywater recycling involve both structural and nonstructural water conservation and have proven most effective to reduce water demands. Results are generally immediate, permanent, and greeted with a high degree of consumer confidence.[3]

Active water conservation involves structural and nonstructural water conservation strategies that directly reduce water demands. *Passive* water conservation techniques, or those that do not directly reduce flow at a fixture or a system, generally involve indirect reductions in water by reducing user flow requirements. This may be accomplished by water efficient building designs that locate fixtures in the proximity of supply sources and hot water heaters, low irrigation landscaping, or by a wholesale change in water conservation habits by the user. Although the level of water reduction achieved using passive techniques is largely dependent on the user's willingness to employ them, such techniques are the least costly and the easiest to integrate into mainstream water conservation.

6.1 Structural Water Conservation Strategies

Active Low-Flow Techniques

1. Use low-flow shower heads that restrict water flow to 2.5gpm or less. Low-flow shower heads implement aeration that reduce droplet size, thus greatly increasing the surface area and velocity of water per equal volume. The result: user satisfaction and shower effectiveness is maintained while reducing water demand as much as 30 gal/shower/person.

2. Use low flow toilets for a low-flow, economically viable alternative for reducing water demand to as little as 1.6 gal./flush. Existing fixtures can implement toilet dams, which reduce the capacity of the conventional closet and the subsequent filling capacity per flush. Consideration should be given to the layout and condition of soil fixtures and waste lines to ensure that an adequate "slug" of water is provided to properly remove all wastes. Clogging, dual-flushing, and insufficient hydraulic loading as a consequence of too little flush water may prove more harm than good.

3. Use a *point-of-use* hot water heater. A 2 gallon, electrically heated tank can be placed at sink and lavatory location to provide instant hot water at a cost of $108.00 or less.

Passive Low-Flow Techniques

1. Design hot water fixtures and supply water heaters in a central and close proximity to each other. Running water until it reaches a suitable temperature at the point of use wastes water and energy. Hot water remaining in excessive piping lengths after use cools and will be likewise wasted when the fixture is used again. Zone distribution schemes using two or more small hot water heaters in place of a single large heater in large and/or multi-level residences can mitigate this problem.

2. Store drinking water in the refrigerator to avoid having to run tap water until it is cool.

6.1.1 *Low Flow Fixture Requirements and Legislation*

A growing number of states have either mandated the use of low-flow fixtures or are currently amending applicable legislation requiring their use. The proposed *National Plumbing Products Efficiency Act*, a newly signed bill, will soon require the construction industry to implement low consumption fixtures and products on a nationwide basis. Tables 6.1 and 6.2 on the following page identify states having or considering low consumptive plumbing product regulations.

Table 6.1 States having low consumption product regulations.
A Review of Products, Processes, and Practices. Residential Water Conservation, Research Division, CMHC, Ottawa, Canada, p. 41.

State	Effective Date	Water Closets	Urinals	Shower Heads	Lavatory/Kitchen Faucets
CA	1/1/92	1.6 gal.	1.0 gal.	2.8 gpm	2.0 gpm
CO	1/1/90			2.5 gpm	2.5 gpm
CT	10/1/90 1/1/92	1.0 gal. 1.6 gal.	2.5 gpm	2.5 gpm	2.5 gpm
GA	7/1/91	1.6 gal.	1.0 gal.	2.5 gpm	2.0 gpm
MA	3/2/89 9/1/91	1.6 gal. 1.6 gal.		3.0 gpm	
NY	1/26/88-	1.6 gal.	1.0 gal.		2.0 gpm
RI	9/1/90	1.6 gal.			
WA	7/1/93	1.6 gal.	1.0 gal.	2.5 gpm	2.5gpm

Table 6.2 States considering low flow product regulations.
A Review of Products, Processes, and Practices. Residential Water Conservation, Research Division, CMHC, Ottawa, Canada, p. 41.

State	Effective Date	Water Closets	Urinals	Shower Heads	Lavatory/Kitchen Faucets
AZ	1/1/92	1.6 gal.	1.0 gal.		2.0 gpm
DE	1/1/91	1.6 gal.			2.5 gpm
NJ	7/1/91	1.6 gal.			
PA	7/1/92	1.6 gal.		2.5 gpm	2.0 gpm
TX	9/1/92	1.6 gal.	1.0 gal.	2.8 gpm	
OR	7/1/93	1.6 gal.	1.0 gal.	2.5 gpm	2.0 gpm

6.1.2 *Low Flow Systems*

Low-flow distribution mechanics, greywater collection, and rainwater harvesting for non-potable irrigation are considered *active* water conservation techniques. Indirect, or *passive* water conservation techniques consist of landscaping, zeriscaping, site orientation, and other environmentally conscious methods for reducing water irrigation demands.[1]

Active Irrigation Techniques:

1. Use a soaker hose. Although not quite as effective as subsurface drip irrigation, surface "weep" lines allow slow rate drip irrigation by greatly reducing water loss due to evaporation and overspray. Although effluent or reuse surface drip is considered undesirable, it is less expensive to use and maintain than subsurface leaching and is not subject to water use restrictions at residential scale.

Passive Irrigation Techniques:

1. Reduce your lawn area. Use more mulch, especially those consisting of recycled polymers such as those made from discarded automobile tires. Use native plants and shrubs that require little irrigation and no ground and surface water hazardous insecticides or fertilizers.

2. *Xeriscaping*$_{tm}$, or the passive use of native landscaping plants and grasses, has demonstrated the ability to save 30% - 80% of the a typical Floridian's outdoor irrigation demand, which can account for 50% or more of the average homeowner's water use. Xeriscaping can be achieved using seven basic principles consisting of:

    1. Planning and design
    2. Soil analysis
    3. Appropriate plant selection
    4. Practical turf areas
    5. Efficient irrigation
    6. Use of mulches, ground cover
    7. Appropriate maintenance

To maximize energy and water efficiency, shading patterns should be developed based on site orientation and locations of shrubs and trees. Shading of east and west planes of a typical site plane will reduce evaporation and also provide cooling of east and west walls of the structure. Passive landscape concepts should be designed to reduce operational components and maintenance, orient plants of similar cultural requirements, use mostly drought tolerant plants, and utilize water conserving irrigation systems such as a greywater drip irrigation. Other passive irrigation techniques involved in the Xeriscaping technique are the grouping of plants according to their water and sunlight requirements to provide a more effective irrigation strategy.

6.2 Non-Structural Water Conservation Strategies

Before the advent of modern mechanical engineering, the finite nature of potable resources remained in perspective and in efficient use. Today, technological advances place increasingly less value on such resources and continue to exploit potable reserves in favor of developmental and economic gain. As a result, the consumer errantly perceives domestic water as an inexpensive "utility" rather than a life-sustaining, exhaustible resource. Legal considerations further contend water optimization techniques such as water reclamation to be an unacceptable alternative by overestimating unfounded health concerns and underestimating the true value and sustainability of the dwindling supply. Therefore, the public perception surrounding resource conservation, reclamation, and reuse presents the most significant element of non-structural water conservation.

6.2.1 *Public Perception and Reuse Education*

Bridging public misconception of recycled wastewater remains a critical issue of concern for reuse acceptability. The success or failure of many reuse projects, both municipally and on-site, will be determined to a large extent by public acceptance. Because of this, such factors as reuse sociopsychology, sociodemographics, and socioeconomics represent prime motivating elements for public acceptance of recycled wastewater.[4] Traditionally, water conservation and environmental consciousness has mistakenly given the impression of economic hardship and personal sacrifice. To correct this skewed ideology, effective consumer communication must first convey that inspite of its title, wastewater is a resource in itself, relegating reclamation as simply a more ecologically efficient use of an existing natural resource in a safe and economically practical manner.

Educating the potential user must be a priority, and may easily be accomplished through the distribution of printed information citing the intent and purpose of the reclaimed water system. Such literature should clearly address controversial issues such as initial cost increases, cross-connection control, reliability, and potential health hazards. Research has indicated that general acceptance rates for extensive commercial and residential reuse can vary from 40% to nearly 90% depending largely on the manner in which the context of such issues are phrased and implemented.[4] For example, terms such "reuse" or "recycled water" should always be used in place of such distasteful terms such as "sewage" or "used wastewater".

6.2.2 *Sociopsychological Influences*

In order to categorize the overall concept of public acceptability, it is proposed that its constituent elements be separated and placed into ordered patterns. The foremost variable influencing the acceptance of dual distribution as identified by William Bruvold of the School of Public Health, University of California involves the degree of bodily contact. By dividing the potential uses of reclaimed water into three categories, (1) direct contact (ingestive), (2) limited contact (non-ingestive), and (3) non-contact, several interesting relationships become apparent. Although 48%-55% of those polled generally opposed direct contact, only 32%-22% considered limited reuse unacceptable, and less than 20%-0% expressed opposition to commercial and residential non-contact reuse.[4] Ranking the data by the degree of acceptance (1 = highest acceptance, 13 = lowest acceptance) research indicates that as the degree human contact decreases, sociopsychological opposition to reuse proportionately decreases (Table 6.3).

Table 6.3 Rank order of acceptance of uses of reclaimed water by degree of contact.
Middlebrooks, E.J. *Water Reuse*. Ann Arbor: Ann Arbor Science Publishers, Inc., 1982.

Degree of Contact	Survey 1	Survey 2	Survey 3	Survey 4
Non-contact reuse:				
Municipal irrigation	2	1	1	1
On-site irrigation	2	2	2	2
Wetland restoration	6.5	3	3	3.5
Mechanical cooling	2	5	4	6.5
Toilet flushing	4.5	4	6	5
Aesthetic impoundments	4.5	6	5	3.5
Limited contact reuse:				
Laundry	9	8	8	8
Recreational impoundments	8	9	9	9
Washdown	10	10	10	10
Direct contact:				
Cooking	11.5	11	12.5	11
Food canning	11.5	12	13	13
Drinking	13	13	12.5	12

6.2.3 *Sociodemographical Influences*

Education remains a primary socioeconomic factor repeatedly demonstrated to affect the acceptance of virtually all technological advancements. In a Clark University study, only 26% of the respondents with grade school educations approved the use of reclaimed water as compared to nearly 65% with some college.[4] Gender may also influence the public acceptance of water reuse. In the Carley study conducted for the AWWA in the 1970's, research conclusively showed that women were less accepting of reclaimed water for limited and direct contact roles than men with equivalent educations. Several studies have indicated age as being the third most influential sociodemographic determinate towards reuse acceptability. Research results have shown an inverse relationship between age and the acceptance of reuse distribution. Older individuals and those residing in areas formerly using conventional water resources were least favorable toward uses of reclaimed effluent.

Finally, regional demographics and associated environmental conditions have shown profound influence on the acceptability of public reuse. Areas of sufficient potable supplies such as the northeastern United States have shown less than 35% approval for reuse as opposed to nearly 70% approval in water scarce or densely populated regions of the southwest and Florida. The reasons for such derivation are considered to be effected by experiences with previous reclamation efforts, water shortages, or a simple lack of interest. Individuals who have been successfully educated on the finite and dwindling nature of their water resources have demonstrated the highest levels of acceptance. Successfully communicating to the general public the inability of potable supplies to efficiently meet future water demands remains statistically significant for any reuse implementation project.

6.2.4 *Socioeconomical Influences*

Although water reuse has preempted positive public response to potable reduction, reuse has similarly resulted in strengthened acceptance as a proven method of reduced environmental degradation. Of nearly all U.S. Office of Water Resources inquiries, 74% or better responded favorably to the concept of wastewater reuse to prevent potential contamination of potable resources as opposed to a 50%+ cost increase to treat an increasingly contaminated water supply without reducing wastewater discharge.[4] When water recycling is viewed economically beneficial to increase potable water quality and reduce potable water demand, reclamation is almost always greeted with a positive public response.

The generalization that the degree of bodily contact remains the prime element behind the acceptability of water reuse is further supported by the uniformity of opinion from respondents consisting of similar sociodemographical and socioeconomical characteristics. Research has indicated that inspite of initial cost increases, the public generally approves the non-contact and limited contact use of reclaimed water if public health, life-cycle economics, water optimization, and environmental enhancement are effectively demonstrated.

However, research has also shown that the level of public acceptability for hypothetical reuse (public opinion data, POD) is not always indicative of the actual level of public reuse acceptability (opinion rating data, ORD) when dual distribution becomes a serious consideration. The actual level of acceptability in this scenario tends to be much higher for non-contact alternatives and reduces linearly as the degree of human contact increases. From the regulatory perspective, a policy analysis has systematically considered health effects, environmental effects, treatment costs, distribution costs, and public opinion data (PAD) for many of the specific reuse options. The general trend revealed by this analysis shows that the policy data is roughly parallel the public opinion data inspite of being consistently more negative.

6.2.5 *Legality of Reuse*

The legal distinction between planned and unplanned reuse influences such factors as water quality, quantity, distribution, and intended reuse. Planned reuse will generally encompass all deliberate alterations of existing hydrological cycles and conventional distribution to reduce potable demand and reduce wastewater discharge in an economically and environmentally sensible manner. Planned reuse may be subjected to the mandated or implied rules, regulations, and policies of several federal statutes and responsible agencies. Current national policy requires that "best practical efforts toward the conservation and prevention of wastewater discharge be exercised prior to any justification of new water projects or expansions". The legislation on the following page corresponds to the national water policies potentially affecting wastewater reuse.

National Water Pollution Control Act, (NWPCA)

The NWPCA and its associated amendments constitute the most direct control over wastewater discharges and potential water reuse. Standards established by this act relevant to reuse include toxicity, effluent quantity, and thermal discharge. This Act has essentially established the requirement for all states to reduce wastewater emissions and reduced energy or associated resources for wastewater treatment. Although economic incentives are provided under the Clean Water Construction Grant Program for those projects in compliance with the enforceable requirements of the Act, assistance for dual distribution may be precluded unless pollution control is the primary objective.

National Environmental Policy Act, (NEPA)

The NEPA requires that a detailed environmental impact analysis (EIS) be included in every proposal that may significantly affect the quality of the human environment. Commercial and residential on-site reuse could be subjected to federal EIS for several reasons including reuse for ornamental or irrigation purposes that could adversely impact neighboring inhabitants. The diverse legal, administrative, and special interest bureaucracy may reduce innovative dual distribution projects to less attractive, costly conflicts.

Safe Drinking Water Act, (SDWA)

Under this federal provision, any discharge of reused water or integration of reclaimed water with potentially potable resources failing water quality standards is subject to cease and desist orders. The standards could preclude reuse if disposal of sub-quality effluent is prohibitively expensive or practically impossible.

Without the strong guidance and supervision of federal influence, states exercise their right to appropriate the use and reuse of water resources, often enacting comprehensive standards more rigid than federal criteria. The State of Florida maintains its position to oversee all aspects of wastewater treatment, reclamation, and permissible reuses as part of its protective responsibilities. The state therefore determines specific water allocation schedules, appropriate water uses, and exercises complete autonomy over most health and safety concerns. The following condensed survey illustrates legislation that responds to the water policy of the State of Florida potentially affecting wastewater reuse. Although the legislation on the following page is not inclusive of all national, state, and local reuse considerations, it nevertheless contains the prominent initiatives and regulatory legislation for the reuse of grey and domestic wastewater within the State of Florida.

Chapter 17-4, FAC, Permits
This statute requires performing reuse feasibility studies prior to permitting new or expanded surface water discharges.

Chapter 17-302, FAC, Surface Water Quality Standards
This statute reiterates the requirement of the feasibility study prior to the permitting of new or expanded surface water discharges.

Chapter 17-40, FAC, Water Policy
This statute makes reuse mandatory in "critical water supply problem areas" if economically, technically, and environmentally feasible.

Chapter 17-600, FAC, Domestic Wastewater Facilities
This statute defines terms pertaining to reuse and treatment standards such as levels of disinfection and reliability.

Chapter 17-610 Part III, FAC, Reuse of Reclaimed Water and Land Application
This statute describes comprehensive rules governing the use of reclaimed water. It is attached to this report as Appendix I.

Section 403.064, Florida Statutes (F.S.)
This section promotes reuse of water as a state goal and requires reuse feasibility studies in designated "critical water supply problem areas".

"Guidelines for Preparation of Reuse Feasibility Studies for Applicants Having the Responsibility for

Wastewater Management" Florida DER, 1991.**
This document describes the Florida DER guidelines for conducting reuse feasibility studies.

6.3 Summary

The use of low flow fixtures has undoubtedly resulted in a net positive gain for the user, who invests in domestic and waste water services, the municipality which provides such services, and the environment, which "generates" raw potable water and ultimately assimilates the resultant wastes. The *extension of service life* for water works infrastructure is possible since treatment plant operating costs for both domestic water and wastewater are directly proportional to the amount of raw water and influent to be treated. *Lower operating costs* for wastewater and reclamation facilities are obtainable since the gross volume of influent is reduced and is more concentrated. *System cost reductions* in both infrastructure and on-site water and wastewater piping and equipment also result from reduced demands and hydraulic loading. Residential developments utilizing low-flow fixtures commonly save a quarter or more water when compared to similar communities that do not. In fact, the use of 1.5 gal. low-flow flush toilets has alone resulted in reductions of domestic water use and resultant wastewater discharges of 23% in residential environments compared to nearly 50% in commercial office settings. The further use of toilet dams in standard 4.5 gal. flush toilets with aerated fittings applied to all potable outlets have systematically reduced domestic demands and wastewater discharges in half.

Perhaps the single most unpredictable design element affecting the implementation of grey and domestic wastewater reuse is the ambiguity of public and institutional acceptance. The most critical misconception held by both are unrelated to reuse quality, reliability, or cost; but rather the premise that potable resources are infinite. A public reuse education program may consider the following influential subjects:

1. The critical need for additional water supplies.
2. The scarcity of additional water supplies.
3. The cost of additional water supplies.
4. The environmental impact of developing additional water supplies.
5. The status of wastewater recovery, treatment, and reuse technology.
6. The safeguards incorporated in wastewater recovery and reuse such as process redundancy, multiple barrier design, and reliability limits.

Although the conservation of water resources is well within reach, it remains imperative that appreciable reductions in water demands do not conceive further development and resource exploitation. If more water efficient systems, both active and passive are not met with a tangible regulation on regional population growth and over development, then continued resource overdraft and environmental degradation will proliferate as a consequence.

6.4 References

1. Stark, Judy. *Learning to do with less water*. St. Petersburg Times, 3 July 1994, p 1B, 6B.

2. *A Review of Products, Processes, and Practices*. Residential Water Conservation, Research Division, CMHC, Ottawa, Canada, p. 41.

3. Popkin, Barney P. *Strategies for Reuse and Conservation.* WATER/Engineering & Management: March 1982 p.36-41.

4. Middlebrooks, E.J. *Water Reuse*. Ann Arbor Science Publishers, Inc. Ann Arbor: 1982.

CHAPTER 7
ECONOMIC ANALYSIS AND SYSTEMS SELECTION RATIONALE

7.0 Introduction

Application of economic models to evaluate returns on the variety of reuse and conservation strategies are often plagued with numerous technical and economic uncertainties. These include unproven or limited technical performance data on *structural* and *non-structural* strategies, unknown future water values, fluctuating inflation rates, undefinable costs and benefits, fee structure, and public education.[2] Those strategies that incorporate engineering, hardware, and physical systems to reduce potable water demand commonly use a *structural economic evaluation* to calculate the *net present value* (NPV) of a select unit or engineering system. The NPV in terms of future benefits in relation to future costs can be determined as:

$$\mathbf{NPV = [W + S + E] - [A + I + M + R]}$$

Where,

W = water savings cash value
S = sewage savings cash value
E = energy savings cash value

A = acquisition cash value
I = operation cash cost
M = maintenance cash cost
R = replacement cash cost

The procedure is simple, and can be used by consumers and utility companies to evaluate not only device selection, but also adequate fee strategies. Unfortunately, non-structural strategies are more difficult to evaluate. Nevertheless, since non-structural approaches have benefits and costs, their net present value can be computed using this technique as well.

In any detailed economic analysis, it is necessary to relate the *short*, *mid*, and *long-term* cost/benefit ratios to derive the average value of reuse strategies such greywater recycling and wastewater reclamation to that of conventional water resource conservation. Table 7.1 shows a relative ranking of overall economic and technical performance comparison of reuse and conservation strategies. Structural and non-structural strategies are compared over the short, mid, and long-term. The *1 - 10* ranking is based on the best overall performance of 10. The ranking suggests that the optimal short-term performances are non-structural water conservation strategies, while the worst short-term solutions are structural reuse strategies. The best long-term performances are structural reuse strategies, while the worst long-term performances are non-structural reuse strategies. Table 7.2 shows generic strategies that appear to be most likely to provide favorable economic benefits to cities and individuals.

Table 7.1 Ranking of strategies.
Popkin, Barney P. *Strategies for Reuse and Conservation.* WATER/Engineering & Management: March 1982 p.36-41.

STRATEGY		TERM: Short	Mid	Long
Structural	Conservation	4	6	8
	Reuse	1	3	5
Non-Structural	Conservation	10	8	6
	Reuse	8	6	4

Table 7.2 Most favorable strategies.
Popkin, Barney P. *Strategies for Reuse and Conservation.* WATER/Engineering & Management: March 1982 p.36-41.

STRATEGY		TERM: Short	Mid	Long
Structural	Conservation	–	Water Reducers	
	Reuse	–	–	Water Recycling
Non-Structural	Conservation	Policy, Education, Economic Incentives		
	Reuse	Economic Incentives		–

7.1 Water Resource Economics

Many utilities throughout central and southern Florida have been mandated to reduce yearly water consumption 4%, leading many to believe that further water restrictions, building moratoriums, and resultant unemployment is only imminent. Yet utility metering and pricing structures have themselves become suspect by actually penalizing water conserving users. Typically, water rates and subsequent wastewater discharge costs are based on volume of potable water consumed by the user, maintaining that most if not all potable water will ultimately reach municipal sewer systems. However, with the exception of St. Petersburg, four of the five principle municipalities within the Tampa Bay area only charge sewer costs as a function of the first few thousand gallons used, assuming that additional water will be used in the form of lawn irrigation and other "non-return" applications. As a result, water used for human sustainment is commonly twice as expensive as water further used for lower priority needs and recreation.

Although a compelling argument can be made that it is unfair to levy sewer charges on water that will never become sewage, the cost of treating and delivering potable resources however are often intended to be absorbed by the cost of both. Furthermore, economists at the Southwest Florida Water Management District (SWFMD) say that utilities are nevertheless sending an economic message that discourages water conservation.

In Hillsborough County for example, residential customers pay $1.72 per 1000 gallons of domestic water for the first 8,000 gallons. The treatment and disposal of the corresponding sewage is over 3 times as much at $5.25 per 1000 gallons of domestic water used. Although water rates slowly rise as water use accelerates beyond 8,000 gallons, the maximum rate of $3.60 per 1000 gallons above 50,000 gallons used does begin to compensate for the $5.25 associated sewage charge that is eliminated in full after only 8,000 gallons used. The result: a conservation minded family using only 7,500 gallons per month will pay $52.00. A wasteful user consuming twice as much pays only $16.00 more. Figures 7.1 and 7.2 compare and contrast water and sewer costs combined. The trend in this densely populated coastal region, closely representing much of urban Florida, illustrates water costs increasing at barely half the rate of the associated water used.

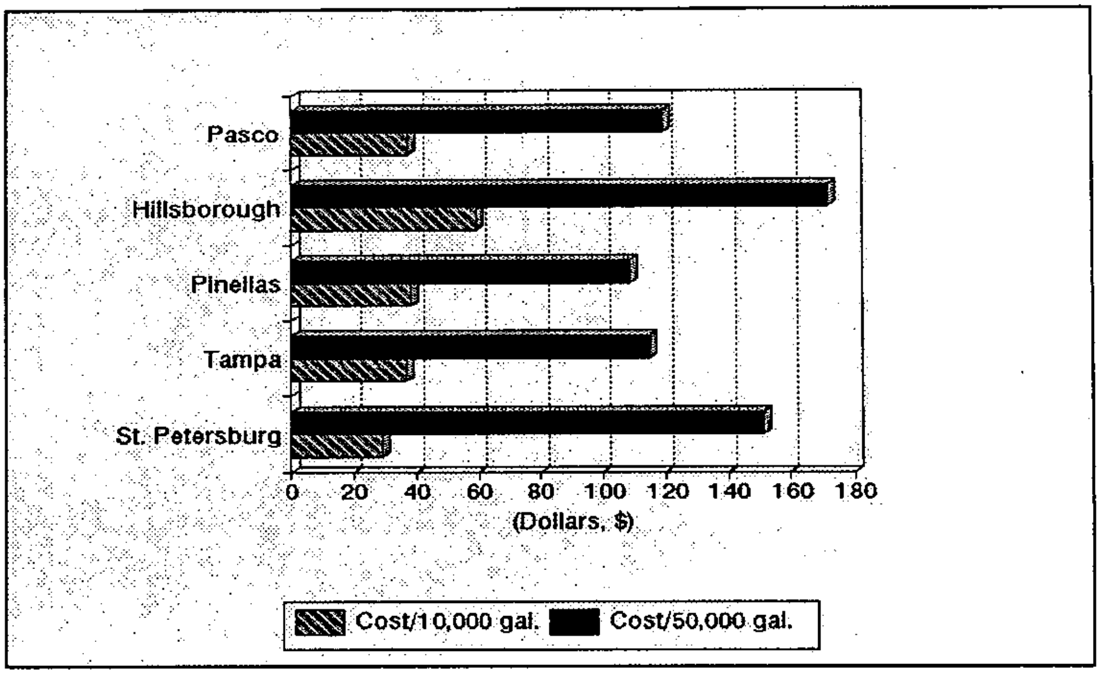

Figure 7.1 Residential water costs per month for Tampa Bay area.
Olinger, David. *The more you save, the higher the price.* St. Petersburg Times, 3 July 1994, p 1B, 6B.

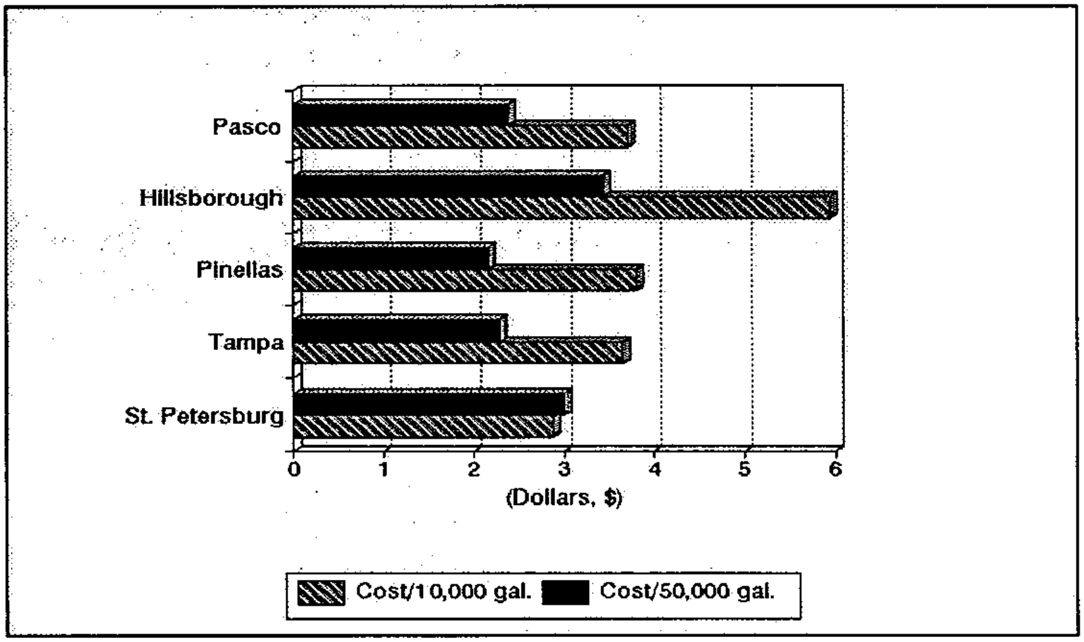

Figure 7.2 Residential water costs per 1,000 gallons for Tampa Bay area.
Olinger, David. *The more you save, the higher the price.* St. Petersburg Times, 3 July 1994, p 1B, 6B.

7.2 Economic Factors

Once greywater recycling or full wastewater reclamation is determined to be the most viable option for cost-effective water optimization under existing circumstances, the focus should then be concentrated toward developing the "concept" into suitable means for dual distribution. Aside from environmental concerns and public perception, reuse economics will most likely be the determining factor regarding the extent, or the further existence of greywater recycling or wastewater reclamation. Numerous economic factors categorized as "system specific costs and benefits" must be addressed when evaluating the life cycled present worth (PW) of on-site reuse in relation to its estimated return. Primary economic factors involve the design, construction, and method of payment attributable to the initial cost of dual distribution. Other factors may include operating costs, economic life, maintenance, interest rate, discount rate and the value of benefits. Such proposed factors will be briefly defined and implemented within a sample reuse analysis and selections evaluation in the following text.

7.2.1 *Initial Costs*

The first of the direct costs termed "initial costs", may include the cost of design, system components, the cost of shipping these components, the taxes involved, and the cost of installation. Estimates of initial costs should be reduced by any water conservation credits that may be offered by water utilities. Such credits may assume the form of a surcharge waiver, often appropriated to traditionally high impact consumers such as high-rise structures that subsequently reduce potable demand and wastewater discharge. It is proposed that initial cost accounting during preliminary design incorporate "ratio estimating" on an order-of-magnitude basis. This method involves the use of ratios based on the known characteristics of the reuse system in relation to known characteristics of conventional systems. Although the order-of-magnitude estimate may only achieve an accuracy between -30% to +15%, it nevertheless is considered an invaluable economic instrument in screening potential design options.

Example 7.1

1. Consider the structure to be classified as a Type 1 residential high-rise, consisting of 170,000 gross square foot of floor area, 200 units, 1000 tenants, 270,000 GPD potable demand, and 207,000 GPD wastewater discharge. The Total Project Cost (TPC) is $17,000,000

2. Consider the initial costs associated with a complete water reuse system serving all potential non-potable applications as per Chapter 5.

3. Consider the use of on-site treatment to be 40% wastewater flow for Type A greywater reuse, and 60% wastewater flow for Type B blackwater reuse. Assume 40% potable and 60% non-potable demand using high volume zoning for all dual distribution supply.

4. Consider the use of single wastewater recovery piping for Type B blackwater systems, and dual wastewater recovery piping for Type A greywater systems.

5. Consider the initial costs of conventional plumbing under Type 1 residential high-rise designation to account for 4% of TPC, 60% of which is to be designated for potable and non-potable supply, 40% of which is to be designated for wastewater recovery.

6a. Consider the initial costs of Type A dual distribution, dual recovery to result in a 35% total developmental length (TDL) supply increase and 10% TDL wastewater increase assuming proportionate reductions in conventional distribution and recovery using a wet vent piping arrangement.

6b. Consider the initial costs of Type B dual distribution, single recovery to result in a 35% TDL supply increase and 0% TDL wastewater increase assuming proportionate reductions in conventional distribution.

7. Consider a typical high-rise surcharge fee of $30,000 or $45,000 to be waived for the implementation of Type A or Type B reuse systems respectively.

Initial cost analysis:

100%	of TPC	= $17,000,000	Total Project Cost	
4%	of TPC	= $ 680,000	Total Conventional Plumbing Cost	(TCPC)
60%	of TCPC	= $ 408,000	Total Conventional Supply Cost	(TCSC)
40%	of TCPC	= $ 272,000	Total Conventional Wastewater Cost	(TCWC)

Type A dual distribution:

TCSC + [TCSC * 35%] =		+	$ 550,800	(1)
TCWC + [TCWC * 10%]	=	+	$ 299,200	(2)
On-site greywater treatment	=	+	$ 215,000*	(3)
High-rise surcharge waiver	=	-	$ 30,000	(4)
Type A initial equipment cost	=		$1,035,000	(5) = [(1)+(2)+(3)-(4)]
Estimated Conventional cost	=		$ 680,000	(6)

Net	increase	$ 355,000
TCPC	increase	52.2 %
TPC	increase	2.1 %

Type B dual distribution:

TCSC + [TCSC * 35%]	=	+	$ 550,800	(1)
TCWC + [TCWC * 0%]	=	+	$ 272,000	(2)
On-site blackwater treatment	=	+	$ 546,480*	(3)
High-rise surcharge waiver	=	+	$ 45,000	(4)
Type B initial equipment cost	=		$1,369,235	(5) = [(1)+(2)+(3)-(4)]
Estimated Conventional cost	=		$ 680,000	(6)

Net	increase	$ 689,235
TCPC	increase	101.4 %
TPC	increase	4.1 %

* Adjusted treatment expenses in lieu of flow characteristics, water composition, and discharge balance.

7.2.2 *Operating and Maintenance Costs*

Operating costs are primarily related to energy and demand. Energy is consumed in the operation of reclaiming and reusing wastewater for dual distribution. In calculating long-term operating costs, it is imperative to consider the energy rates likely to be in effect over the useful life of the system. Projected yearly energy rates should be obtained from the local utility. Maintenance costs can also be projected on an annualized basis and may include the cost of replacement parts, replacement labor, equipment repair, and the cost of maintaining control systems. For combined wastewater treatment and dual distribution in large commercial applications, the annual operation and maintenance costs are typically 2% of initial equipment costs or approximately $0.15 per gross square foot (GSF).[4]

Example 7.2

1. Consider the structure be classified as a Type 1 residential high-rise, consisting of 170,000 gross square foot of floor area, 200 units, 1000 tenants, 270,000 GPD potable demand, and 207,000 GPD total wastewater discharge.

2. Consider Type A reuse capable of supplying 40% of the non-potable demand resulting in a proportionate 40% reduction in potable water formerly used for non-potable applications. Assume a 40% reduction in wastewater discharge.

3. Consider Type B reuse capable of supplying 60% (all) of the non-potable demand resulting in a proportionate 60% reduction in potable water used for non-potable applications. Assume a 60% reduction in wastewater discharge.

4. Consider the total Type A initial equipment costs to be $1,035,000 for 40% greywater reuse and 60% wastewater discharge.

5. Consider the total Type B initial equipment costs to be $1,369,235 for 60% blackwater reuse and 40% wastewater discharge. Assume added annual treatment and flow characteristics accounted within the initial cost.

Operating and maintenance analysis:

170,000 GSF x $0.15 per GSF = $ 25,500 average annual operating and maintenance cost

Type A dual distribution:

2%[$1,035,000 initial equipment cost] = $ 20,700 total annual operating and maintenance cost

Type B dual distribution:

2%[$1,369,235 initial equipment cost] = $ 27,384 total annual operating and maintenance cost

7.2.3 *Utility Costs*

An integral element of water economics involves limiting potable demand and subsequently reducing wastewater discharge. Although constituents of environmental concern, these factors pose intrinsic value to the water optimization scheme of reuse. For reclamation to be considered a viable alternative, it must be less expensive to reclaim an acre/ft of water than to import one. Utility costs, or those costs termed necessary to perform the basic function of the domestic and sanitary system, consist primarily of potable water, reclaimed water, and sewer fees. The combined costs associated with water and sewer in relation to total building flow are the principal factors guiding the economic acceptability of dual distribution.

Example 7.3

1. Consider the cost associated with domestic water and sanitary services to be moderate at $1.85/1000 gal and $0.75/1000 gal respectively resulting in a combined water and sewage surcharge of $2.60/1000 gal.

2. Consider the structure be classified as a Type 1 residential high-rise, consisting of 270,000 GPD potable demand, and 207,000 GPD total wastewater discharge.

3. Consider Type A reuse capable of supplying 40% non-potable demand resulting in a proportionate 40% reduction in potable water formerly used for non-potable applications. Assume a 40% reduction in wastewater discharge.

4. Consider Type B reuse capable of supplying 60% (all) non-potable demand resulting in a proportionate 60% reduction in potable water formerly used for non-potable applications. Assume a 60% reduction in wastewater discharge.

Utility cost analysis:

Conventional domestic flow	=	[270,000 GPD] x [365 D/yr]
	=	98.6 MGY
Conventional domestic cost	=	[98.6 MGY] x [$1.85/1000 gal]
	=	$182,410 total annual water costs
Conventional sanitary flow	=	[207,000 GPD] x [365 D/yr]
	=	75.6 MGY
Conventional sanitary cost	=	[75.6 MGY] x [$0.75/1000 gal]
	=	$56,700 total annual sewer costs

Type A 40% domestic reduction	=	[270,000 GPD] x [365 D/yr]
	=	40% [98.6 MGY]
	=	[59.2 MGY] x [$1.85/1000 gal]
	=	$109,520 total annual water costs

Type A 40% sanitary reduction	=	[207,000 GPD] x [365 D/yr]
	=	40% [75.6 MGY]
	=	[45.5 MGY] x [$0.75/1000 gal]
	=	$ 34,125 total annual sewer costs

Type B 60% domestic reduction = [270,000 GPD] x [365 D/yr]
= 60% [98.6 MGY]
= [39.4 MGY] x [$1.85/1000 gal]
= $ 72,890 total annual water costs

Type B 60% sanitary reduction = [207,000 GPD] x [365 D/yr]
= 60% [75.6 MGY]
= [30.2 MGY] x [$0.75/1000 gal]
= $ 22,650 total annual sewer costs

7.2.4 *Economic Life and Interest Rate*

The economic life of an on-site dual distribution and reclamation system can be determined in a variety of ways. One way is to base it on the anticipated design life of the system itself, or its "useful life". Another is to base the system life on the anticipated life of the structure involved. Reuse systems technology at present estimate the typical useful life of dual distribution to extend approximately 20 years.[5] In lieu of the fact that most large-scale urban developments are constructed through lender financing, the interest rate paid in addition to the principal for borrowed funds determines the "real" cost of a reuse system and its components. Hypothetically, a "high" average interest rate of 12% will be used to evaluate the real cost of system specific costs and benefits over the economic life of reuse. However, an actual life-cycle economic analysis should always employ a sensitivity analysis when establishing an interest rate in lieu of its surmountable effect on the cost of dual distribution relative to worth.

7.2.5 *Discount Rate*

The discount rate is an interest rate applied in reverse to determine the present value of future investment. The present worth or present value is divided by the economic life of the proposed system to develop annualized cost data in "present worth dollars". In this scenario, one computes the future annual value of the initial cost investment in terms of present value dollars. By applying a capital cost recovery factor to the initial investment, the future annual value or amortized first cost of the initial investment can be determined for life-cycle reuse analysis. The capital cost recovery factor "**CCRF**" and the amortized investment "**A**" are calculated as:

$$\mathbf{CCRF} = [I(1+I)^n] / [(1+I)^n - 1]$$
$$\mathbf{A} = P\,[\mathbf{CCRF}]$$

where,

I = **Interest rate per interest period**
n = **Number of interest periods**
P = **Present sum of the initial investment**

Example 7.4

1. Consider the net initial investment increase of Type A dual distribution to be a present sum (P_1) of \$355,000.

2. Consider the net initial investment increase of Type B dual distribution to be a present sum (P_2) of \$689,235.

3. Consider the interest rate to be fixed at 12% compounded annually.

4. Consider the economic life of both dual distribution systems to be 20 years.[20]

Discount rate analysis:

$$CCRF = [I(1+I)^n] / [(1+I)^n-1] = [.12(1+.12)^{20}] / [(1+.12)^{20}-1]$$

$$CCRF = [\ 1.1575552\ ] / [\ 8.6462931\ ]$$

$$CCRF = 0.1338788$$

Type A dual distribution:

$$A_1 = P_1\,[CCRF] = \$355{,}000\ [0.1338788]$$

The increased future value or amortized first cost of \$355,000 for Type A dual distribution (A_1) will be equivalent to \$47,526.97 annual "disbursements" until the end of reuse service (n = 20 years).

Type B dual distribution:

$$A_2 = P_2\,[CCRF] = \$689{,}235\ [0.1338788]$$

The increased future value or amortized first cost of \$689,235 for Type B dual distribution (A_1) will be equivalent to \$92,273.96 annual "disbursements" until the end of reuse service (n = 20 years).

Table 7.3 Value of benefits summary for Type A and Type B dual distribution alternatives.

System specific costs	Conventional	Type A	Type B
Initial cost increase (P)	N/A	\$ 355,000	\$ 689,235
Operation and maintenance costs (O & M)	\$ 6,300	\$ 20,700	\$ 27,384
Economic Life (n)	20 yrs	20 yrs	20 yrs
Interest rate (I)	12%	12%	12%
Discount rate: amortized annual cost (A)	N/A	\$ 47,526	\$ 92,273
Utility cost: domestic water (\$1.85/1000 gal)	\$ 182,410	\$ 109,520	\$ 72,890
Utility cost: sewer (\$0.75/1000 gal)	\$ 56,700	\$ 34,125	\$ 22,650
Total annual costs	\$ 245,410	\$ 211,871	\$ 215,197

7.3 Economic Analysis Matrix

Cost/benefit calculations for a required resource are most often related to the market value using discounted cash flow techniques. Yet significant issues indirectly related to water economics such as environmental impact and public perception are not readily quantifiable in dollars. A variety of economic parameters are commonly involved in on-site reuse planning, design, and construction. Economic variables such as the amount and timing of the capital investment, O & M costs, and system life-cycle represent other intangible factors. The goal of reuse as a value-engineering alternative is to estimate dollar amounts for each of the reuse options and to then determine which alternatives offer the optimal cost benefit for each cumulative cost factor, both tangible and intangible.[3] Economic evaluations are most easily quantified using an *economic analysis matrix*, which subjects various reuse alternatives to present economic factors established in order of precedence. A numerical comparison is then drawn identifying the performance of each applicable alternative simultaneously. The weighted criteria can be revised or "re-weighted" providing the flexibility to improvise to changing design and economic conditions.

The order of precedence, or the "weight" each economic factor may have on the decision process within the analysis matrix may vary, depending on the building characteristics and the contractual arrangement between the owner, the builder, and the building occupants. In a "turn-key" operation where a developer has secured a short-term, high interest construction loan, the reward is quick sale and departure. In this scenario, the developer would have no economic incentive for implementing a higher initial cost, life-cycle valued dual distribution system unless such cost-effective reuse could pass profitable marketability on to the future owner or tenants. Figure 7.3 demonstrates the application of the analysis matrix using the economic criteria established in Example 7.5. The weighted criteria are arranged in order of precedence from the greatest economic determinate, in this case initial costs, to the least, a water/sewage impact surcharge waiver.

Example 7.5

1. Consider the building to be classified as a "Type 1" residential high-rise consisting of 200 sub-let units under owner/management.

2. Consider all utilities to be the sole responsibility of the tenant except sewage disposal and domestic water service. The maintenance of the complex grounds are additionally the responsibility of owner/management.

3. Consider the cost associated with domestic water and sanitary services to be moderate at $1.85/1000 gal and $0.75/1000 gal respectively resulting in a combined water and sewage surcharge of $2.60/1000 gal.

4. Consider that the functional analysis has identified four alternatives that adhere to the project constraints and recognize water optimization. The chosen alternatives consist of the following: (1) groundwater supplementation, (2) complete interior and exterior reuse, (3) direct greywater reuse for subsurface irrigation, and (4) the use of low flow fixtures and aerator fittings.

5. Consider the economic analysis criteria identified in descending order to consist of the following: (1) initial costs, (2) economic life, (3) discount rate (present worth), (4) domestic service reduction, (5) sanitary service reduction, (6) operation and maintenance costs, and (7) high-rise surcharge waiver.

Matrix instructions:

1. Insert the relevant economic analysis criteria into the vertical spaces proceeding the block entitled "Desired Criteria".

2. Insert the weight below for each respective criteria listed.

3. Below the block entitled "Alternatives", list the current design first followed by each of the proposed water optimization and reuse alternatives.

4. Place the appropriate rating (1-5) for each criteria in the triangulated space provided, based on the level in which the criteria is satisfied by the proposed alternative (excellent=5, very good=4, good=3, fair=2, poor=1).

5. Calculate the performance of each alternative by multiplying the criteria weight by the rating given in the triangular space.

6. Tabulate each row and rank each alternative in descending order. The alternative with the highest combined score will indicate the apparent water optimization choice, provided the criteria weight and rating are accurate.

DESIRED CRITERIA	INITIAL COSTS	ECONOMIC LIFE	DISCOUNT RATE	DOMESTIC COST	SANITARY COST	O & M	SUR. WAIVER	
	A	B	C	D	E	F	G	
ALTERNATIVES: CRITERIA WEIGHT	10	8	7	6	4	3	2	TOTALS
Current project (conventional design)	5 / 50	3 / 24	1 / 7	2 / 12	1 / 4	3 / 9	0	106
Supplemental source (groundwater withdrawl)	4 / 40	3 / 24	2 / 14	3 / 18	1 / 4	3 / 9	0	109
Complete reuse (interior and exterior)	3 / 30	4 / 32	5 / 35	5 / 30	5 / 20	2 / 6	5 / 10	163
Direct reuse (subsurface leaching)	4 / 40	2 / 16	3 / 21	3 / 18	4 / 16	2 / 6	0	117
Low flow fixtures	3 / 30	3 / 24	4 / 28	4 / 24	4 / 16	4 / 12	3 / 6	140

Figure 7.3 Reuse alternatives economic selections matrix.
Grosskopf, Kevin R. *Water Reclamation and Reuse Within Multi-Level Structures.* University of Florida, 1993.

Once the concept of reuse has been selected as the optimal VE proposal, a basic cost/worth ratio can be derived showing each potential reuse alternative in like terms. Briefly, cost involves the purchase of the item, whereas worth involves the least cost for performing the function as defined within the functional analysis. Therefore, the value of one reuse system, or the relation of its worth to cost, can be easily compared to that of another.

7.4 Economic Analysis Nomograph

To mitigate the labor intensive analysis of fluctuating system specific cost as previously illustrated, an integrated equation of interdependent linear relationships forming the basis of Figures 7.4 and 7.5 have been developed. The resultant "nomograph" as derived from a similar template originating in "Greywater Systems", HPAC, allows a rapid assessment of the economically beneficial characteristics of dual distribution systems by providing an inherent flexibility to adjust to a full range of water and sewer costs, water usage, initial cost increase, and fluctuating interest rates. It therefore establishes a uniform means of evaluating cost-effective dual distribution under a variety of potential circumstances. The nomograph is therefore considered applicable to most urbanized commercial and residential structures.

The proposed nomograph cannot account for several economic criteria such as varying grey to blackwater flow ratios characteristic of most commercial and residential structures. Furthermore, the nomograph is incapable of quantifying economic elements not associated with the system specific costs previously mentioned. The nomograph however, may be considered as a useful "slide-rule", providing a preliminary feasibility overview into the economics of the sample dual distribution systems contained herein. Figure 7.4 represents the nomograph being used to evaluate the preliminary economic feasibility of both "Type A" and "Type B" dual distribution systems in relation to the conventional alternative assuming the following conditions:

Example 7.6

1. Consider the system specific costs as provided in Examples 7.1-7.4 and summarized in Table 7.3.

Nomograph instructions:

1. Enter the lower right portion of the nomograph with the anticipated total potable water consumption for all uses based on the conventional system.

2. Move vertically up to the combined utility cost for water purchase and sanitary sewage charges (e.g. $1.85/1000 gal for water, and $0.75/1000 gal for sewage).

3. Move horizontally to the left to form "Baseline X".

4. In the upper right portion of the nomograph, enter the estimated additional cost (Total Project Cost percent increase) of the dual distribution system.

5. Move vertically down to the annual interest rate (cost of money) used in the analysis.

6. Move horizontally to the left to form "Baseline Y".

7. If the proposed reuse system is Type A dual distribution, go to the intersection of "Baseline X" and the Type A line of the nomograph located in the lower left quadrant.

8. If the proposed reuse system is Type B dual distribution, go to the intersection of "Baseline X" and the Type B line of the nomograph accordingly.

9. From the appropriate intersection, move vertically up to the horizontal separation line and then up and left at the indicated 45^0 angle to an intersection with "Baseline Y".

10. From this intersection point, move vertically down once again to the intersection of "Baseline X".

11. If the final intersection with "Baseline X" lies within the lower right field between the sector dividing line and the respective alternative, regardless of the type of dual distribution to be tested for, than resultant alternative would preliminarily appear feasible and should be subjected to more detailed economic analysis.

12. If the final intersection falls to the left and above the sector dividing line, then the economic feasibility of the scheme may be suspect.

The performance of the nomograph in Figure 7.4 is consistent with the life-cycled economic comparison obtained in Table 7.3 using the same system specific criteria. The nomograph strongly identifies reuse as economically feasible for both Type A and Type B dual distribution alternatives, the former providing slightly more potential. Research has identified that the costs associated with on-site Type A greywater treatment are not reduced proportionally to the reduction in wastewater flow and contaminate concentrations in relation to Type B blackwater systems. As a result, blackwater systems capable of recycling more than twice the flow of fecal wastewater, often resulted in a 69% initial cost increase while reducing potable demand and subsequent discharge nearly 60%. The life-cycle evaluations and nomographs demonstrate that Type A dual distribution or "limited" reuse systems, represent a rather small window of opportunity in relation to complete Type B reuse. Such systems are considered economically feasible mostly in residential structures implementing direct reuse or on-site treatment and attaining a minimum 40% greywater flow.

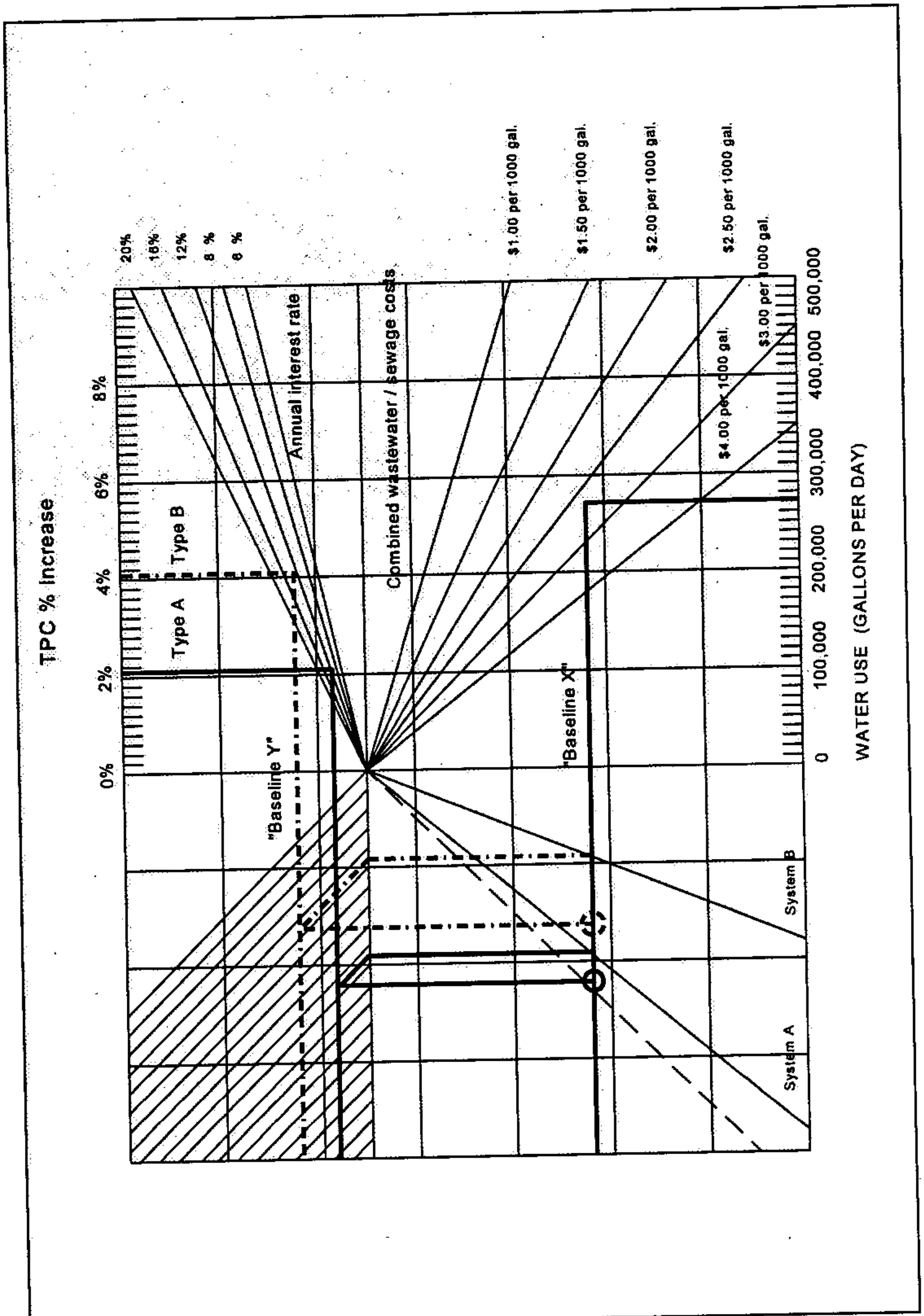

Figure 7.4 Grey and conventional wastewater reuse economic selections nomograph.
Grosskopf, Kevin R. *Water Reclamation and Reuse Within Multi-Level Structures*. University of Florida, 1993.

Further research involving the linear relationships of the nomograph has indicated a variety of other potential economic evaluations available. Assuming that the two most critical characteristics of any engineering economic analysis involves the cost of a product factored by the volume of such a product required, the total water use and combined water/sewage cost per 1000 gal will be evaluated in lieu of fixed systems costs and interest rates. By plotting a controlled range of water use or flow in relation to associated costs per 1,000 gal, other linear relationships can be developed. The point at which the plotted linear functions intersect the system selection lines can be considered the point of economic feasibility for that system.

The cost per 1,000 gal of combined waste and domestic water factored by the total flow per 100,000 gal of combined water and domestic water is the flow/cost factor (FCF). Values for a FCF are used to determine the minimum volume of such combined flow per 100,000 gal and combined cost per 1,000 gal to achieve economic feasibility to water use optimization such as dual distribution. A FCF is obtained by factoring any combination of flow and cost values that yield the same product, thus creating Baseline X. For example, to obtain the desired FCF of "4", one may plot any combination of flow/100,000 gal and cost/1,000 that factor to equal "4" (i.e., flow at 200,000/100,000 x cost at $2.00/1,000 gal or flow at 100,000/100,000 gal x cost at $4.00/1,000 gal). If a constant FCF is maintained, as in this case "4", a linear relationship of constant FCF values are thus plotted to form Baseline X.

The point at which the Type A function originating from Baseline X intersects the System A range at the dividing line is referred to as FCF_{Amin}. Similarly, the point at which the Type B function, or the test for Type B feasibility intersects the System B line is referred to as FCF_{Bmin}. The Type B function theoretically has no economic maximum, the only limits residing within the physical capability of the reuse system itself. The modified nomograph is thus able to distinguish the exact range of economic feasibility for each system under any given set of circumstances. For example, the nomograph in Figure 7.4 determined correctly that under given conditions, reuse would be economically feasible. Yet this preliminary usage of the nomograph would be unable to assess the performance of the system beyond "yes/no" terms, thus requiring laborious life-cycled economic analysis.

By employing the enhanced FCF method, researchers can not only determine whether or not reuse is economical, the FCF may also determine under what combinations of specific costs and benefits those systems delivering the optimal dual distribution potential. Figure 7.5 demonstrates the application of the proposed FCF under identical conditions employed in Figure 7.4. The Type A and Type B functions indicate the FCF_{Amin} and FCF_{Bmin} equivalent to 5.4 and 6.2 respectively. By reversing the nonmograph method from the point of FCF_{Amin} and FCF_{Bmin} on the FCF_A and FCF_B plotted functions, one can determine the required flow given a fixed cost, or the required cost given a fixed flow for the economic feasibility of each dual distribution system. For example, Figure 7.5 has identified FCF_{Amin}, or the point at which the Type A dual distribution system becomes an economical reuse alternative, as being 5.4. The resultant horizontal line will intersect both the cost and flow lines on given intervals.

If flow were the fixed variable at 2.0(100,000 gal) then Type A dual distribution would only be feasible if the combined costs were to exceed \$2.70 per 1,000 gal. However, if cost were fixed at \$2.00 per 1,000 gal, flow would have to exceed 2.7(100,000) gal for System A to achieve economic acceptability. In either case, the FCF_{Amin} factors to be 5.4. Maintaining the FCF_{Amin} and FCF_{Bmin} respectively provides a cost/flow assessment relative to fixed initial and interest investment costs.

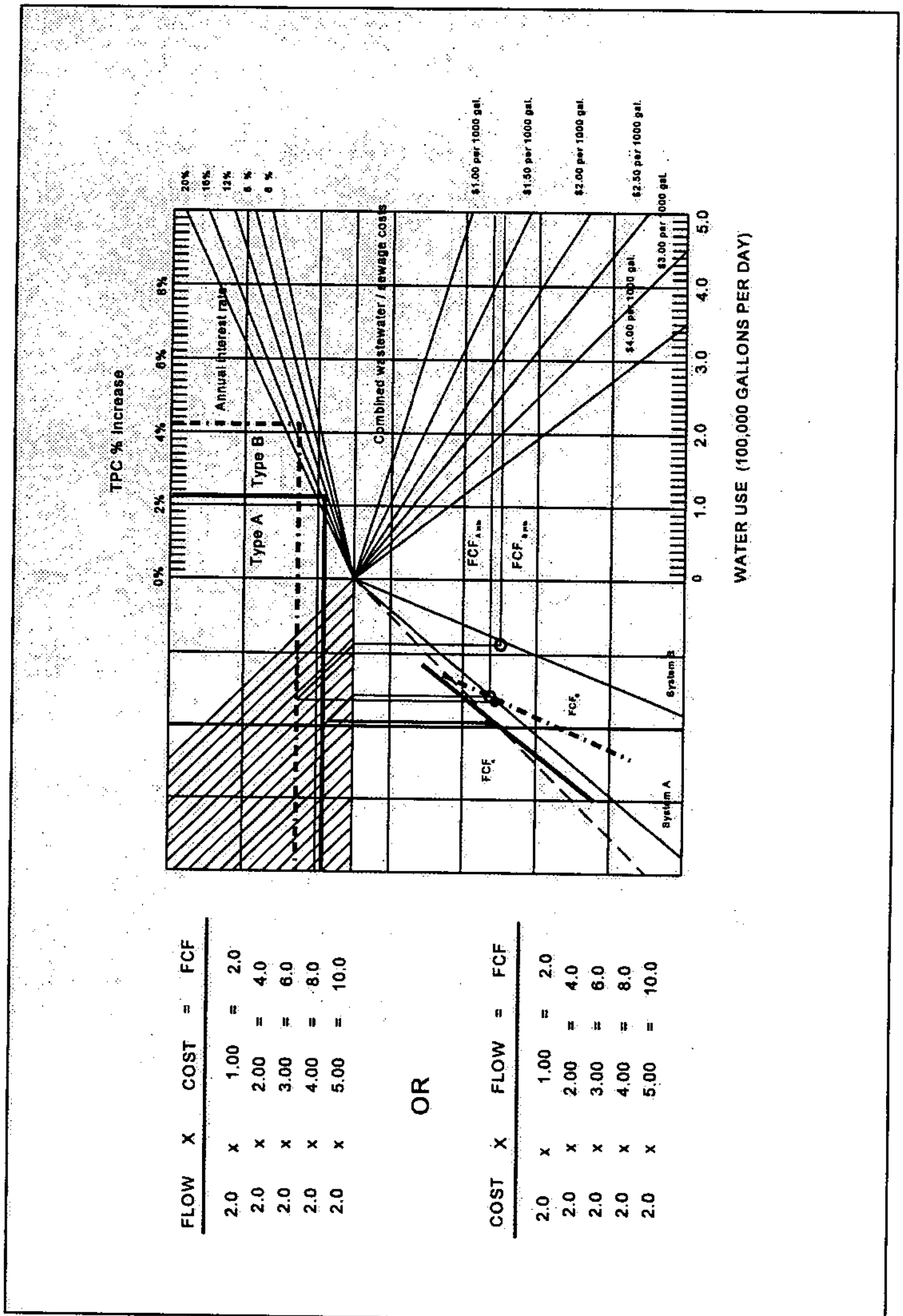

Figure 7.5 Flow/cost factor (FCF) selections nomograph.
Grosskopf, Kevin R. *Water Reclamation and Reuse Within Multi-Level Structures*. University of Florida, 1993.

7.5 Economic Abstracts

In an effort to assess the extent and magnitude of water cost increases throughout the United States, an AWWA sponsored survey entitled "The True Cost of Water" was intended to identify municipal water services supplying 1,000 people or more at costs exceeding $0.75/1000 gal. The AWWA concluded that the responding 55% of the 10,466 utilities projected costs significantly higher than expected and that no area of the country was immune to water shortages and subsequent high rates, regardless of regional demographics. States in the water plentiful Ohio River Valley were found to ensue water charges well in excess of even the most water scarce semiarid areas of the nation. Furthermore, it is suggested that high water rates have retarded economic development in such regions, regardless of water availability and urban or rural classification.

Half of the high rates are less than four years old. Additionally, 47% of the utilities indicated further cost increases within the next five to ten years. Only 1.4% of the utilities expecting rate increases cited water pollution or discharge requirements as a cause for the increase. Ninety percent or more required added per capita charges to recover the costs associated with augmenting existing supplies and reducing potable overdraft. A majority of municipal utilities have stated a need for additional water resources within the next five years. Therefore, market research pricing and application should prove useful to accurately assess the current economic state of potable resources and the validity of reuse distribution to supplement them.

7.5.1 *Market Research Pricing*

Although a fair, equitable, and effective water valuation must derive the intrinsic value of water to our society and the deficit of resources to the ecosystem, the true cost of water in terms of "human economies" remains the essential foundation for evaluating the economic feasibility of reclamation. Current water rates in Florida vary greatly, from $0.80 to nearly $8.00 per thousand gallons in select locations of the Florida Keys. Although several methods may be utilized to assess the value of potable resources, the true cost of water is often difficult to determine. The intention of the reuse economic analysis contained herein is to provide the flexibility to evaluate the potential for water recycling under a full range of fluctuating economic determinates. However, the outcome of any cost-benefit comparison will be largely predicated by the price of raw potable resources in relation to the life-cycled investment for dual distribution.

The greatest challenge for reuse acceptability rests not with systems analysis, but rather the traditional undervaluation of a limited potable resource. Methods of valuating water resources traditionally involve economic practices such a resource replacement cost and contingent valuation costs (willingness to pay approach). Although valid economic principals, such methods fall short in accurately assessing the intangible elements of resource depletion and environmental degradation. Florida's Water Reuse Task Force applied a general water pricing method termed "eMergy Analysis" to determine the overall cost of water. The eMergy of a resource equates to the energy cost of production of such a resource by the ecosystem. Although economists have greeted the method with skepticism through a misunderstanding of its thermodynamic intricacies and its relevance to the current market value, the eMergy method may nevertheless prove useful for long-term public policy and resource management. The results of the eMergy study derived at the University of Florida conclude that groundwater in Florida has a mean value of $0.90 per thousand gallons.[6] In lieu of market research pricing, it would be a reasonable assumption to expect water rates and associated surcharges to accelerate beyond the consumer inflationary rate, thereby providing greater discounted rates for reuse benefit relative to the interest debit on the initial systems cost.

7.5.2 *Market Research Application*

The Irvine Ranch Water District (IRWD) located in Orange County, California has implementing the first successful interior high-rise use of reclaimed water in the United States. In a value-engineering study conducted for interior potable and non-potable dual distribution, the following data (Table 7.4) were collected for the seven story Three Park Plaza using municipally supplied effluent. An economic analysis using the system specific costs and benefits listed in Table 7.4 indicates the potential for capital cost recovery within fewer than five years.

Table 7.4 Total water use, Three Park Plaza, Irvine California. State of California. Irvine Ranch Water District. *Reclaimed Water Use in Non-Residential Buildings.* Irvine: 1991.

Percentage of domestic (potable) water used	21.54%
Percentage of reclaimed (non-potable) water used	78.46%
Cost of domestic water	$0.53/1000 gallons
Cost of reclaimed water	$0.43/1000 gallons
Total estimated cost of construction	$28,240,000.00
Total estimated cost of conventional plumbing	$717,470.00
Total estimated cost increase (%TPC)	<1.0%
High volume water surcharge fee (deferred)	$35,110.00
Developer's capital cost increase (%TPC)	<0.5%

7.6 Summary

Greywater and domestic reclamation systems are classified as *structural reuse strategies*, or those that conserve water resources using engineered systems and hardware. Analysis has indicated that such reuse alternatives are a mid and long-term solution toward limiting water demands and subsequent wastewater discharge. Non-structural reuse and conservation strategies, or those that involve social change or policy toward conservation without the use of physical systems and hardware, have demonstrated exceptional short-term economic potential and have proven to remain productive well into the project life-cycle.

Tangible economic factors affecting the life-cycle economic benefits of a reuse alternative include initial costs, operations and maintenance costs, utility costs, economic life, interest rate, and discount rate. Tangible economic factors are easily quantifiable and present worth of a future structural reuse strategy are accurately determined. Intangible economic factors such as public perception, fee structures, and environmental initiatives, are either unable to be quantified in dollars or are susceptible to variance over time.

Economic factors, both tangible and intangible, can be derived from a (1) *structural economic evaluation*, (2) *value of benefits summary*, (3) *economic analysis matrix*, or a (4) *economic analysis nomograph.* The structural economic evaluation located on page 1 provides a very simplistic solution to costs (debits) and benefits (credits) for basic economic parameters. The value of benefits summary is without question the most accurate yet intensive method for determining the net worth of a future reuse investment. The economic analysis matrix provides a side by side comparison of all applicable reuse alternatives by weighing economic criteria according to level of importance and totaling the numeric performance of each option with regard to each individual criteria. The nomograph analysis and *flow-cost factor (FCF)* quickly identifies life-cycle reuse potential and the minimum costs and flow required to achieve economic gain.

7.7 References

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CHAPTER 8

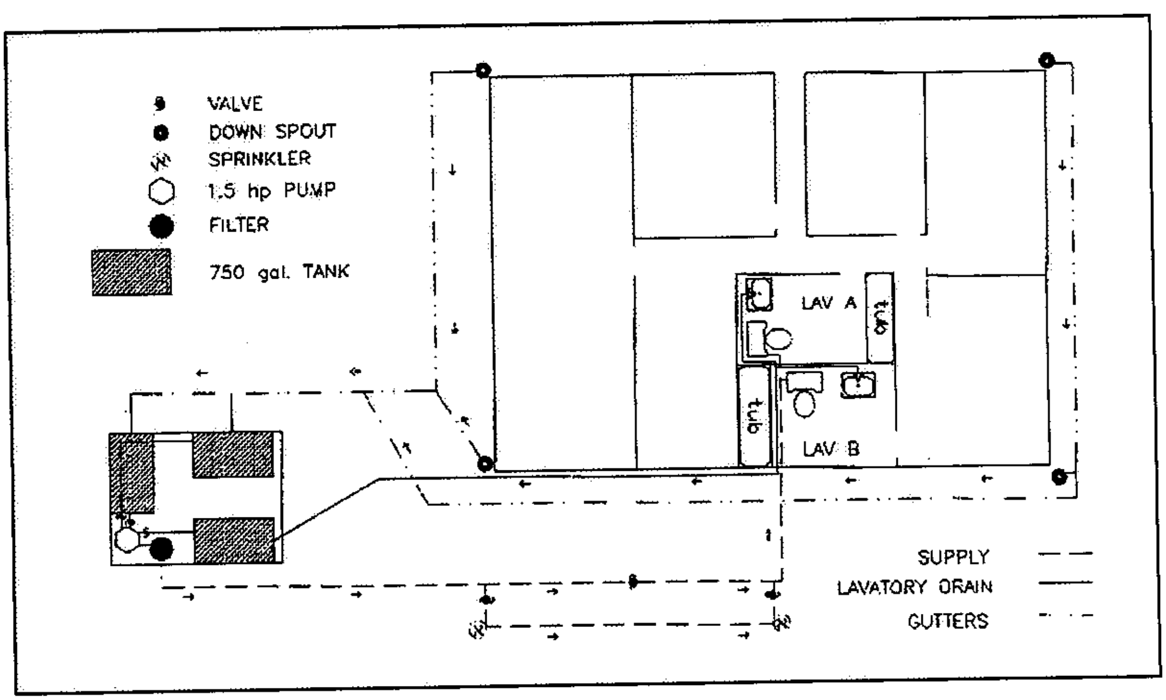
FIELD STUDY

8.0 Introduction

Starting in August of 1994, a water reuse system was installed at the University of Florida Energy Research Park. The objective of the study was to demonstrate the practical applications of water reuse on a local, residential level. The system was designed to meet the needs of a single residential household. A three person household was used for creating a model to assess usage needs. An existing building at Research Park provided the setting for the actual testing of the system. Two lavatories and the roof drain spouts were retrofitted with piping that could deliver the water to nearby storage tanks when the valves of the pipes were open. Figure 8.1 illustrates the installed system in plan view. It outlines the supply, return, and discharge piping of the reuse system. The drawing is not to scale.

Figure 8.1
Research Facility
Plan View

The storage tanks and pumps for the system were located in a shed approximately 25 feet away from the retrofitted building. The shed contained three underground, 750 gallon, precast concrete tanks and a



threeway pump. Two tanks stored the water delivered by the pipes carrying run-off from the drain spouts. For the remainder of this chapter that water is referred to as *run-off water*. The third tank collected non-potable water from the lavatory sinks; this water is referred to as *greywater*. No water was collected from the toilets. Once the water was collected, it provided supply water to the irrigation system (run-off water) or the toilets (greywater).

When the system was installed the original pipes to the sewer system were left intact and operational. When the reuse system is active a valve closes the necessary pipes to allow the non-potable water to be collected rather than deposited in the sewage system.

8.1 Purpose

This study was the first part of a multi-phase investigation. The purpose of this study was to install the reuse system; create a model of the water usage needs of a three person household; obtain data pertaining to the water usage needs at the site; perform mechanical tests of the system to ensure proper installation; and monitor operation of the system.

The preliminary testing consisted of opening the pipes to transport the run-off water to the tanks. This water was used to irrigate the lawn area. When the system was active, the greywater was collected and pumped to the toilets for reuse. The water from the toilets, referred to as *black water*, was returned to the sewage system. The household model was used to determine the amount of non-potable water a system could provide as well as the amount of water needed to meet the supply needs of the toilet. In an ideal reuse system, the amount of non-potable water provided by the hygiene activities should equal the household non-potable needs.

8.2 Methodology

This study was comprised of several separate tasks:

- ♦Document the daily water usage of a three person household.
- ♦Install the pumps, storage tanks, and related piping.
- ♦Construct protective cover for tanks and pump.
- ♦Install necessary supply and return piping to transport water.
- ♦Install irrigation system for the lawn area.
- ♦Collect greywater from the sinks and reuse the greywater in the toilets.
- ♦Collect run-off water from the roof and reuse for irrigation.
- ♦Modify lavatory fixtures to create a dual system.
- ♦Evaluate Biological Hazards and Exposures.

8.2.1 Household Model

The amount of non-potable water to be collected and reused was determined by observing the daily hygiene routine of a three person household comprised of two males and one female. Average times for completing specific hygiene rituals were assessed over a period of fourteen days. The flow rates of the faucet aerators and shower heads were measured by timing the filling of a bucket with a known capacity. Multiplying a known flow rate for a given faucet by the time needed to complete a hygiene task will provide the volume of water used per task.

8.2.2 Installation

At a location approximately 25 feet from the reuse facility, three large holes were excavated. A 750 gallon, precast, concrete tank was placed and secured in each excavated site (see Figure 8.2).

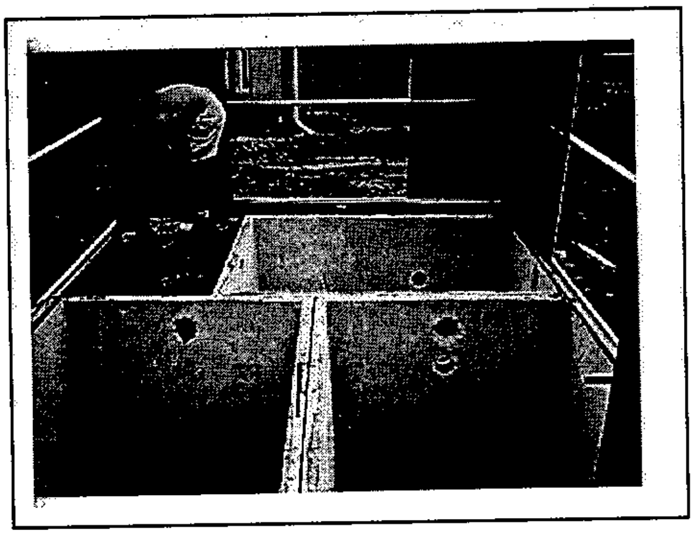


Figure 8.2
Installation of Tanks

A one and a half horsepower jet pump, similar to the type used for residential pools, was connected to the tanks with inch and a half PVC pipe. Manually operated valves were used to select the tank which was to be drawn from at a given time. The pump could only draw water from one tank at a time. A standard swimming pool cartridge filter unit was incorporated into the system to rid the water of minuscule debris immediately before being supplied to the sprinkler or toilet. Figures 8.3 and 8.4 illustrate the connection of the pump, tanks, filter, and supply line that carries the water to the toilets or the irrigation system depending on which tank is in use. A shed was constructed over the tanks and equipment. The shed served multiple purposes: to keep unwanted animals and debris from entering the tanks, to protect the pump, filter, and valves from the outdoor elements, and to protect the public in the area from possible danger.

Figure 8.3
Plan View of Shed at Research Facility

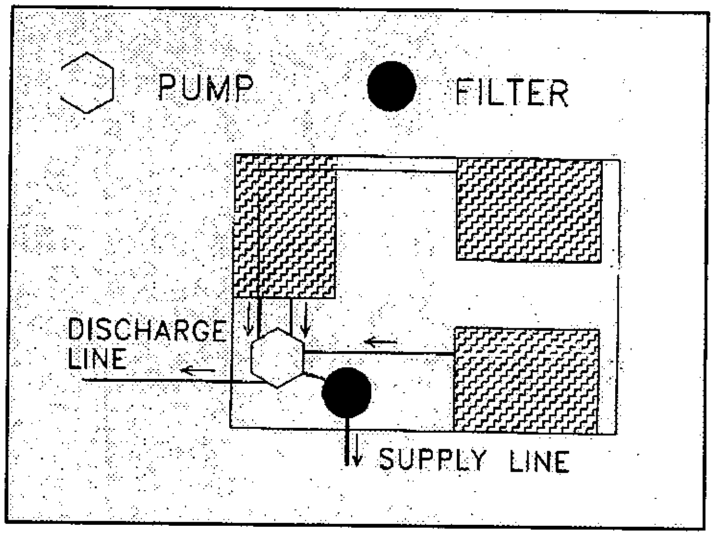
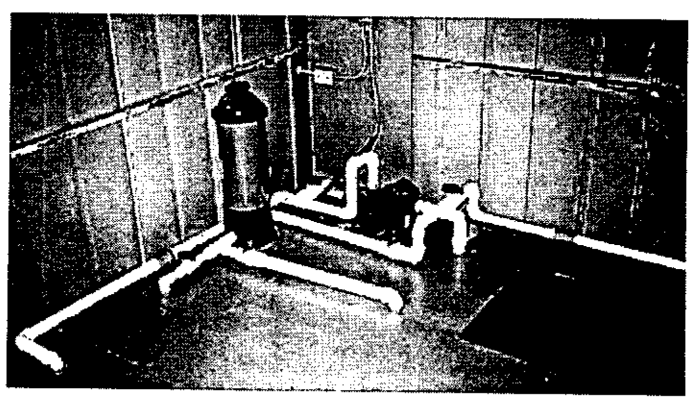


Figure 8.4
Photograph of Filter, Pump, and Piping



Supply and return piping was installed to connect the tanks to the lawn sprinklers and lavatory facilities. The sinks were retrofitted with new traps that could direct the water either to the sewer system or to the tank. Gate valves were used to manually regulate the flow of the water to either station. Figure 8.5 demonstrates the plumbing design under each sink. The greywater return pipes from sink A were directed through the wall that separated the two lavatories. These pipes connected with the return pipes carrying the non-potable water of sink B. This line was fed through the exterior wall of the building and routed to the storage facility.

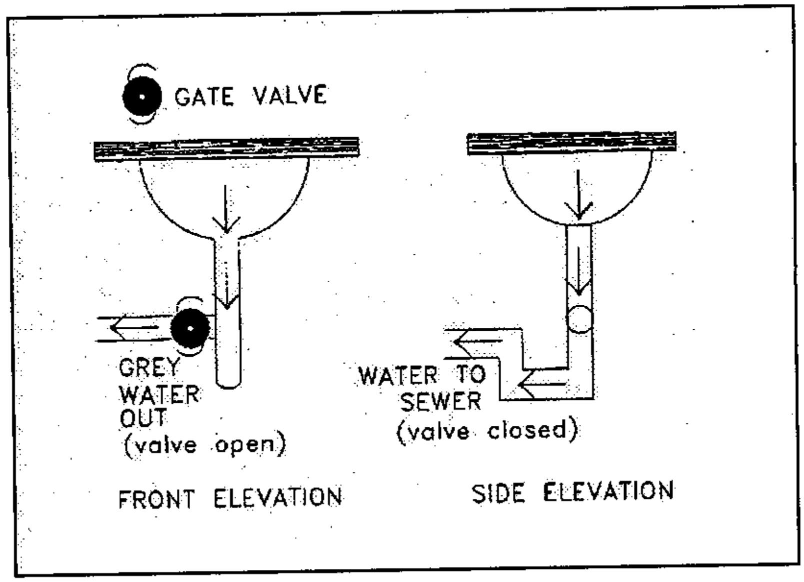


Figure 8.5
Retrofit of Lavatory Sinks

All interior piping that was installed was a new addition or a slight modification to the existing lavatory supply and return plumbing. The existing lavatory piping continued to provide a means of transporting the non-potable water to the sewer lines and municipal water to the toilets when the reuse system was inactive. A valve was connected to the municipal water supply lines so that the supply could be shut off when the greywater system was active. The toilets were also retrofitted so as to become dual piped fixtures, with the domestic water being at a higher elevation than the reuse piping. Figure 8.6 is a photograph of a toilet after the retrofit was complete.

Figure 8.6
Photograph of Toilet Retrofit

An air gap was used to prevent potential cross-connection. The water closets were fitted with an additional float to regulate the intake of the greywater into the flush tank (see Figure 8.7). A half inch PVC pipe with a gate valve was fitted to the bottom of the flush tank to supply grey water instead of municipal water when the valve was opened. This configuration prevents a cross-connection as long as the pressure in the municipal water line does not drastically decrease. Figure 8.8 is a schematic of the retrofitted lavatory toilet system.

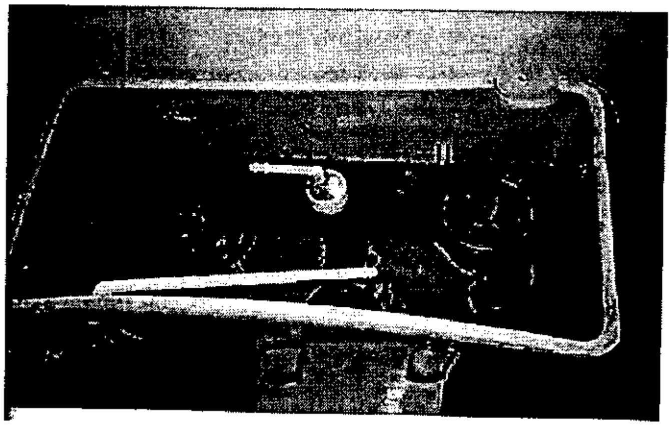


Figure 8.7
Interior of Retrofitted Flush Tank

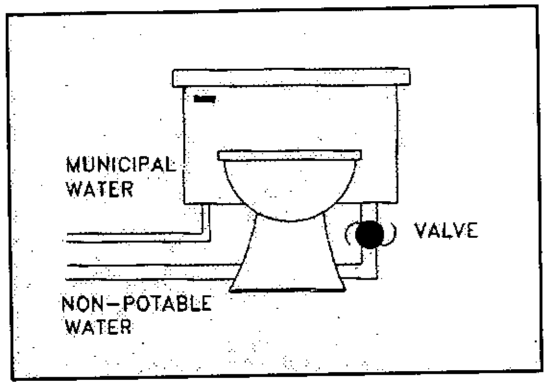


Figure 8.8
Retrofit of Lavatory Toilet

The existing drain spouts (see Figure 8.9) of the building were connected to a four inch PVC pipe that carried the rainwater into the tanks. The pipe was placed underground on a 1:4 slope to allow the rainwater to gravity feed into the tanks. Sprinklers were installed twelve feet apart in the center of a 20 ft. by 35 ft. plot of lawn. Figure 8.10 demonstrates the plumbing for the irrigation system and the intermediate plumbing scheme for the greywater supply between the tanks and the lavatory facilities.

Figure 8.9
Existing Gutter and Drain Spout

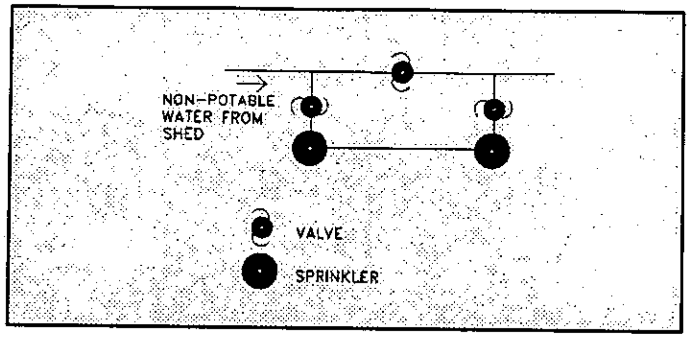


Figure 8.10
Spray-Irrigation Plumbing System

8.2.3 Run-off water Reuse

Information regarding the average annual rainfall for Gainesville, Florida, was obtained from the Water Resources Atlas of Florida. The amount of water required to maintain the lawn was also researched.

During a rainfall, the run-off was carried to the two run-off water storage tanks. The water was pumped out of one of the two designated tanks to the sprinklers. Once water has collected in the tanks the run-off water system could be activated. To operate the system the electrically operated pump was turned on and a valve to one of the run-off water tanks was manually opened. When a valve to one tank is open the other two valves must be in the closed position in order for the system to run properly. Additionally, the valve to the sprinkler on the side closest to the shed must be open and the valve to the building and lavatory facilities must be closed. The valve located after the sprinkler closest to the building (see Figure 8.1) must also be closed. When the valves are in their previously indicated positions the system is considered to be active. The pump will then draw water from the selected tank. The water will pass through the filter and move from the storage facility through an inch and a half PVC pipe to the sprinklers. Figure 8.11 illustrates the position of the valves and flow of water when the irrigation system is active. *Please note that with the given plumbing configuration, the greywater and run-off water systems cannot be tested simultaneously.*

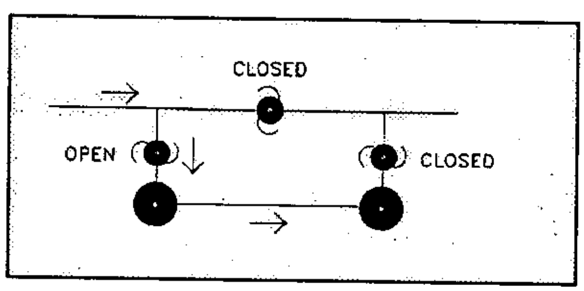


Figure 8.11
Valve Positions for Active Run-off water Supply for Irrigation

If the level of the tanks gets too high, the water can be pumped through a manually opened discharge line. The previous Figure 8.1 illustrates the location of this line. To activate the discharge system, the valve of the tank to be drained is opened, the valve on discharge pipe is opened, and the pump is turned on. This water does not pass through the filter.

8.2.4 Greywater Reuse

To activate the greywater system, a previously installed gate valve, located beneath the sink, was turned to open the line which connected the sinks to the storage tanks. Refer back to Figure 8.5 which illustrated the configuration of the sink plumbing. When the pipe was open, the water from each sink was diverted to an inch and a quarter PVC pipe and transported to the storage tank.

Soon after reaching the tank, the greywater was pumped back to the facility. The valves on the pipes delivering municipal water to the water closets were closed. The greywater lines inside the building lavatories were opened to allow the supply for the toilets to enter the flush tanks. The valve at the greywater tank in the shed was turned to the open position and the pump was activated. The sprinkler valves were both closed and the intermediate valve to the lavatories was opened. When the system is configured as such, it is considered to be active (see Figure 8.12). As the purpose of this portion of the investigation was only to test system mechanics, the water was delivered to the water closets untreated. When the toilets were flushed, the blackwater went directly to the sewer system. After each testing session was complete, the valves were returned to their inactive position, allowing the lavatories to revert to their standard supply and return procedure.

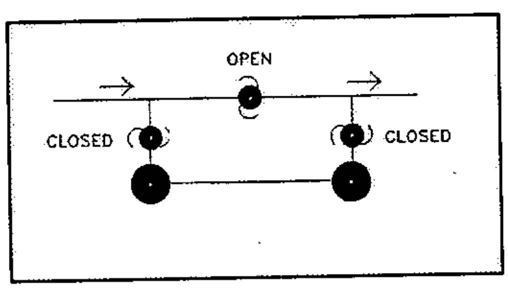


Figure 8.12
Valve Positions for Active Greywater Supply to Building

8.2.5 System Maintenance

The pump has a basket filter which provides primary filtration to remove large pieces of debris before the water enters the pump. This basket must be manually emptied regularly to keep the pump functioning properly. The cartridges for the final stage filtering system must also be changed on occasion.

8.3 Results

The results contained in this portion of the report are typical of those that were obtained in dedicated testing.

8.3.1 Household Model

The length of time required by each person to perform individual hygiene tasks was recorded daily for fourteen days. An average time (in minutes) was determined for each individual's task. The time was multiplied by the predetermined flow rates of the faucets (in gallons/minute) and then by the number of times the task was performed each day to determine the volume of water used per task (in gallons). The average volumes of all tasks were then summed to calculate the average water usage per day (in gallons) for the entire household.

t = task duration (minutes)

Q = flow rate (gal./min.)

V = amount of water used per day (gallons)

$$V_n = Q * t * \#$$

$$V_1 + V_2 + \ldots\ldots + V_n = V_{total}$$

n	HYGIENE TASK	Q	AVG. TASK DURATION	# of TIMES PERFORMED	V_n
1.00	•Male Shower	3.75	7 min.	2.00	52.50
2.00	•Female Shower	3.75	11 min.	1.00	41.25
3.00	•Hand Washing	1.5	.17 min.	15.00	3.83
4.00	⊠Male Shaving			2.00	3.00
5.00	•Teeth Brushing	1.5	.75 min.	9.00	10.13
				V_{TOTAL}	109.71

• Continuously running water was assumed as the standard.
⊠Water was run until an average of 1.5 gallons had filled the sink.

Table 8.1
Average Daily Water Usage

8.3.2 Run-off water Reuse

When the pump was activated, and the valves were in the correct position, the sprinklers functioned as expected.

Calculations were done in order to approximately determine the amount of rain the drain spouts would deliver to the tanks given the estimated monthly rainfall for Gainesville, Florida and the area of the roof.

$$\mathbf{A = \text{area of the roof } (in^2)}$$
$$\mathbf{R = \text{monthly rainfall per area (inches)}}$$
$$\mathbf{V_1 = \text{volume of rain provided by drain spouts per month (gallons)}}$$
$$\mathbf{V_1 = A * R}$$

conversion factor:

$1\ ft^3 = 1728\ in^3 = 7.48$ gallons

Table 8.2 contains the expected monthly intake of rain by the tanks.

$A_{roof} = 374,400\ in^2$

Month	R (inches) *	V_1 (gal.)
January	3.00	4862.00
February	4.00	6483.00
March	5.00	8104.00
April	3.00	4862.00
May	3.80	6159.00
June	7.00	11345.00
July	8.50	13777.00
August	9.00	14587.00
September	6.00	9725.00
October	4.00	6483.00
November	2.50	4052.00
December	3.00	4,862
	ANNUAL TOTAL	95,301

Table 8.2
Predicted Monthly Intake of Rain
* Source: *Water Resources Atlas of Florida*

The irrigation system must provide an adequate supply of water to a lawn area approximately 20 ft. by 35 ft. The area is covered with Bahia Grass, a hardy, drought tolerable grass that needs very little water to maintain itself. The system is comprised of two sprinklers centered in the lawn area. The flow rate for each sprinkler is 2.5 gallons per minute. The run-off water supply proved to be adequate, considering the moderate rate of dispersion of the sprinklers in conjunction with the minimal water requirements of the grass. When the system is active for two hours at a time a combined maximum of 600 gallons of water is used by the sprinklers. While the flow rate of the sprinkler (Q) will remain constant, the duration (t) and frequency of the use of the system can be adjusted for different seasons as shown below. The irrigation needs of the lawn may vary throughout the year. The amount of water available to use for irrigation will also be a variable.

t = duration of system use (minutes)

Q = flow rate (gal./min.)

V_2 = volume of water used per watering (gallons)

$$V_2 = Q * t * 2$$

Due to the storage capacity of the tanks, the system should be able to meet the needs of the lawn even during months of little rain with minimal city water supplement. Table 8.3 illustrates the approximate number of two hour waterings the rainfall will enable, based on the information provided in Table 8.2. These numbers were determined by dividing the gallons of rain per month by the volume of water used each time the system is activated. In this case, 600 gallons was used as the nominal requirement.

V_1 = volume of rain provided by drain spouts per month (gallons)

N = number of waterings per month

$$V_1 \backslash V_2 = N$$

If V_2 equals 600 gallons per watering...

Month	V_1 (gal.) V1 (gal.)R (inches) *	N V_1 (gal.)
January	4862.00	8.10
February	6483.00	10.80
March	8104.00	13.50
April	4862.00	8.10

May	6159.00	10.30
June	11345.00	18.90
July	13777.00	23.00
August	14587.00	24.30
September	9725.00	16.20
October	6483.00	10.80
November	4052.00	6.75
December	4,862	8.10

Table 8.3
Estimated Number of Monthly Waterings

8.3.3 Greywater Reuse

The greywater tests for this portion of the investigation were only meant to test the operability of the mechanical and plumbing systems. The initial tests of the system verified that the piping and pumps were operating properly. The lavatory toilets each had a capacity of 1.6 gallons per flush. For a three person household, the average number of flushes per day ranges from 15 - 25. Meeting the usage needs of the toilet would require 24 - 40 gallons of water each day. Thus, the amount of water required by the toilets is approximately 1/3 of the non-potable water supplied by the household (refer back to Table 8.1).

8.3.4 Biological Hazards of Greywater

Greywater and run-off water samples were taken from specific locations throughout the system for testing and analysis. Although the initial results indicate potentially dangerous water, the treatment of same was outside the scope of this report.

8.4 Summary

The field model required considerable modification to allow the project to fit into the financial constraints. It also required field decisions that were necessary to adapt the reuse system into the existing building. This project provides a full scale working model as was originally planned, but also has provided an opportunity for additional research to refine the cost of new and retrofit reuse systems, and also pointed out the hazards associated with reuse systems. The model has provided an opportunity to perform multiple tests beyond the scope contained in this report, which are enumerated in Chapter 9.

CHAPTER 9
CONCLUSION AND RECOMMENDATIONS

9.1 Conclusions

The system in place at the Energy Research Park has the potential for a variety of investigations pertaining to the collection and reuse of greywater and run-off water. While this study represents the foundation for much of the research associated with greywater reuse systems, the potential regarding the modeling and testing of a full scale system has many possibilities for future research. The system created by this project represents a very important step in this process of developing a viable cost effective reuse system. Further research may investigate a number of potential features in the following section of this report.

The research has substantiated a greywater reuse system can quite effectively reduce the potable demand in residential and commercial settings, but the key to creating a user friendly system is to reduce the maintenance requirements and increase the overall safety of the system while keeping costs at a minimum. The relationship between cost, safety, performance, and maintenance yields the first area of concern -- autoregulation. Currently, the system in place functions manually in that either the system is actively turned on or off. Whether this is via a timer or by hand, the system exists in either one of the two states. This presents a problem. While a simple timer solution may work for a system with a single supply and a single return loop, the basis for a reuse system lies in the ability to collect various forms of greywater as well as run-off water. For the system to function at an optimal level, it must be able to monitor itself and supply non-potable reuse water to a prioritized group of functions. For example, if there is a shortage of greywater in the holding tanks, functions like irrigation should be turned off until additional water can be collected. On the other hand, if there is as excess of water, as is often the case during the rain-filled summer months in Gainesville, to what system can the excess water be directed in order to avoid waste or flooding of the pump room. As more systems are integrated into this collection cycle, the concept of autoregulation increases in importance.

When autoregulation becomes viable, two additional systems become almost basic to the greywater reuse facility -- leaching fields for irrigation and overflow control, and a treatment loop for the purification of reuse water. In order to improve the factor of safety of the overall scheme, two features must be modeled and tested -- the chemical/biological makeup of the collected water and the level of the contact of greywater.

Within this report, the relationship between the level of contact and the acceptability of a greywater reuse system is outlined by establishing which non-potable functions of the house are most acceptable to the occupant. If the quality of the greywater could be increased, it would follow that the level of acceptability would increase as well. As a result, a thorough investigation into treatment systems regarding their practicality, economic viability, and safety is critical in establishing a self-contained and cost effective greywater reuse system. While technology in this area has been well-documented within this report, the problems associated with implementation are yet to be encountered. Concepts such as cycle times and system cleanouts need to be established based on local conditions and system loads. As more greywater becomes reusable, the issue of greywater management initiates a need to implement more efficient systems of irrigation through subsurface leeching fields and potentially deeper greywater returns to the aquifer rather than the surface cleanout results in ponding.

The issues presented in this document represent the basis for generating a model for further investigation into the subject of greywater reuse. The current full scale model has the functional infrastructure for economical, practical, safe, and user-friendly greywater reuse system. Areas of primary concern include: safety, (maintenance of air gaps between municipal and non-potable supply), economic viability (actual reduction in second costs associated with a greywater reuse system), and the overall maintenance of the system. These issues and the resulting options must be tested as a complete system in order to introduce a greywater reuse system for public use.

9.2 Recommendations

While the test facility at the research park has shown that a high level of acceptance can be achieved in reusing greywater and capturing the otherwise wasted run-off water, the real potential of this research and test facility lies in the following areas:

♦The system needs to be monitored over a time period that exceeds the scope of this study, wherein variables which include, but are not limited to water color, smell, and bacteria testing are further examined.

♦Safety precautions need to be further evaluated regarding the real application of greywater in the water closets of a residential dwelling. Concerns such as a pet drinking out of the water closet, or a small child climbing on the fixture will require a level of disinfection in the system. Field testing will be required to determine how safeguards can be built in place to mitigate the potential hazards associated with greywater reuse.

♦Autoregulation, as discussed in the conclusion, needs development in a systematic empirical methodology, which would include backup support to ensure a fail-safe system. Reasonable assessment of the split-level air gap protective system for the water closets proved successful in this field study, but further analysis needs to be accomplished to assure that plumbing errors would not allow a cross-connection.

♦Sub-surface irrigation of greywater into lines close to the surface would provide nutrients for vegetation and also provide protection to the home dweller that may engage in activities in direct contact with the yard surface. The system model that has been developed for this project is very appropriate for modification to include such a leaching system. This methodology may be the best way to dispose of and still utilize greywater.

♦Purification of greywater is always an alternative but rarely cost effective on a small scale basis. With new technology on the market, this concept is certainly a subject that warrants continual monitoring and revisiting. Ultimately, the intent of purification would be to provide an easily maintained package system for greywater that would be cost effective for a residential dwelling.

♦Acceptance of a greywater system is yet to be evaluated. Located in a University of Florida research park, the full-sized model for this study, provides many opportunities for future simulation. With employees of the University of Florida occupying the dwelling, human factors related to the greywater system can be further examined and analyzed. Modifications to the system operation can be made to accommodate either actual or perceived greywater connotations.

♦Blackwater is an area not addressed in this study although this waste is something that has definite potential for research, within this same site, for subsurface irrigation.

♦Roof Cooling is an area that also has tremendous potential for greywater reuse, but the contamination of the run-off water would be compromised if this was done, but this system needs evaluation.

♦Air Conditioning Systems are an area that also bears the need for field testing as discussed in Chapter 5.4 of this text.

GLOSSARY

Air-gap separation (AG): A physical break between the supply line and receiving vessel.

AWWA standard: An official standard developed and approved by the American Water Works Association (AWWA).

Biochemical oxygen demand: The quantity of oxygen utilized in the biochemical oxidation of organic matter present in wastewater.

Biological treatment: Methods of wastewater treatment in which bacterial or biochemical action is intensified as a means of producing oxidized wastewater.

Blackwater or black waste: Water that has come from a sanitary sewer line, which in this report is limited to the water closet waste water.

BOD_5: The five day biochemical oxygen demand, indicating the quantity of oxygen utilized in five days by wastewater under a controlled environment.

Coagulation/filtration: A process by which clustered particles are removed from effluent by means of filters or screens.

Coagulant/flocculent: Individual particles which have come together to form a cluster (coagulant) containing fine particles which are in suspension in water coagulant (flocculent).

Coagulated waste water: Oxidized wastewater in which colloidal and finely divided suspended matter have been destabilized and agglomerated by the addition of suitable floc-forming chemicals.

Conventional-plant water recovery: Linking the existing wastewater treatment facility with a new water resource recovery treatment facility designed to reclaim wastewater to a quality suitable for indirect potable or non-potable reuse.

Cross connection: An unprotected actual or potential connection between a potable water system used to supply water for drinking purposes and any source or system containing unapproved water. Bypass arrangements, jumper connections, removable sections, swivel or changeover devices, or other devices through which backflow could occur should be considered to be cross connections.

Direct injection: A type of groundwater recharge that involves placing advanced treated effluent directly into the groundwater shed.

Direct reuse: The use of reclaimed wastewater that has been transported from a wastewater reclamation to the water reuse site without intervening discharge to a natural body of water.

Direct potable reuse: The direct piped connection of water recovered from wastewater to a potable water supply distribution system or a water treatment plant.

Disinfected wastewater: Wastewater in which the pathogenic organisms have been destroyed by chemical, physical, or biological means.

Double check valve assembly (DC): An assembly of at least two independently acting check valves including tightly closing shut-off valves on each side of the check valve assembly, and equipped with the necessary test cocks for analysis.

Dual distribution: The supply of both domestic potable water and reclaimed non-potable water.

Effluent: The outflow from a body of water such as a stream or that from a first use of potable water which renders that water as waste. Effluent from sewage is categorized by degree of treatment. For example, primary effluent is the effluent from a wastewater treatment process which provides removal of sewage solids so that it contains not more than 0.5 milliliter per liter per hour of settle able solids as determined by an approved laboratory method.

Fecal coliforms: Members of the coliform bacteria group capable of producing gas from lactose at 44.5°C.

Filtered wastewater: An oxidized, coagulated, clarified waste water which has passed through natural undisturbed soils or filter media, such as sand or diatomaceous earth, so that the turbidity as determined by an approved laboratory method does not exceed an average operating turbidity of 2 turbidity units and does not exceed 5 turbidity units more than 5 percent of the time during any 24 hour period.

Greywater: Outflow from primary treatment and septic sedimentation (see effluent).

Groundwater recharge: A process of using reclaimed effluent to replenish groundwater aquifers.

Indirect reuse: The use of wastewater reclaimed indirectly by passing it through a natural body of water or use of groundwater that has been recharged with reclaimed wastewater.

Multiple barrier design: The use of multiple pathogen barriers such as lime treatment, ozonation, reverse osmosis, and chlorination to ensure public health protection.

Multiple point chlorination: Chlorine will be applied simultaneously at the reclamation plant and at subsequent chlorination stations located at the use area and/or some intermediate point.

Non-withdrawal use: Water used to sustain plant and animal life, provide transportation, propagate aquatic wildlife, and for hydroelectric generation.

On-site treatment: The treatment, or additional treatment performed on location for applying reclaimed water to sensitive interior and exterior applications and subsequent disposal.

Oxidized waste water: Wastewater in which the organic matter has been stabilized, is nonputrescible, and contains dissolved oxygen.

Potable water: Water that is of drinking quality.

Primary effluent: The effluent from a waste water treatment process which provides removal of sewage solids so that it contains not more than 0.5 ml/L/hr of settle able solids as determined by an approved laboratory method.

Primary user: Any person receiving reclaimed water directly from a producer and thereafter either distributing the water to others or applying it to a beneficial use.

Producer: Any person treating wastewater so that it is suitable for direct beneficial use or controlled use that would not otherwise occur and allowing such uses to occur.

Reclaimed water: Water which, as a result of treatment of domestic wastewater, is suitable for direct or beneficial use or a controlled use that would not otherwise occur.

Reclamation plant: An arrangement of devices, structures, equipment, processes and controls which produce a reclaimed water suitable for the intended reuse.

Reduced pressure principle back-flow prevention device (RP): A back-flow preventer incorporating not less than two check valves, an automatically operated differential relief valve located between the two check valves, a tightly closing shut-off valve on each side of the check valve assembly, and equipped with the necessary test cocks for analysis.

Reliability limits: The feasibility studies involving the establishment of criteria for assessing the relationship between the cost of added reliability and the return on investment from added reliability.

Reuse water: Wastewater other than toilet and or urinal wastes, non-fecal.

Run-off water: Water that is collected from rain or other forms of precipitation, that normally comes from the runoff of the building's roof.

Sanitary sewer: A pipe which carries sewage and excludes storm, surface and ground water.

Secondary sedimentation: The removal by gravity the settle able solids remaining in the effluent after the biological treatment process.

Secondary user: Any person receiving reclaimed water directly from a primary user.

Stack venting: A method of venting a fixture or fixtures through the soil or waste stack.

Storm sewer: A sewer used for conveying rain water, surface water, condensate, cooling water or similar liquid wastes.

Surface spreading: A type of groundwater recharge in which reclaimed water percolates from storage basins through unsaturated zones into groundwater.

Surficial flow: Water which moves underground in a lateral direction at the top portion of the aquifer just at the water table line.

System flexibility: The ability of the system to respond to variations in source wastewater quality and quantity and to future variable that may affect performance requirements.

System reliability: The ability of the system to consistently produce the required water quality objectives throughout the application of process redundancy and multiple contaminant barriers.

Tertiary treatment: Treatment that involves AWT (Advanced Waste water Treatment) clarification processes such as activated carbon, reverse osmosis, ozonation, and ion exchange.

Third main system: The use of a third municipal infrastructure supply delivering reclaimed effluent for non-potable use.

Total Kjeldahl Nitrogen: The sum of free ammonia and organic nitrogen compounds in wastewater expressed as elemental nitrogen.

User connection: The point of connection of a user's piping to the water supplier's infrastructure.

Vent stack system: A pipe or pipes installed to provide a flow of air to or from a drainage system or to provide a circulation of air within such system to protect trap seals from siphonage and back pressure.

Water quality (reclaimed): The ability of an alternative water recovery treatment to meet physical, chemical, microbiological, and toxicological performance standards.

Wet vent: Wastewater collection piping serving to collect only fluid wastewater and venting.

Withdrawal use: Water taken from its source and used in some kind of manmade system before being released again.

APPENDIX I

University of Florida
Initial Joint BCN-IFAS Greywater Trial System Design

A1.0 Introduction

The intent of this joint research initiative is to compliment previous developmental efforts related to reclaimed water technology as it applies to modern building design and construction in the State of Florida. The scope of this effort is to investigate reuse and rainwater technologies as an environmentally sound, economically feasible natural resource capable of supplementing existing potable overdraft and excessive wastewater discharge. Greywater reuse implies the recycling and reuse of septic effluent, non-fecal wastewater, or collected rainwater from typical commercial or residential structures for non-potable use.

The following Draft Proposal and Evaluation is intended to establish a joint IFAS - BCN working relationship for the exploration of existing technologies and proposed greywater systems specific to urban and rural reuse treatment and distribution. Developing economically and environmentally conscious water optimization strategies by implementing greywater utilization in a safe and practical manner is the objective.

A1.1 Greywater System Construction Impact

All schedules of site modifications and temporary construction will be presented and approved by the IFAS Coordinator and committee before commencement. Site, facility and construction phase activities are proposed to commence on or about **Friday, May 13** following the end of Spring Semester 1994. This time frame will allow greater student participation and minimize disturbance to facility activities.

A1.1.1 *Utilities Impact*

Construction and restoration phase activities require 1 - 110/120Vac duplex outlet for light equipment and tools operation. Potable water is required for limited concrete batching (if not ready mix) and for general washdown. Usage of utilities during construction and restoration phases are considered negligible.

A1.1.2 *System Modifications, Operations & Maintenance, and Restoration*

No modification to the interior potable distribution system is required. A temporary exterior supply is requested for systems make-up and flow modeling. The potable requirement is proposed to include approximately 20' lf TDL of ½" galv/pvc to 1 receiving vessel. No direct cross-connection shall exist between the potable supply and the non-potable supply. Make-up will only occur using an AWWA approved air gap separation and approved back flow prevention devices. Pressure in the non-potable system will intentionally be maintained 10 psi lower than the potable system. The exterior potable supply will continue to provide a spigot during temporary retrofit and will be restored to original condition upon completion of research.

A1.1.3 *Facility Modifications, Operations & Maintenance, and Restoration*

All modifications to existing facility waste piping will be economicaly considered for minimal impact to the project. All modifications to the finishes or structure of the facility will be returned to original condition.

A1.1.4 *Site Modifications, Operations & Maintenance, and Restoration*

All temporary facilities will be professionally maintained. Such facilities will completely obscure all equipment. Facilities will compliment existing building and landscape aesthetics of the Institute for Food and Agricultural Sciences (IFAS) compound. All temporary facilities that are not intended to be turned over to IFAS management after research completion will be removed and all landscaping and site modification will be restored to original condition. All modifications to site drainage and rainwater piping will be completely restored.

A1.2 Greywater System Testing and Site Visitation Impact

Testing and site visitation is requested for 2 hours on a MWF schedule for flow evaluations, systems integrity, water sampling, and general operations and maintenance.

A1.2.1 *Utility Impact*

Potable water for washdown, make-up, and flow modeling is considered negligible. Electrical service to (1) 1/3hp sump pump, (1) 1hp pressure pump-filtration unit, (2) 2 x 4 pnl. lights, (2) 110/120Vac duplex outlets, and (1) 1/2hp irrigation pump (optional) is not expected to be greater than 50kW hours per month. A 30A circuit is requested for temporary usage.

A1.3 Greywater System Design Specifications

A1.3.1 *Reuse Discharge and Non-Potable Supply Guidelines*

All reuse water, rainwater, and potable water supplies and distribution shall be strictly monitored as per American Waterworks Association (AWWA) and Standard Plumbing Code (SPC) guidelines and regulations for potable and non-potable treatment and dual-distribution.

A1.3.2 *Minimum Separation Distances*

The minimum proposed separation between potable water mains and non-potable water lines shall be no less than three feet horizontally and no less than one foot vertically. Florida Administrative Code (F.A.C. 17-610.470.3) stipulates the following:

Maximum obtainable separation of reclaimed water lines and domestic water lines should be practiced. A minimum horizontal separation of five feet (center to center) or three feet (outside to outside), shall be maintained between reclaimed lines and either potable water mains or sewage collection lines.

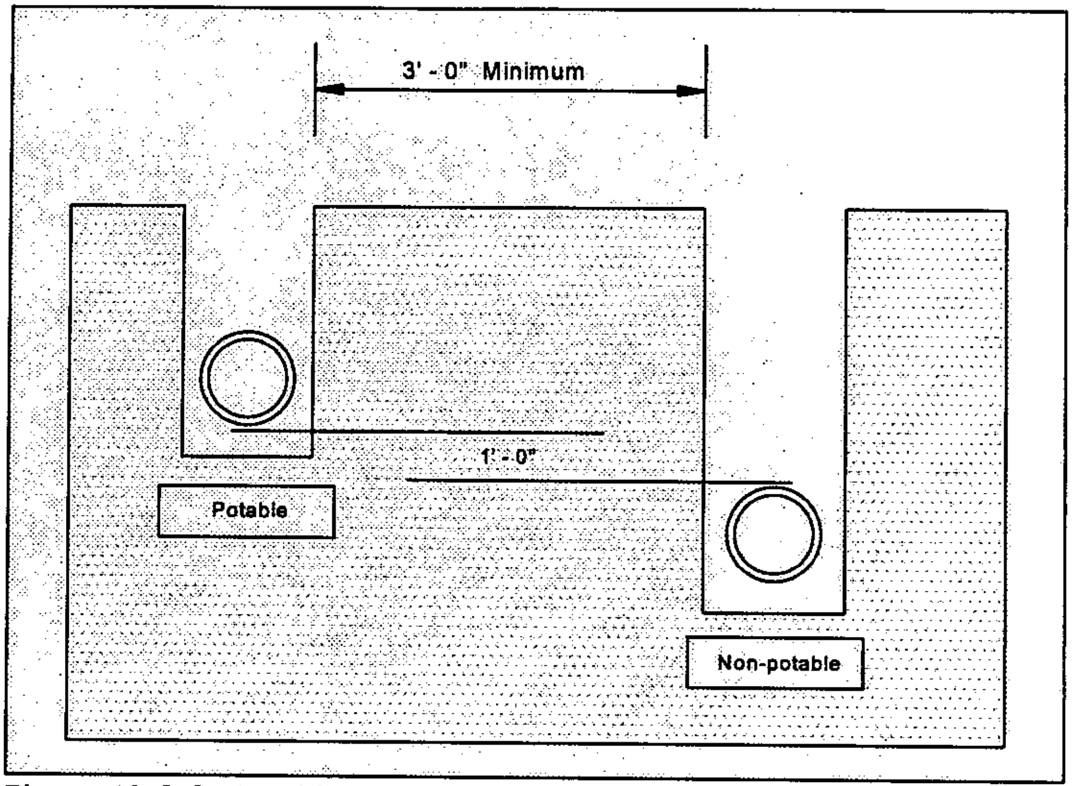


Figure A1.3.2 Potable and non-potable minimum separation distances. Kibert, Charles J. *Guidelines for the Use of Reclaimed Water.* University of Florida.

A1.3.3 *Air-Gap Separation and Potable Flow Modeling*

Potable water make-up and "flow modeling" make-up for non-potable supplies shall be equipped an AWWA air gap type cross-connection at the receiving vessel. Such direct cross-connections shall provide a minimum air gap (AG) separation equivalent to double the diameter of the supply pipe, measured vertically from the flood rim of the receiving vessel to the supply pipe. AWWA approved air gaps shall maintain a minimum 1" separation and shall be entirely visible, providing reasonable clearance from obstructions.

A1.3.4 *Backflow Prevention Devices*

Non-potable flow shall be maintained at least 10 psi lower than the parallel potable supply to prevent non-potable back flow in the event of accidental cross-connection. To further eliminate the possibility of back siphonage of reuse water into potable lines, back-flow prevention devices must be located on the potable make-up lateral to the reuse/non-potable receiving vessel. A check valve assembly shall be implemented on all potable water sources in accordance with F.A.C 17-640.

A check valve assembly or reduced pressure principle backflow prevention device (RP) should as a minimum, fully conform to AWWA Standard C506-78 (R83). A check valve assembly should be located as close to the user's connection and should be installed above grade if possible, and in a manner readily accessible for testing and maintenance. It is recommended that check valves and backflow prevention devices be excluded from non-potable mains in an effort to further reduce similarities between the two, unless on-site exposures would impact the quality of the non-potable supply.

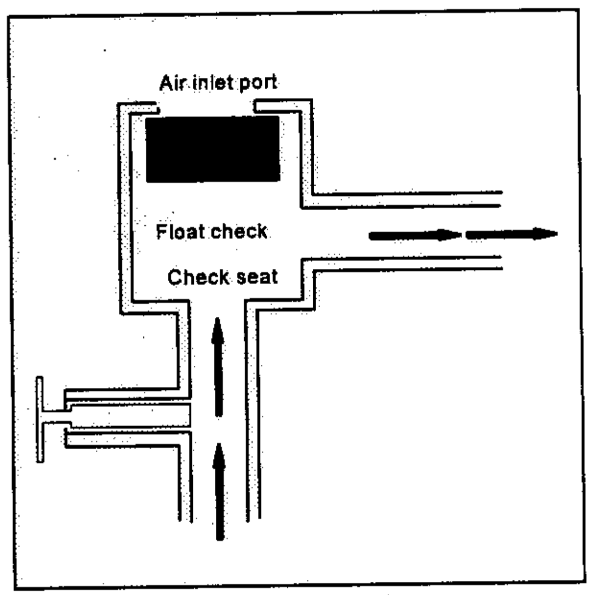


Figure A1.3.4 Typical air-vacuum check valve.
Mueller, Jerome F. *Plumbing Design and Installation Details*. Mc Graw-Hill.

A1.3.5 *Signage and Material Differentiation*

Lines supplying non-potable water should be tagged a standardized color of purple. In addition to material differences and signatured labels, this color coding is proving imperative to avoid confusion between potable (blue) and sanitary (green) mains. Recyclable thermoplastics such as high density polyethylene (HDPE) and "thick-wall" polyvinylchloride (PVC) shall be incorporated in minimal pressure applications as a further means of identification from potable or waste lines. Signage at the point of non-potable use shall fully identify the existence and intent of the non-potable system (see Appendices III).

A1.3.6 *System Reliability and Safety Provisions*

Flow splitting valves shall be provided at (1) sink, and (2) lavatories to allow immediate discharge into conventional wet-vent to sanitary sewer system in the event of greywater system failure or over capacity.

A1.4 Greywater Flow Recovery Requirements

A1.4.1 *Reuse Water Discharge Volume*

Interior commercial discharge volume (typical 8 person office environment)

Maximum discharge volume	68 gpd/1364 g/month
Minimum discharge volume	50 gpd/1020 g/month

Interior residential discharge (typical 6 person dwelling environment)

Maximum discharge volume
273 gpd/8190 g/month
Minimum discharge volume
205 gpd/6140 g/month

A1.4.2 *Rainwater Discharge Volume*

Rainwater shall be collected for primary sedimentation and filtration for direct spray irrigation and subsurface infiltration/indirect aquifer recharge.

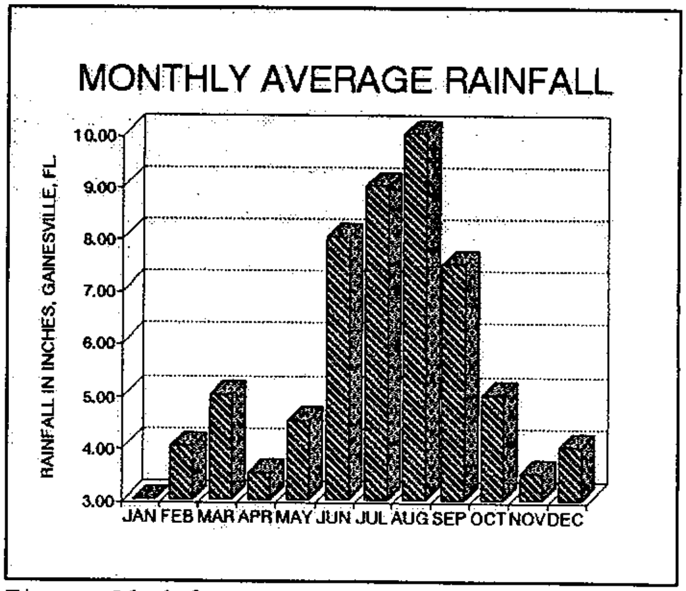


Figure A1.4.2 Monthly average rainfall, Gainesville, Florida.
Atlas of Florida. *Water Resources.* Florida State University, 1985.

Volume calculation:

Roof area	30' x 73' = 2190 sf.
Average monthly rainfall	67"/yr./12 = 5.6"/mo.
Maximum average monthly rainfall	10.2"/mo.
Minimum average monthly rainfall	3"/mo.
Maximum RNW flow	2190sf. x 10.2" x 7.5gal/cf = 15,060 g/month = 450 gpd
Minimum RNW flow	2190sf. x 3" x 7.5gal/cf = 4,100 g/month = 140 gpd

A1.5 Greywater Treatment Systems and Requirements

All recovery basins and storage tanks shall be of 2500 psi RC with #3 rebar struts 12" o.c. vertically and #3 rebar 12 o.c. horizontally, either cast in place (CIP) or precast. Tanks and basins shall be constructed below grade with a 1'-0" containment wall/flood rim above grade as specified. Tanks and basins shall be epoxy coated to prevent uncontrolled leakage. Tanks and basins shall be provided #40 grid screening to prevent fine particles and water borne pestilence (mosquitoes) from contaminating the reuse supplies. All discharge flow, recovery, and basin transfer shall be conventional gravity fed unless otherwise specified.

A1.5.1 *Rainwater Flow Basin*

Primary rainwater flow basin shall be capable of containing 1 day maximum rainwater flow:

Maximum rainwater flow	450 gpd
Rainwater flow basin	3'(overflow rim) x 4' x 5' x 7.5 = 450 gal

Primary rainwater is permitted for direct spray/drip irrigation and surficial discharge. Overflow will be provided from the rainwater flow basin to the existing storm sewer. An optional pump and spigot may be installed to provide spray irrigation.

A1.5.2 *Reuse and Rainwater Blending Basin*

Secondary reuse/rainwater blending basin shall be capable of containing 1 day maximum reuse/rainwater combined flow:

Maximum rainwater flow	450 gpd
Maximum reuse water flow	273 gpd
Total	723 gpd
Rainwater flow basin	2.667'(storm overflow) x 5' x 7.5' x 7.5 = 750 gal

Secondary blended reuse/rainwater is permitted for direct subsurface infiltration/indirect aquifer recharge. Check baffles are provided to allow gravity fed flow equalization between the blending basin and adjacent chambers. Emergency overflow will be provided from the reuse/rainwater blending basin to the existing storm sewer in a controlled manner. An overflow port is provided 6" below the rainwater basin overflow rim/rainwater supply port to allow controlled discharge without rainwater basin contamination. At no time may untreated blending water be released for surface irrigation or runoff.

A1.5.3 *Leach Field Discharge and Subsurface Irrigation Capacity*

Subsurface infiltration/indirect aquifer recharge using direct (untreated) reuse/rainwater, may be gravity fed from the reuse storage tank, through a mesh screen filter, control valve, and pressure regulator. The header line (manifold) may have a flush valve/vacuum breaker that would in turn feed the drip lines. Conventional drip lines are usually inserted 4 to 12 inches below grade. An automatic flushing valve/vacuum breaker is placed at the end of the flush line and is commonly embedded in gravel to prevent soil scour during clean out. To minimize the problem of emitter clogging associated with reuse subsurface irrigation, it is recommended that drip lines be provided turbulent flow of 1 to 2 gph using 0.06" to 0.07" orifices constructed of PVC or PP (polypropylene) to resist most acidic constituents of domestic wastewater and Florida's "aggressive" soil characteristics. Modifications to the subsurface leaching system using effluents and commercial greywater flow modeling will further involve the addition of the following parameters:

1. The quality and quantity of organic matter and its affect on the fertility of the soil and the amount of water that can be retained.
2. Soil texture and particle size and its affect on removing potential contaminates in the wastewater effluent.
3. Soil structure, which affects the permeability of the soil.
4. Topography, which affects surface runoff and erosion.
5. Infiltration rate, which indicates how much runoff may occur.
6. Subsurface geology and underground water movement.
7. Impermeable layers of clay strata, which can impede percolation
8. Fractured areas which could allow treated wastewater to reach groundwater prior to the natural filtration of potential contaminates.
9. Excess water, which affects soil stability, internal friction, density and the ultimate bearing capacity of the founding strata (shrinking and swelling).

Table A1.5.3a Drip leaching and irrigation construction criteria.
Assessment of Greywater and Combined Wastewater Treatment and Recycling Systems. PHCC, 1992.

Construction item	Minimum	Maximum
Number of drain lines per valved zone	1	N/A
Length of each perforated line	N/A	100 ft
Bottom width of trench	12 in	18 in
Spacing of lines, center to center	4 ft	N/A
Depth of cover lines	10 in	N/A
Depth of filter material cover of lines	2 in	N/A
Depth of filter material beneath lines	3 in	N/A

Table A1.5.3b Soil capacity and criteria for subsurface drip irrigation.
Assessment of Greywater and Combined Wastewater Treatment and Recycling Systems. PHCC, 1992.

Type of soil	Minimum ft^2 of drip area/100 gal. reuse discharge	Maximum absorption capacity/ft^2 of area/day
Course sand or gravel	20	5
Fine sand	25	4
Sandy loam	40	2.5
Sandy clay	60	1.66
Clay with sand or gravel	90	1.10
Clay	120	0.83

A1.5.4 *Sand Media Filtration and Breakpoint Chlorination*

Sand media filtration will provide advanced secondary treatment and biological clarification for the removal of organics passing primary clarification. Sand media filtration will filter blended reuse/rainwater for a 90% reduction in BOD (Biochemical Oxygen Demand) and TSS. Interior non-potable water will maintain BOD at 20 ppm or less. Non-potable water will remain below 2-5 nephelometric turbidity units (NTU's). Acceptable non-potable water will be pumped to the breakpoint chlorination and dye chamber for the application of a residual disinfectant and identification dye to differentiate non-potable water from potable supplies.

A1.5.5 *Non-Potable Storage*

Non-potable storage and chlorination basin shall be capable of containing 4 day interior non-potable demand (commercial):

Average four day non-potable demand	120 gpd x 4 days = 480 gal
Non-potable storage and chlorination basin	4.334' x 3' x 5' x 7.5' = 490 gal

Treated NP overflow will be provided from the non-potable storage and chlorination basin to the RNW basin for recycling or stormwater discharge.

A1.5.6 *Potable Flow Modeling*

Potable make-up will be provided for systems backup in the event of extended dry periods or for flow modeling if an imbalance in reuse recovery occurs. Potable water will not be used for any subsurface infiltration or irrigation. The amount of potable water required for emergency make-up and flow modeling is considered negligible.

A1.6 Reuse, Rainwater, and Non-Potable Flow Equalization

A1.6.1 *Commercial Reuse Flow*

Interior commercial use (typical 8 person office environment)

Average potable demand	150 gpd (5 days/week) 3750 g/month
Average flow:	
Toilets (82.4% flow)	120 gpd/3000 g/month
Lavatories (11.8% flow)	19 gpd/ 425 g/month
Sinks (5.9% flow)	11 gpd/ 225 g/month
Total	150 gpd/3750 g/month

A1.6.2 *Residential reuse flow*

Interior residential use (typical 6 person dwelling environment)

Average potable demand	420 gpd (7 days/week) 12600 g/month
Average conventional flow:	
Toilets (40%)	168 gpd/5040 g/month
Shower (35%)	147 gpd/4410 g/month
Sink/Dishwasher (15%)	63 gpd/1890 g/month
Lavatory (5%)	21 gpd/630 g/month
Laundry (5%)	21 gpd/630 g/month
Total	252 gpd/6930 g/month

A1.6.3 *Non-potable demand*

Average non-potable demand (commercial):	
Toilets (82.4% flow)	120 gpd/3000 g/month
Average non-potable demand (residential):	
Toilets (40%)	168 gpd/5040 g/month

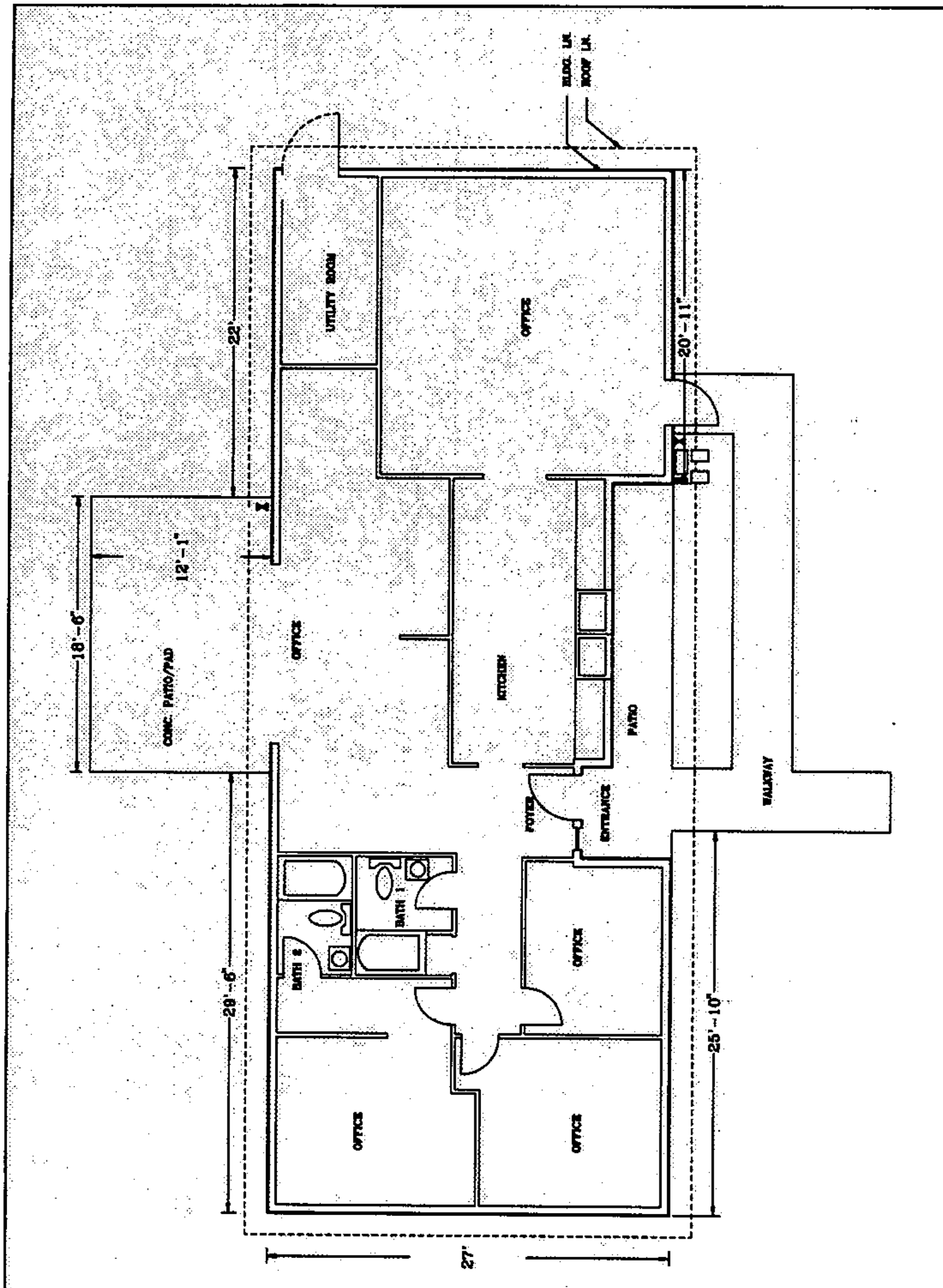


Figure A1.7.1 UF-IFAS existing facility floor plan.
Grosskopf, Kevin R. University of Florida, 1994.

A1.7 Proposed Construction Drawings

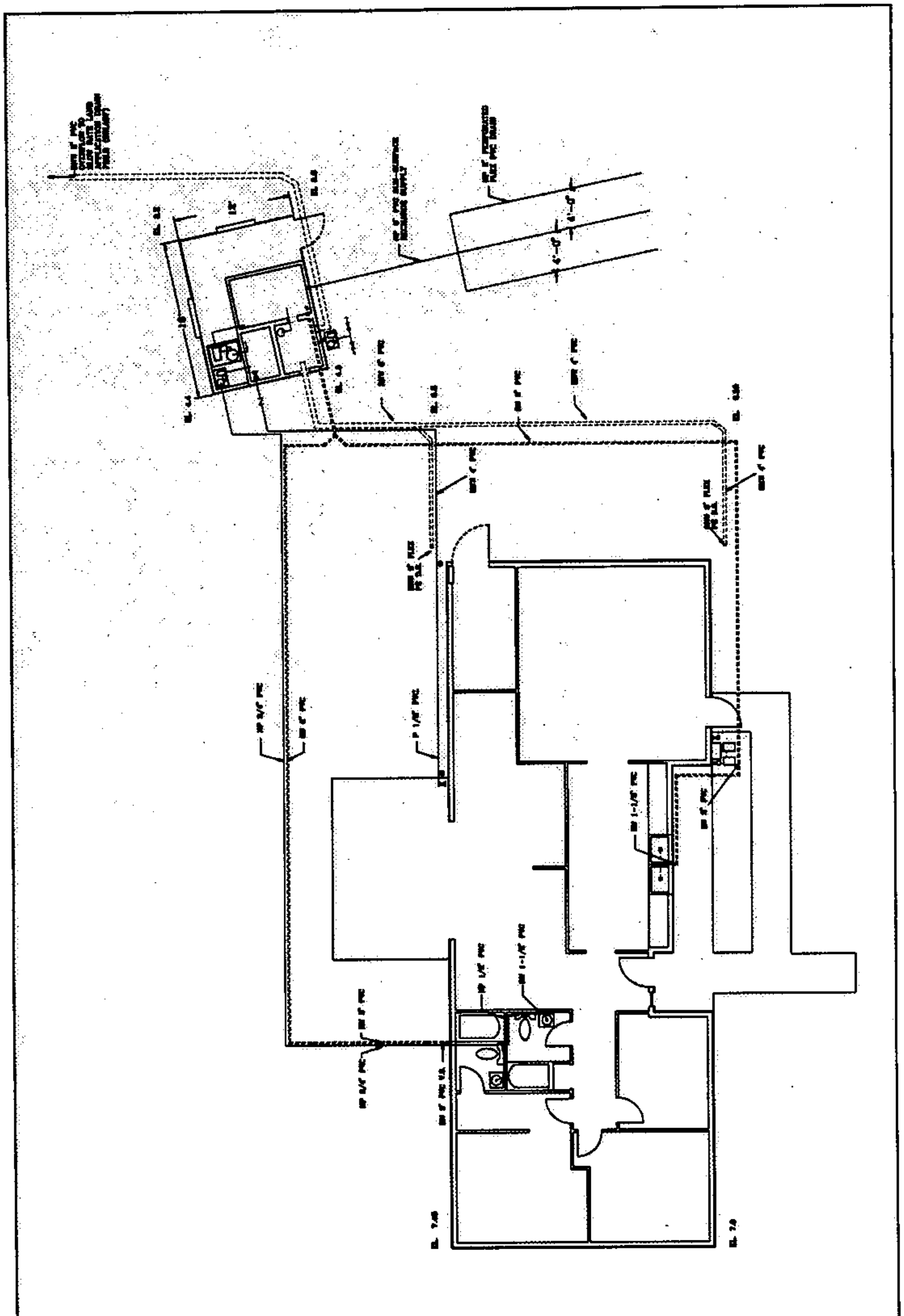


Figure A1.7.2 UF-IFAS greywater system and facility site plan.
Grosskopf, Kevin R. University of Florida, 1994.

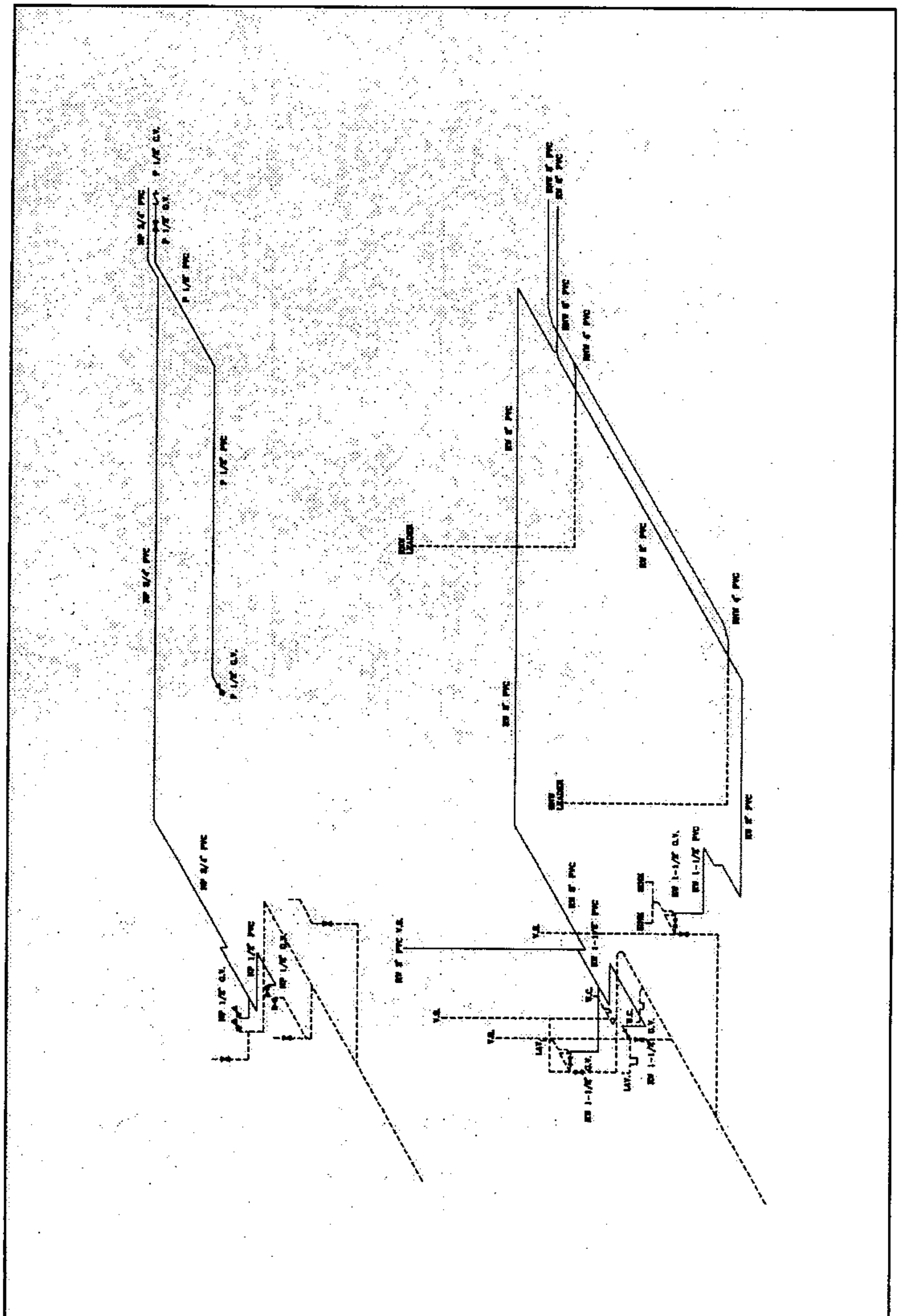


Figure A1.7.3 UF-IFAS greywater dual recovery and distribution riser diagram.
Grosskopf, Kevin R. University of Florida, 1994.

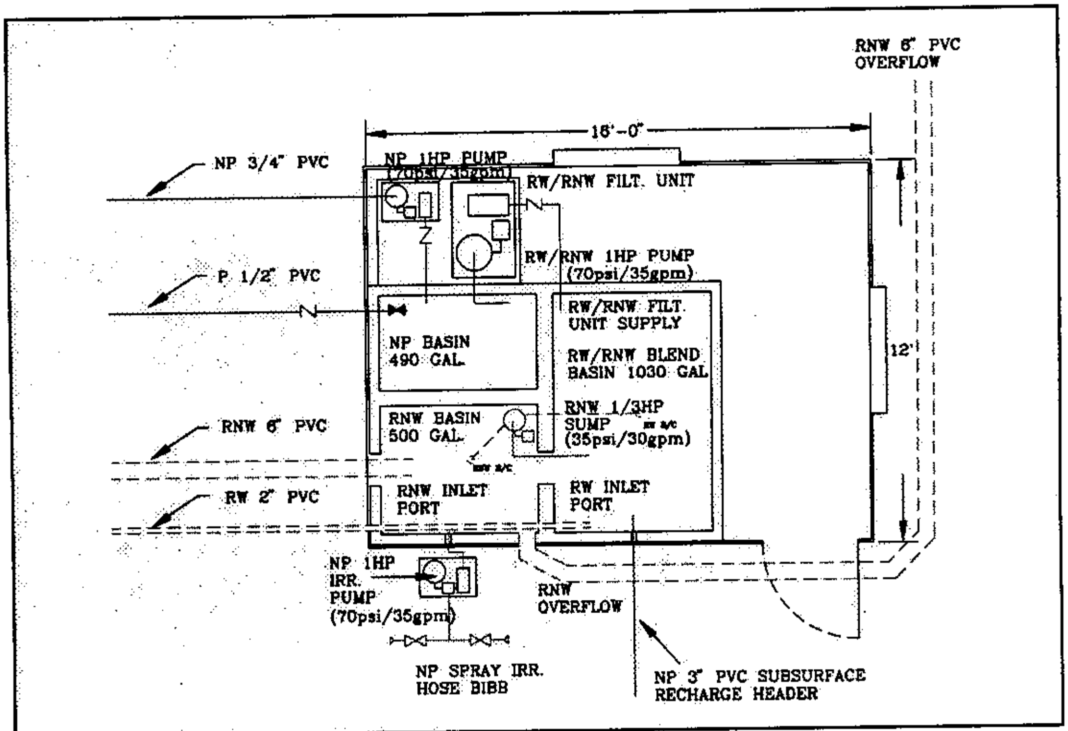


Figure A1.7.4 Greywater facility design specification plan.
Grosskopf, Kevin R. University of Florida, 1994.

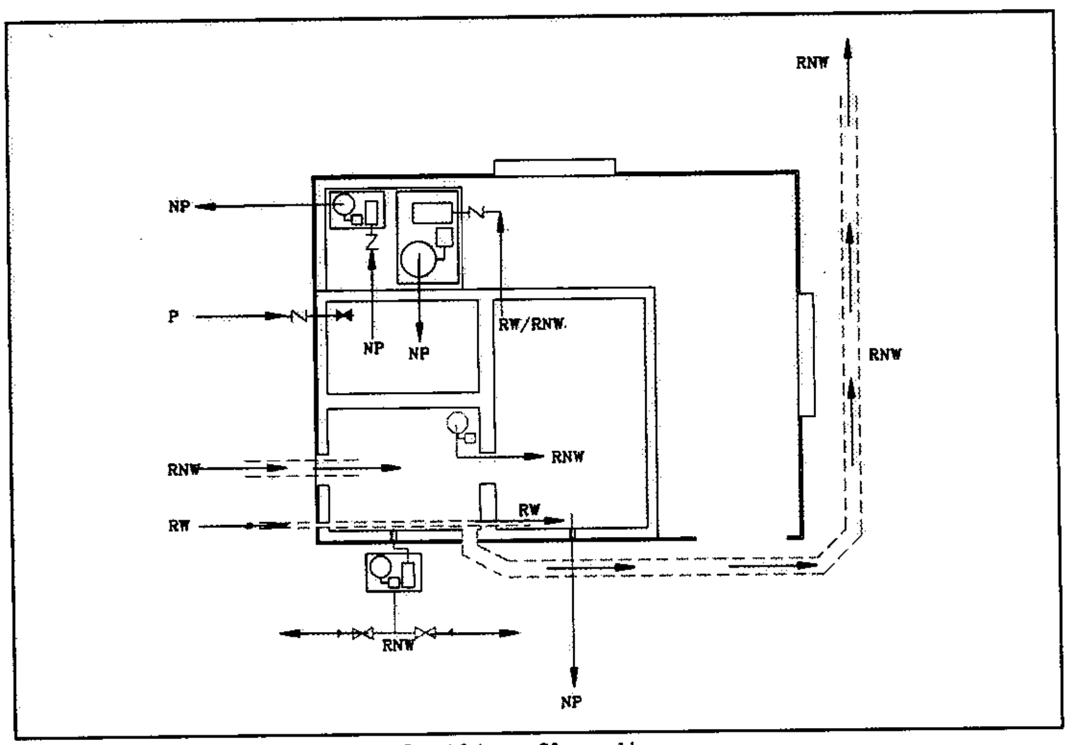


Figure A1.7.5 Greywater facility flow diagram.
Grosskopf, Kevin R. University of Florida, 1994.

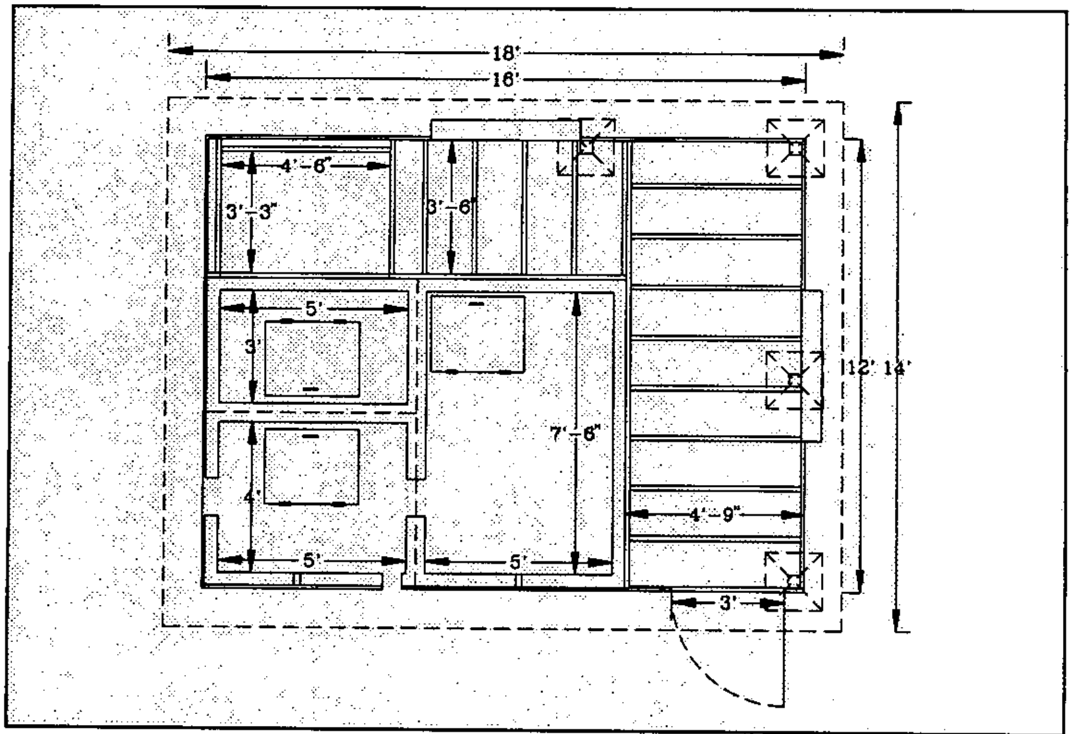


Figure A1.7.6 Greywater facility floor and structural plan.
Grosskopf, Kevin R. University of Florida, 1994.

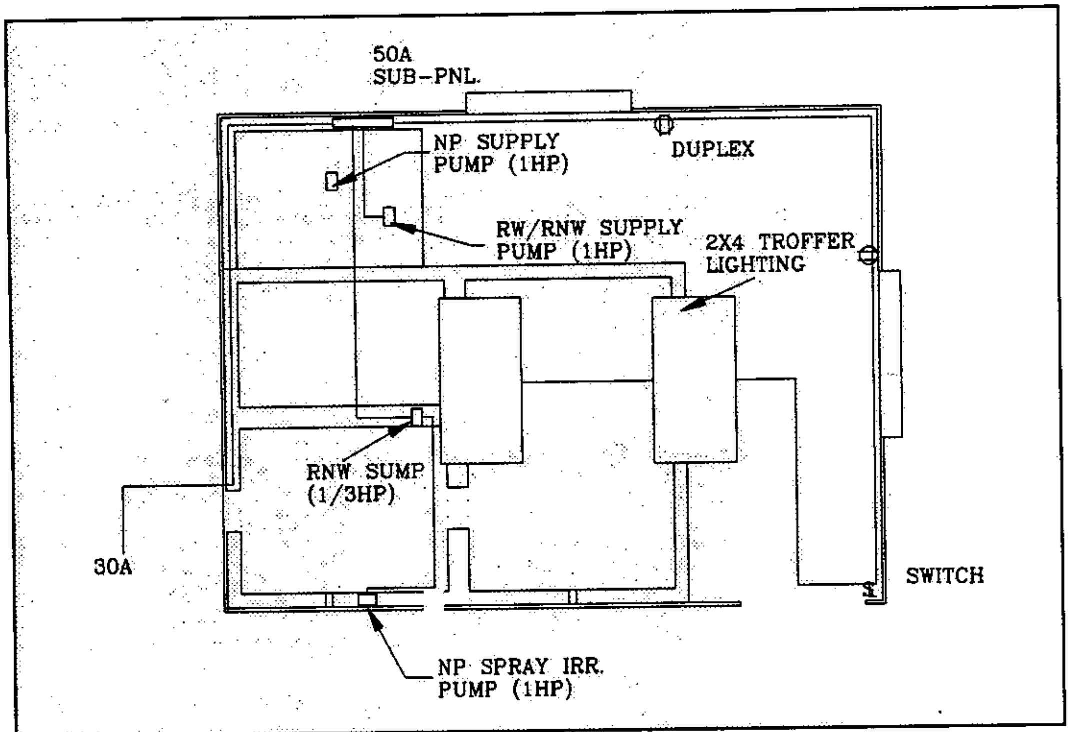


Figure A1.7.7 Greywater facility electrical requirements plan.
Grosskopf, Kevin R. University of Florida, 1994.

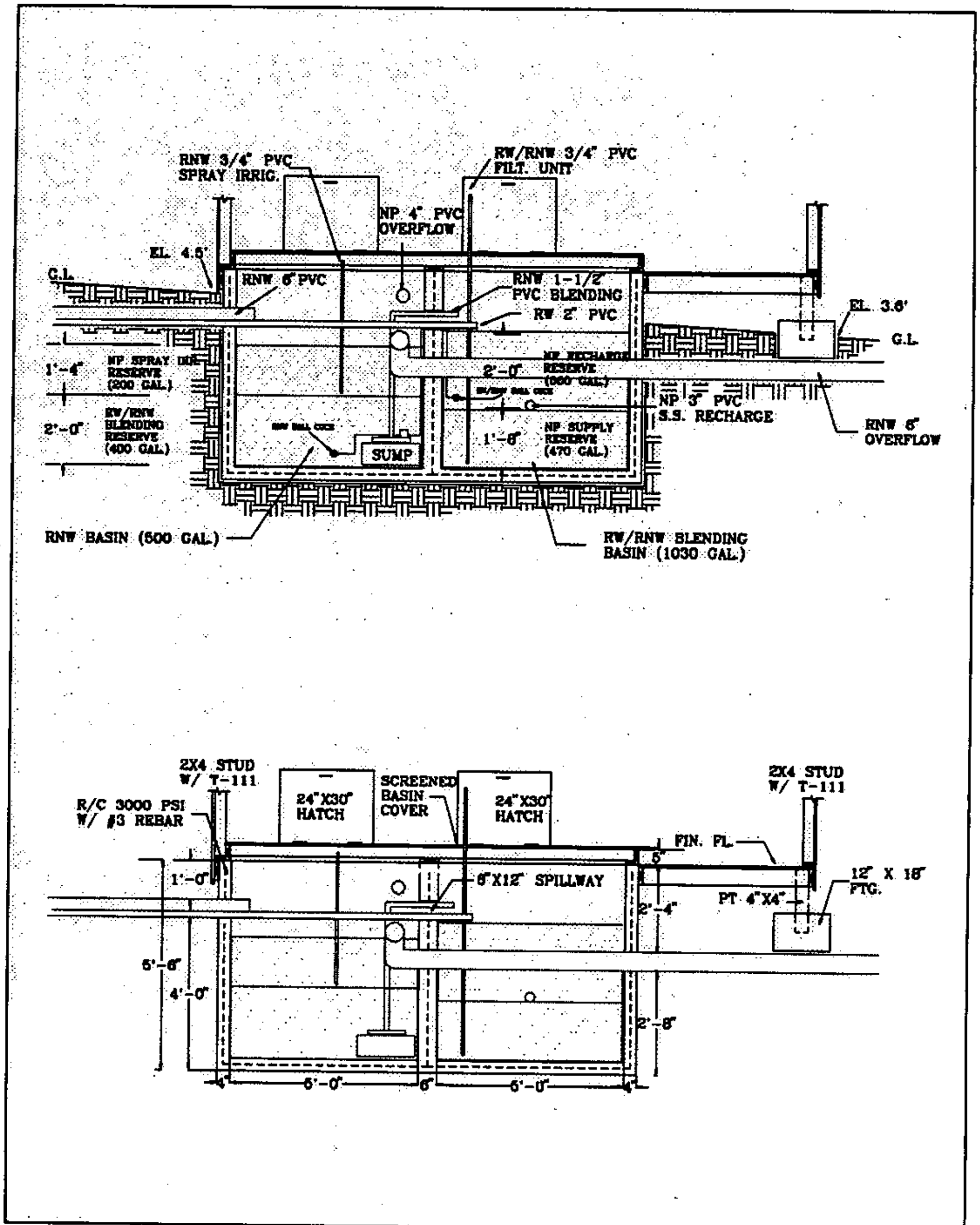


Figure A1.7.8 Greywater facility west elevation.
Grosskopf, Kevin R. University of Florida, 1994.

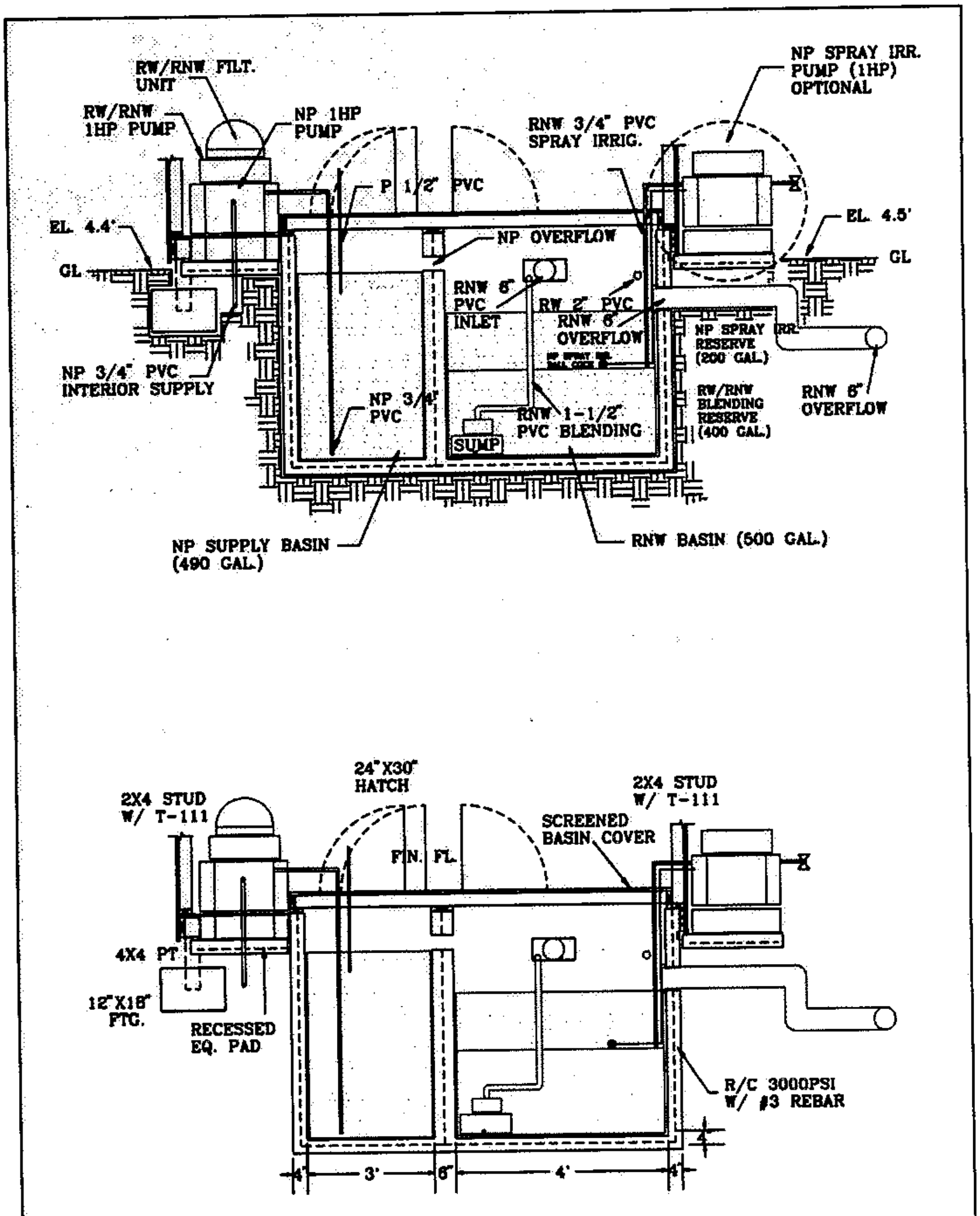


Figure A1.7.9 Greywater facility north elevation.
Grosskopf, Kevin R. University of Florida, 1994.

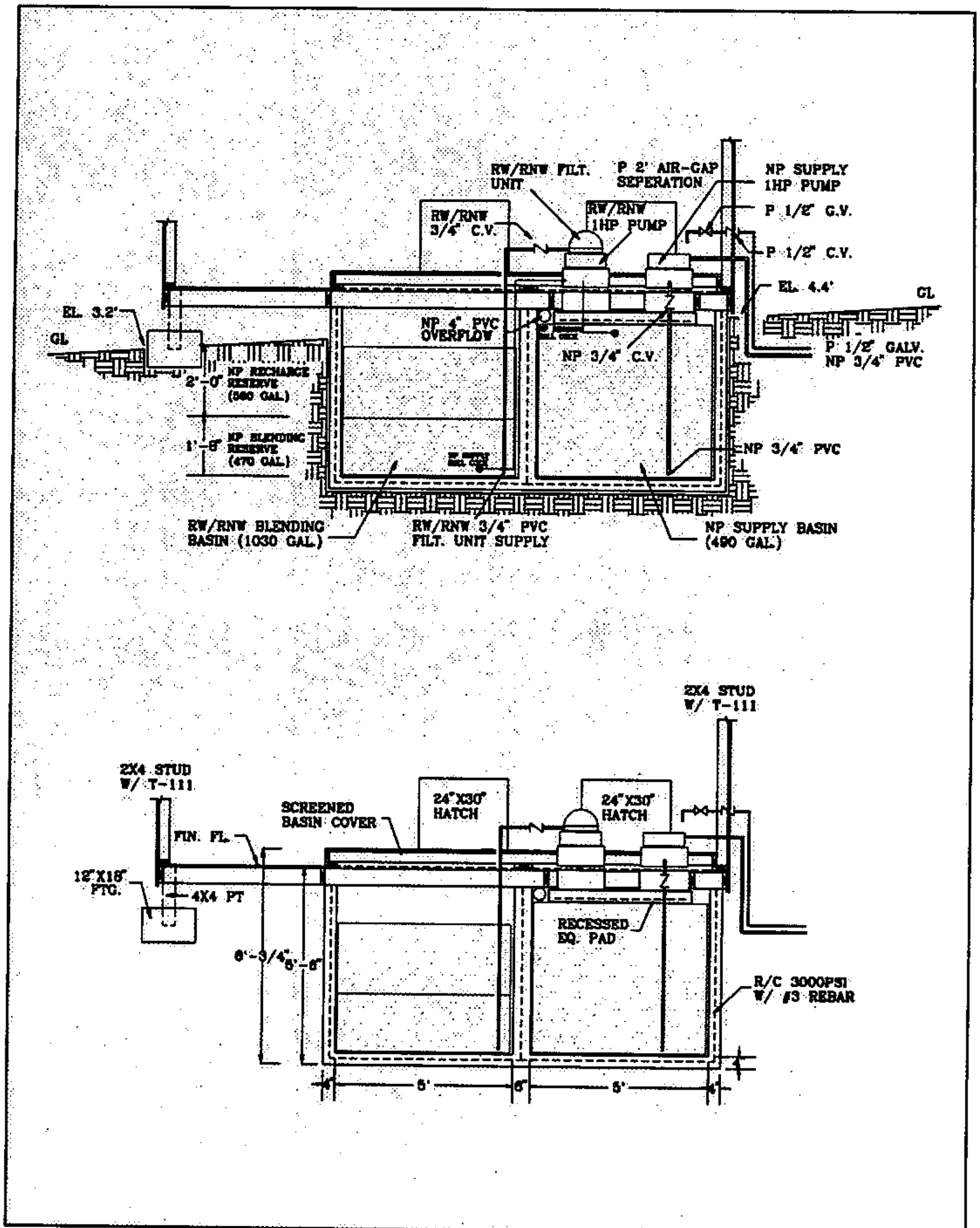
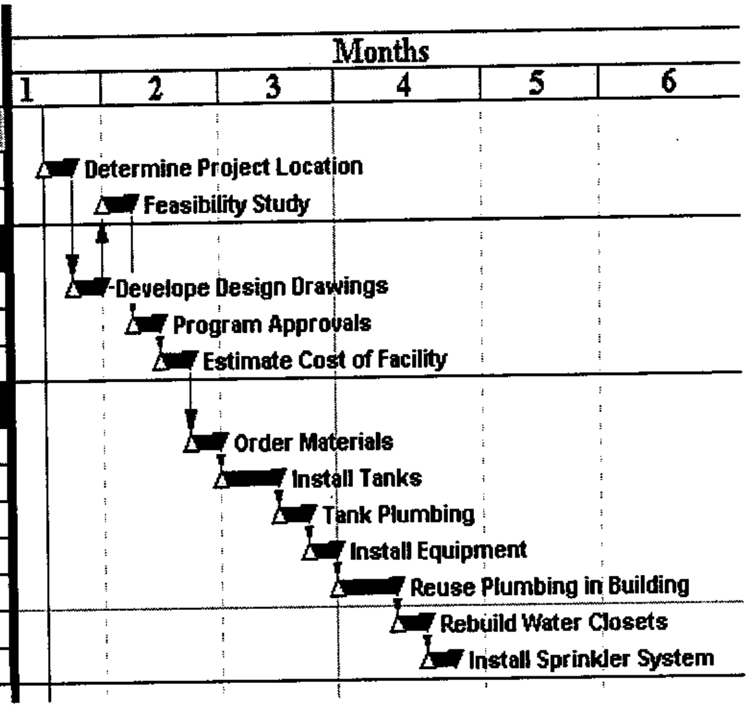


Figure A1.7.10 Greywater facility east elevation.
Grosskopf, Kevin R. University of Florida, 1994.

A1.8 Model Construction Schedule

Activity ID	Activity Description
Pre-Design Phase	
100	Determine Project Location
120	Feasibility Study
Design Phase	
110	Develope Design Drawings
130	Program Approvals
140	Estimate Cost of Facility
Construction Phase	
160	Order Materials
170	Install Tanks
180	Tank Plumbing
190	Install Equipment
200	Reuse Plumbing in Building
210	Rebuild Water Closets
220	Install Sprinkler System



APPENDIX II

State of California
Irvine Ranch Water Management District

Sample Reclaimed and Greywater Signatures and Operations Guides

A2.0 Introduction

The Irvine Ranch Water Management District has the benefit of being a new system design. In many ways this district has provided innovative technology application that is applicable in other areas such as Florida. In accordance with current and proposed reuse codes and standards, the following sample signatures and forms are presented. The proposed identification signatures and reclaimed water conditions adhere to existing Florida Statutes (F.S.) and Florida Administrative Code (F.A.C.) requirements regarding wastewater reuse identification and management. The samples contained herein promote statewide urban reuse and conservation for water resource optimization, providing an environmentally conscious, safe service to the general public for all non-potable purposes.

ON-SITE INSPECTION REPORT

NAME OF SITE: ________________ BLDG. FILE # __________

INSPECTION BY: ______________ / ____________________

FLOORS INSPECTED:	THRU:			
PIPE TAPED:	YES	☐	NO	☐
CENTRAL CORE:	YES	☐	NO	☐
DIST. TANKS TAPED:	YES	☐	NO	☐
MIN. SEPARATION:	YES	☐	NO	☐
MAINS TAPED:	YES	☐	NO	☐
DBL. METER PIT:	YES	☐	NO	☐

COMMENTS: ____

SEAL

MANAGEMENT DISTRICT DATE TIME

Form A2.1.1 Sample dual distribution report form.
State of California. *Reclaimed Water Use in Non-Residential Buildings*. Irvine Water Management District, 1991.

SEAL

WATER MANAGEMENT DISTRICT

CROSS CONNECTION TESTING
COMMERCIAL/MULTI-TENNAT RESIDENTIAL NOTIFICATION FORM

Address Tested: ______________________

____

Date Tested: ______________________

Time Tested: ______________________

Water Purveyor: ______________________

Building Management: ______________________

Agencies Invited: ______________________

____

____

- -

CROSS CONNECTION NOTIFICATION RSVP FORM

Address:

Date of Test:

Company Name:

Representatives:

I (WE) WILL ATTEND: ☐ I (WE) WILL NOT ATTEND: ☐

Figure A2.1.2 Sample cross-connection testing notification form. State of California. *Reclaimed Water Use in Non-Residential Buildings.* Irvine Ranch Water Management District, 1991.

CHECK LIST FOR COMMERCIAL AND MULTI-UNIT RESIDENTIAL RECLAIMED WATER SYSTEMS

1. BLDG. #

2. ADDRESS: ______________________________

____

3. OWNER: ______________ ______________
NAME ATTENTION

4. BLDG. SUPERINTENDENT:

____
NAME PHONE # MAILING ADDRESS

5. CONSTRUCTION COMPANY:

____
NAME PHONE # MAILING ADDRESS

6. PLUMBING CONTRACTOR:

____
NAME PHONE # MAILING ADDRESS

7. OTHER:

____
NAME PHONE # MAILING ADDRESS

8. COMMENCEMENT OF SERVICE: ______________

9. DRAWINGS ON FILE: YES ☐ NO ☐

Figure A2.1.3 Sample general conditions approval form. State of California. *Reclaimed Water Use in Non-Residential Buildings*. Irvine Water Management District, 1991.

10. MODIFICATIONS: YES ☐ NO ☐

Description: ______________________________
____
____

11. BEGINNING OF LICENSE PERIOD: ______________

12. DOUBLE METER ASSEMBLY:

(P): POTABLE:

METER # ______ ACCOUNT # ______ SIZE ______
DESIGN PRESSURE ______ psi PEAK FLOW ______
UNITS ______ # FLOORS ______ # FIXTURES ______

(R): RECLAIMED:

METER # ______ ACCOUNT # ______ SIZE ______
DESIGN PRESSURE ______ psi PEAK FLOW ______
UNITS ______ # FLOORS ______ # FIXTURES ______

13. DOUBLE CHECK VALVE ASSEMBLY:

14. MAXIMUM OBTAINABLE SEPARATION DISTANCE: ______

15. CROSS-CONNECTION CONTROL: YES ☐ NO ☐

SIGNATURE OF OWNER (S) ______________
DEPARTMENT OF ENVIRONMENTAL REGULATION
____
STATE HEALTH DEPARTMENT ______________
COUNTY HEALTH DEPARTMENT ______________

Figure A2.1.4 Sample general conditions approval form (p.2.) State of California. *Reclaimed water use in Non-Residential Buildings.* Irvine Water Management District, 1991.

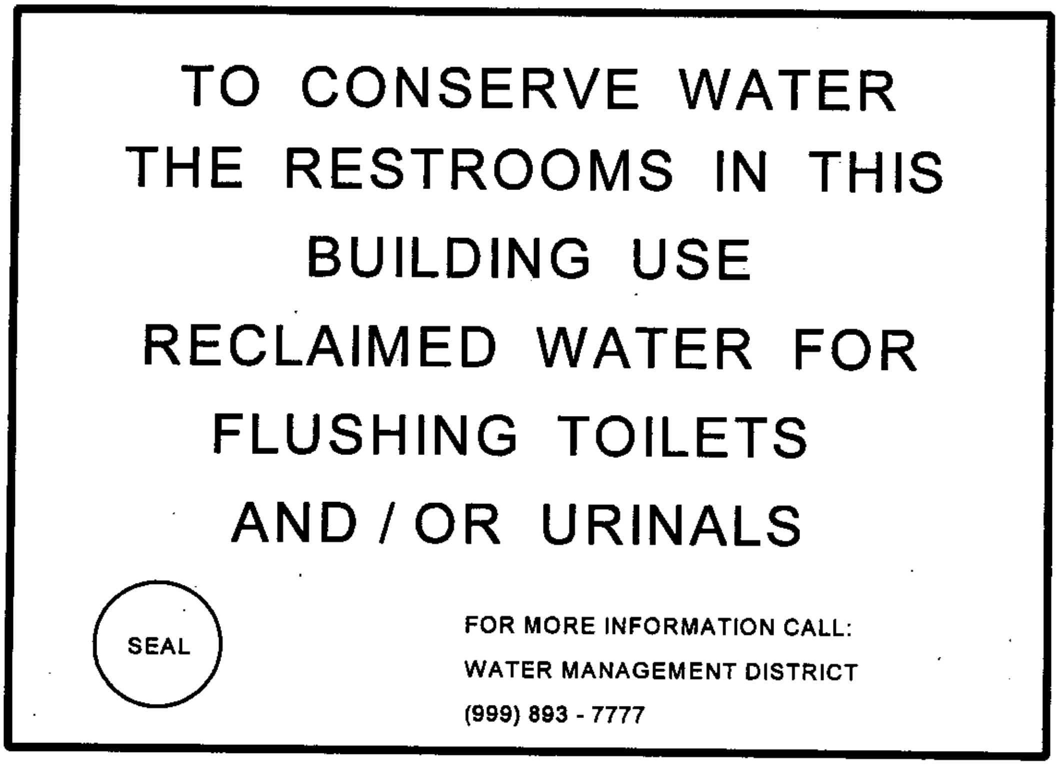


Figure A2.1.5 Sample public restroom signature.
State of California. *Reclaimed Water Use in Non-Residential Buildings.* Irvine Water Management District, 1991.

CAUTION

RECLAIMED WATER

DO NOT DRINK

NOTICE

CONTACT BUILDING MANAGEMENT

BEFORE PERFORMING ANY WORK

ON THIS WATER SYSTEM

Figure A2.1.6 Sample limited access plumbing signature.
State of California. *Reclaimed Water Use in Non-Residential Buildings.* Irvine Water Management District, 1991.

APPENDIX III

Florida Administrative Code (F.A.C.) 17-610, Part III

A3.0 Introduction

Chapter 17-610 of the Florida Administrative Code, Part III, contains the primary guidelines for reuse in Florida. Although this section provides the foundation for reuse legislation and codes enforcement, it is relatively new and flexible to interpretation. Only those sub-sections pertinent to commercial and multi-tenant residential are paraphrased herein.

Reuse; Slow-Rate Land Application Systems; Public Access Areas, Residential Irrigation, and Edible Crops

17-610.450 Description of System

This type of reuse system involves the irrigation of areas that are intended to be accessible to the public, such as residential lawns, golf courses, cemeteries, parks, landscape areas, and highway medians. Public access areas may include private property that is not open to the public at large, but is intended for frequent use by many persons. Reclaimed water may be available for fire protection, aesthetic purposes (such as decorative ponds or fountains), irrigation, dust control on construction sites, or other reuse activities. These reuse systems feature reclaimed water that has received high-level disinfection.

17-610.451 Minimum System Size

No treatment facility with a design average daily flow of less than 0.1 MGD shall have produced reclaimed water made available for reuse by slow-rate land application in public access areas.

17-610.460 Waste Treatment and Disinfection

(1) Preapplication waste treatment shall result in a reclaimed water that meets, at a minimum, secondary treatment and high-level disinfection. The reclaimed water shall not contain more than 5.0 mg/L of suspended solids before the application of the disinfectant.

(2) An operating protocol as described in F.A.C 17-610.463, shall be developed an implemented.

(3) Filtration shall be provided for TSS control. Chemical feed facilities for coagulant, coagulant aides, or polyelectrolytes shall be provided. Such chemical feed facilities may be idle if the TSS limitation is being achieved without chemical addition.

17-610.462 Reliability

Facility reliability shall have a Class 1 reliability as described in F.A.C. 17-610.300(4)(c). DER shall approve alternate levels of treatment facility reliability if the permittee provides reasonable assurances in the engineering report that the facility will provide a level of reliability equivalent to Class 1 reliability.

17-610.463 Monitoring and Operation Protocol

(1) Reclaimed water limitations shall generally be met after the disinfection and before discharge to the reuse system. The TSS limitation shall be achieved before disinfection, regardless of the actual reclaimed water compliance monitoring location.

(2) The treatment facility shall include continuous on-line monitoring for turbidity before application of the disinfectant. Continuous on-line monitoring of total chlorine residual or for residual concentrations of other disinfectants, if used, shall be provided at the compliance monitoring point. The permittee shall develop, and DER shall approve, an operating protocol designed to ensure that the high-level disinfection criteria will be met before the reclaimed water is released into the reuse distribution system.

17-610.468 Access Control and Warning Signs

The public shall be notified of the use of reclaimed water. This shall be accomplished by the posting of advisory signs in the area where reuse is practiced.

17-610.469 Application/Distribution Systems

Application of reclaimed water on public access facilities shall be controlled by agreement with the wastewater management entity or by local ordinance. Above ground hose bibbs (spigots or other hand operated connections) shall not be present. Hose bibbs shall be located in locked, below grade vaults which shall be clearly labeled as being of non-potable quality. As an alternative to the use of locked, below grade vaults with standard hose bibb services, hose bibbs which can only be operated by a special tool may be placed in non-lockable underground service boxes clearly labeled as non-potable water. Reclaimed water shall not be used to fill swimming pools, hot tubs, or wading pools.

17-610.470 Potable Water Cross-Connections

(1) No cross-connections to potable water systems shall be allowed. The permittee shall establish and obtain DER approval for cross-connection control and inspection program.

(2) Reclaimed water shall not enter a dwelling unit or a building containing a dwelling unit except as allowed by F.A.C. 17-610.476 and 17-610.477.

(3) Maximum obtainable separation of reclaimed water lines and domestic water lines shall be practiced. A minimum horizontal separation of five feet (center to center) or three feet (outside to outside), shall be maintained between reclaimed water lines and either potable or sewage collection lines.

(4) All reclaimed water valves and outlets shall be appropriately tagged or labeled to warn the public that the water is not intended for drinking. All piping, pipelines, valves, and outlets shall be color coded or otherwise marked, to differentiate reclaimed water from potable or other water.

17-610.471 Setback distances

(1) There shall be a setback distance of 75 feet from the edge of wetted area of public access land application area to potable supply wells that are existing or have been approved by DER or HRS (but not yet constructed).

(2) No setback distance is required to any non-potable water supply well.

(3) Within 100 feet from public eating, drinking and bathing facilities, low trajectory nozzles or other means to minimize aerosol formation shall be used.

(4) No setback distances are required for private swimming pools, hot tubs, or eating facilities.

17-610.476 Toilet Flush

Reclaimed water may be used for toilet flush in commercial or industrial facilities or buildings. Reclaimed water may be used for toilet flush in motels, hotels, apartment buildings, and condominiums where the individual guests or residents do not have access to the plumbing system for repairs or modifications.

17-610.477 Fire Protection

(1) Reclaimed water may be used to provide fire protection. Reclaimed water may be supplied to fire hydrants. Hydrants shall be color coded, shall have tamper proof hold-down nuts, and shall be capable of being operated only with a special wrench. Hydrants supplied reclaimed water shall have no cross-connection to the potable water supply.

(2) Reclaimed water may be used to provide fire protection in sprinkler systems located in commercial or industrial facilities or buildings. Reclaimed water may be used to provide fire protection in sprinkler systems located in motels, hotels, apartment buildings, and condominiums where the individual guests or residents do not have access to the plumbing system for repairs or modifications.

17-610.479 Aesthetic Purposes

Reclaimed water may be used for aesthetic purposes. Such uses include, but shall not be limited to decorative fountains, ponds, lagoons, and pools.

17-610.480 Other Reuse Applications

The DER shall approve other uses of reclaimed water if the following requirements are met:

(1) All requirements of F.A.C. 17-610, Part III are met; and

(2) The engineering report provides reasonable assurance that the intended use will meet applicable rules of DER and will protect the public health.

17-610.490 Permitting Concept

Normally, a single permit for the reuse system will be issued to the wastewater management facility. Regulation and management of the individual users of reclaimed water will be by the wastewater management entity through binding agreements with the individual users of reclaimed water or by local ordinance. Individual permits for use of reclaimed water shall not be issued to individual property owners.