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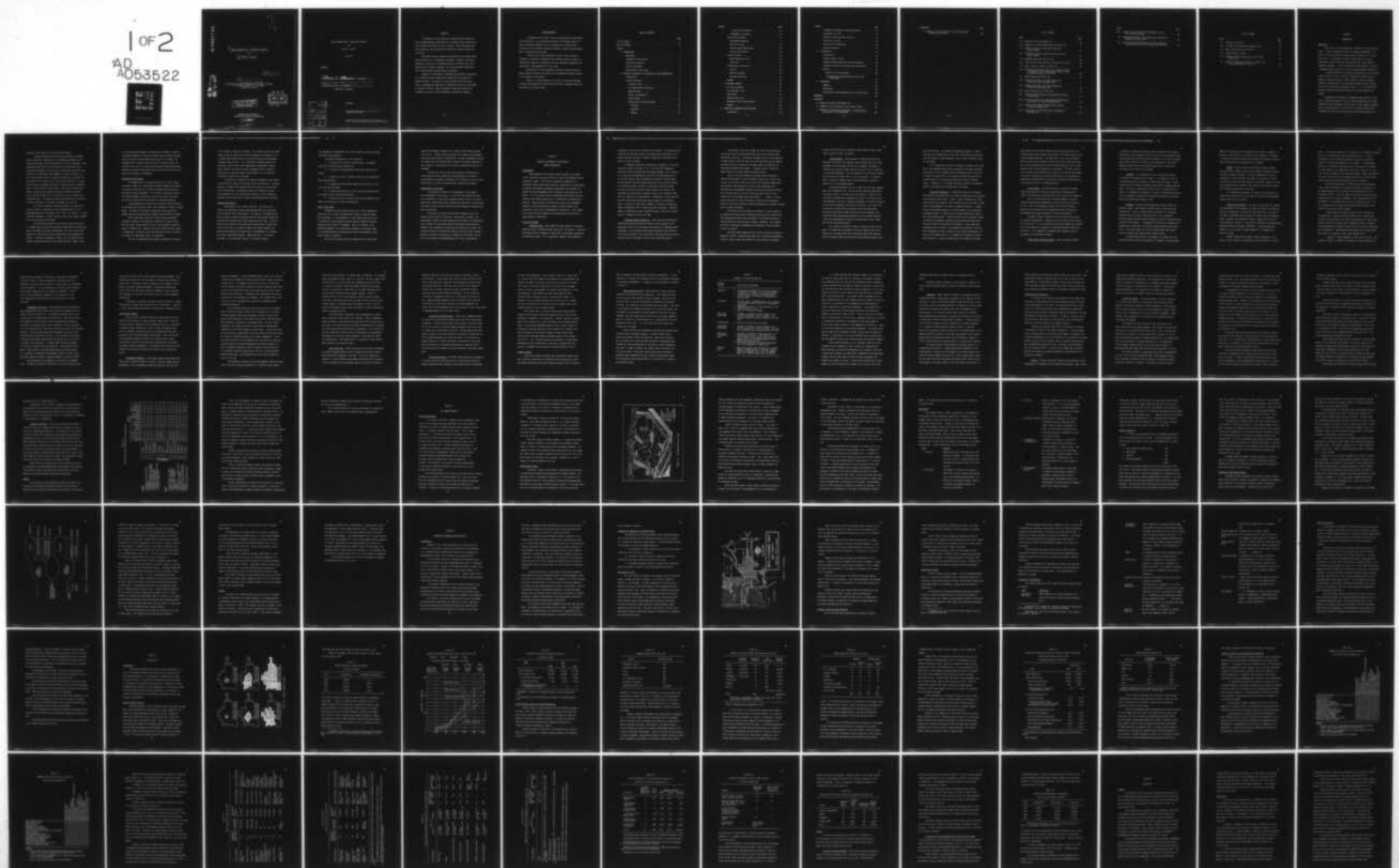

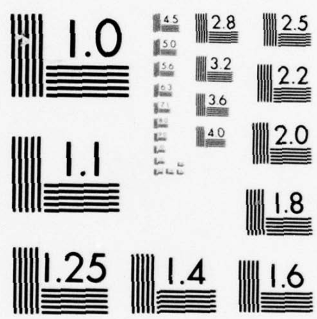
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WATER CONSERVATION: RESIDENTIAL IMPACTS

by

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Master's thesis

An Engineering Report Presented in Partial Fulfillment
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ABSTRACT

The purpose of this study was to determine the constraints and mis-understandings associated with residential water conservation and to analyze the actual savings in dollars, water and energy that are achieved by the selection and installation of water conserving facilities.

Residential water conservation programs have only been implemented during crisis or emergency situations. However, the recent awareness on the part of the American public, primarily due to the deterioration of energy resources, has focused greater attention on the interrelationships between water and energy.

Research is undertaken to determine the potential constraints to a residential water conservation program and the reasons for conserving water. An analysis of various water conserving facilities is developed and applied to a residential area with an estimate of savings in dollars, water and energy. Additional impacts are reviewed as a result of this residential conservation program.

ACKNOWLEDGEMENTS

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Chapter 1

INTRODUCTION

Background

Many cities in the southwest are faced with a dwindling water supply. Some are dependent entirely upon pumped groundwater, frequently from an aquifer with limited natural recharge and a falling water table. The favorable climate of these semi-arid regions continually attracts many people from other areas, many seeking a permanent residence. Cities are faced with the problem of providing a dependable water supply for a rapidly expanding desert population.

Increasing population, increasing urbanization, and increasing industrialization are all trends in contemporary society that are generally accepted as facts. These trends are causing increased demands for water and with the projected population growth patterns for the future indicate a shortage of water. It is inevitable that changes allowing for more efficient use of existing supplies are needed.

Compounding the problem of inadequate water supplies in the face of population growth are the real estate promotions which often attempt to entice purchasers with artificial lakes, expansive grassed areas, shrubs and trees, all of which are significant water users. A swimming pool for every new home begs the incoming population to subscribe to the ideal of an oasis-like environment.

A general impression gained during the study is that most people think water conservation is an emergency procedure to be practiced seriously only during periods of critical shortages. This impression might only be an artifact of the studies which have experienced shortages. But the idea is reinforced by the fact that the policy of most water works managers and water utilities is to furnish reliable and copious supplies of good water to everyone on the system, at all times, and at artificially low prices. In some places there are systematic efforts to increase the use of domestic water in order to derive more revenue. Many price structures are geared to making large supplies of water available at wholesale rates, and many systems are still working on a flat rate basis for un-metered water. For metered systems the universal policy seems to be one of providing all the water a customer will pay for.

In the West, especially where the doctrine of "acquisition and use" prevails, conservation of even household water is not encouraged because of the general rule: "use it or lose it." Cities, with some exceptions, in order to protect their water rights, attempt to use all the water they can get.

The traditional attitude of the American public that water is a common good, along with the general feeling that our supplies of natural resources are almost inexhaustible, has led to little real concern for conservation of water except under dire emergency conditions. The relative cheapness of water, and its stable price is probably conducive to more or less unrestrained use. Water is one of the few remaining bargains in these days of monetary inflation. The growing tendency to have more natural greenery around the house and the inclusion of more water using devices in our homes, not accompanied by a financial pinch to pay for the extra water, may account in part for our increasing per capita consumption and waste. Whatever the causes, there seems to be no great inclination to save water under ordinary circumstances.

Statement of the Problem

The combination of the austere reality of a fixed natural fresh water supply and a continuously expanding demand has promoted an increasing awareness of the need for developing new long-term approaches to water management. This need has become more acute as the country becomes increasingly involved with controlling water pollution and concerned with availability of energy resources.

Water managers and planners have turned to traditional means of increasing the supply but offer little incentive or means to reduce demand. Increases in the supply expand waste loads appreciably thereby requiring enlarged waste treatment and distribution systems.

While traditional solutions to water resources problems customarily attempt to add additional quantities of water to the existing supply, these answers are not to be considered necessarily wrong or inappropriate. However, when one realizes the water supply is altered only in physical state and quality but never in quantity, the concept of "additional" water is farfetched.

The idea of additional water needs is prompted by a concept of an affluent society and lifestyle. For instance, the jets of water used to clean our teeth and the shower massage which prepares us for a relaxed deep sleep are water using appliances which have promoted increased usage of water. Yet, almost daily newspaper editorials, headlines, and television news commentaries acknowledge a growing water shortage. On the other hand, inadequate effort is made to foster ways of reducing consumer water demands or to increase the efficiency of water use in the home.

The majority of obstacles to reducing consumption and increasing efficiency of water use are human rather than physical. The human problem is probably more important than the physical but both offer viable alternatives. Although the majority of research has dealt with attempting to solve the physical obstacles, little attempt has been made involving the social aspects of developing water resources.

Purpose and Objective

The purpose of this study is two-fold. The first is to identify the constraints and misunderstandings that are associated with residential water conservation. The second is to determine the actual savings in dollars and water that will be achieved through the selection and installation of water conserving facilities. Prior to analyzing the results of the selection and application of water conserving facilities in residential homes, this study considers six areas having potentially valuable input to development of a residential water conservation program. These areas are: (1) cultural attitudes, (2) institutional impacts, (3) economic aspects,

(4) technological alternatives, (5) public education, and (6) residential water usage patterns.

The specific objectives of this study are:

1. To identify the cultural, institutional, and economic constraints affecting water conservation.

2. To provide an understanding of why water should be conserved.

3. To identify sources of domestic water use and residential water usage patterns.

4. To identify selected water conserving facilities for use in existing and new homes.

5. To analyze the savings in dollars and water realized from a residential water conservation program.

6. To provide a basis from which areas are considered in this report can be pursued in future investigations.

Value of the Study

Although individual domestic water use is small compared to total water use in terms of proportional impact on the environment and the economy, in the aggregate it is much more significant since it represents a consolidated use which requires extensive transport systems and high levels of treatment. And, as it relates to the household component, is collected and returned to the resource pool as a concentrated point discharge again requiring substantial treatment to render it harmless.

Not only will water conserving equipment have a significant impact on wastewater treatment but in water use and energy consumption as well. Energy savings associated with reduced flow equipment have significant economic ramifications. Economic advantages accruing to reduced costs for potable water treatment and energy reductions in use of water in the household can be used to increase the quality of treatment.

The results of this study, when properly integrated with a sound program of public education and consideration of cultural, institutional and economic influences, will provide the basis for the formulation of a timely residential water conservation program.

Organization of the Study

This chapter provides a brief background on the subject being considered in this study. It outlines the problems that need to be considered in providing an adequate supply of water for future generations, defines the study's purpose and objectives, and identifies the study's value to future planners and decisionmakers concerned with water conservation.

The study is divided into two parts, Chapters 2 and 3 are devoted to the analysis of cultural, institutional, economic, and technological aspects of water conservation followed by an examination of the reasons for conserving water and residential usage patterns. Chapters 4 and 5 address the selection and application of water conserving facilities in residential homes of the City of Mesa, Arizona. Chapter 6 finalizes the study with a summary of the results, conclusions of the study, and recommendations for future investigation.

Chapter 2

POTENTIAL CONSTRAINTS TO RESIDENTIAL WATER CONSERVATION

Introduction

Many attempts to solve water supply problems in non-water crisis situations have been directed to reducing the demand from the residential sector. The success of community acceptance of a residential water conservation program is determined to a great extent by whether the community adequately understands the "problem" and whether the water management entity adequately understands the community. It is the latter that has widespread implications and which requires some indepth studies prior to institution of conservation measures. Other strategic considerations by the water management community include institutional impacts, economic aspects, and constraints in the form of technological alternatives. This chapter in four main sections addresses the understanding and analysis of these potential constraints.

Cultural Attitudes

Historical Uses. Basic needs for water caused it to take an important place in mythology along with earth, fire and air. Water was associated with the concepts of cleanliness, purification, decoration, and medicinal values. It is significant, however, that historical attitudes vary the most in the area of sanitation. The association of religious and spiritual beliefs with bathing and cleanliness is prevalent with most cultures, a symbolic cleansing of the body with a purity of soul or rebirth.

In medieval times public bathing was accepted as "it was not necessarily rude to be nude" (1:41). But with the reformation, attitudes toward the human body and bathing changed. Dirt, disease, evil, and sex were temptations of the Devil and nakedness was sin. In the 17th century these attitudes were brought to the New World by the Puritans, and some states passed laws either banning bathing or limiting the number of baths an individual could take (2:20). It may be the Puritan tradition which accounts for the fact that bathrooms are traditionally designed primarily for cleansing rather than for relaxation and rejuvenation. Nevertheless, it was not until the 19th century that bathing was again accepted in the Western World. By the early 20th century symbols of prestige included the number of bathrooms within a house and their lavishness. Today the number of bathrooms and their respective water fixtures are a major source of consumption within the home.

Attitudes Toward Elimination. While fears and prohibitions regarding bathing have not been related to other aspects of the human body, most of us view human waste products as something almost intolerable. The attitudes toward human elimination and the facilities associated with it are significant since about 45% of the water currently used in the home is used to carry away human waste.

Traditionally, the use of wastes for fertilizer substitutes and nutrient value are considered taboo due to the dirtiness associated with their use. In everyday verbiage we tend to avoid mention of human wastes unless the terms are being associated with excrement; and then, the use is accepted since these words are obnoxious and contaminate whatever they contact. A negative value is placed on waste products and almost anything related to them.

Not only are these negative attitudes toward elimination formed and reinforced in early childhood in words like "stinky" and "dirty," but cultural traditions are also reinforced by common fears. Kira observes that "because of a fairly direct anatomical and neuromuscular correspondence between the body parts used for elimination and those used for sex, our attitudes towards sex are also linked with our attitudes toward elimination . . . (3:54). In fact, one can see how as a result of organic confusion and intellectual extension, even the elimination functions themselves can become invested with our sexual attitudes."

The toilet training of American children is a good example of our negative attitudes toward elimination where we warn and embellish with threatening stories using the threats of infectious disease to frighten them into accepting their parents' standards. This changes the child's attitude of acceptance and fascination of body products to fear and disgust.

Attitudes toward human waste are closely related to olfactory sensations as well. Anything that smells bad is abusive and therefore the public want to deny the existence of their wastes by accepting anything that will help to dispose of these products quickly, odorlessly, and as silently as possible.

Recycled Water. With increases in population growth and affluence of society, now temporary water shortages may well become permanent unless attitudes and habits are changed. One means of increasing the amount of water available for daily use is recycling or reclaiming wastewater. But the acceptance of artifically treated water has been poor other than in crisis situations. As treated water is used for purposes close to the human body, the public's aversion to its use becomes greater.

Reclaimed wastewater has and is being used for many purposes other than residential use. But as the uses specified come closer to personal contact, attitudes grow more negative. Bruvold (4:33) found that "psychological repugnance and concern over the purity of reclaimed water" were most frequently mentioned as reasons for opposition but that knowledge of the need for increased water supply did not result in a more positive attitude toward reclaimed water. Bruvold concluded that neither ecological nor environmental considerations were important determinants of the preferred response; rather the psychologically negative attitude toward "dirty" water was the main determining factor.

As a result of Bruvold's studies it might be likely for the public to change their attitudes if they were exposed both to the benefits of reclaimed water and to additional educational material since the studies noted that those with more education showed a more positive attitude. As reclamation technology improves, a step by step use of reclaimed water for the public starting with those uses for which there is least opposition, such as lawn irrigation, might be instituted.

It is significant to note in Wilkinson's studies (5:37) that four of ten Americans would have no objection to drinking recycled waste water if their community health authorities said it was safe. In Denver, Colorado, 85% of the residents stated they would drink recycled water if its quality was the same as Denver's present supply. Therefore, it is probable that under certain circumstances people's attitudes about recycled water can change.

Desire For Aesthetics. The American desire for affluence and prestige has pervaded not only inside the home but to the exterior and surrounding area as well. Water is used to keep the car clean, hose off the dirty sidewalk, and to maintain all of the lawns, shrubs, trees, and groundcover in a green or blooming condition. A common desire of residential owners is to have beautiful lush landscaping and somehow there is a feeling that continued watering will make it more lush and more green. Cotter and Croft (6:55) conducted a study to identify the aesthetic and human factors which were associated with water applied to residential landscapes. It was found that residents attach a variety of psychological and aesthetic values to their landscapes and that a simple "use less water proclamation" or even price increases would in all probability be doomed to failure from the onset. A survey indicated that few residents associated water application with plant needs and that watering patterns were characterized by more frequent applications with short durations than would be deemed desirable. The conclusions of the study indicated that the most feasible method of reducing municipal peak water usage was to minimize excesses and utilize landscape design criteria which conserve water and are aesthetically attractive. The other implication is that since residents tend to apply up to 50% more than needed to maintain the aesthetic and health qualities of the landscape, an educational program should be initiated to improve the water application practices as well as landscape designs.

Social Change. The modification of a society's attitudes toward water usage and sanitation requires the consideration of certain attributes which are perceived by our culture to be important.

Jersild (7:158) noted that the establishment of cultural values begin manifesting themselves as early as the first few days of life. The first knowledge a newborn has of his environment begins with the parents; with increased capacities of perception and communication comes knowledge of culture and tradition.

A system of values is peculiar to a particular culture and our societal expectations. Adoption of any new item into the culture will occur only if it is consistent with existing values; any introduction of new behavior or patterns not consistent generally meet with difficulty. It is important to recognize that changing cultural attitudes can be extremely traumatic.

Factors Which Influence Change. There are several factors to consider in addressing the ways social attitudes can be changed. Certainly any new introduction into a culture must have greater satisfaction than the existing culture can provide if it is to be accepted. Mead (8:340) noted that in order to gain acceptance, a new item or behavior pattern must provide some satisfactions in the form of privilege, social status, and prestige.

Prestige. It is especially vital to consider the factor of prestige in planning for any change. It is especially vital to consider the factor of prestige in planning for any change. People do not like to be forced into behavior they feel is inappropriate for them. The factor of prestige and social status is exemplified currently in the number of bathrooms in a house; if conservation measures are to be adopted, values must be reversed and water-saving devices must be the prestigious things to have.

Economics. Because of the importance society attaches to economic success, some financial benefits must be associated with conservation. Foster's studies (9:62) noted that "if an economic potential does not exist or cannot be built into a program of directed change, the most careful attention to social and psychological factors will be useless." An example of this was the introduction of technological innovations of new crops into agriculture after World War II. Only where there were direct economic gains were farmers willing to change their agricultural custome (48:36).

If water-saving toilets, for example, are cheaper than conventional toilets, there may be greater willingness to accept change.

Mead (8:312) points out that changes are more readily accepted if a penalty is required for a continuation of old behavior. Therefore, if fines were levied on those using more than the acceptable amount of water the motivation of change would be increased.

Newness. While a premium is generally placed on newness and originality, unless an item closely resembles something already existing it might be rejected. Thus the resemblance of the early automobiles to the horse-drawn carriages or the design of TV sets in cabinets to look like other pieces of furniture. Those car styles that have differed too radically from familiar styles have not been well received by the public in the past.

It is important, therefore, for water saving devices to be attractively designed and not to differ too radically from equipment already familiar to our society.

Groups and Individuals. The group or individual who attempts the introduction of an innovation to the public often will determine the public acceptance or rejection of that innovation. The group or individual, sometimes called the agent of change, must be respected, highly regarded, and trusted by society. Agents who can use the same vocabulary, dialect, or slang which is peculiar to the group being approached often are the most influential. As Barnett observes, however, it is rare that one agent appeals to all segments of a society (10:380).

Another characteristic common to most individuals is the desire to feel a sense of relationship or identification to a social group. If the group approves of an innovation it is generally accepted by all of the members who identify themselves with it. This is consistent with our traditional beliefs of choosing a marriage partner that meets the credentials of our family. If educational materials or innovations regarding water conservation are important to a few leaders of an established social group, they will in turn have a strong influence on the remaining members. Water conservationists need to consider that the message must get to all groups even though groups may have traditional conflicts of interest.

The rate of acceptance of different groups once exposed to a few innovation depends on the degree to which an innovation can be understood which will also affect the time necessary for its acceptance (48:84). The more complex innovations of course, require longer periods of time for acceptance. Fear and suspicion will be minimized if a new element can be tried on a temporary basis. If not, acceptance may be reinforced by hearing from someone who has tried or used the new item or concept.

In some cases it may take an actual crisis for people to try mechanisms. Studies on the East Coast in 1971 revealed that during a water-shortage-crisis period the population in certain communities voluntarily reduced water consumption by 60%; in another area consumption was reduced to 18% and after the crisis, consumption only increased 5%. These temporary shortages served to make people more aware of the amount of water they consumed (11:4).

Acceptance is almost mandatory in the case of a crisis. But Everett M. Roger's "Diffusion of Innovation" closely examines the stages which are common to individuals as they adopt an innovation into their culture. These are awareness, evaluation, and trial. Awareness occurs when the individual in a given society is introduced to the innovation. It is at the point of evaluation, which follows, that personal communications are especially important. Finally, prior to the achievement of adoption of the innovation is the trial stage where the individual tries the new idea in his own situation.

Inducements to Conserve. Both manufacturing and advertising have encouraged Americans to have an attitude that spending and consuming lead to the "good life." New models are better than old and anything which is damaged should be thrown away. When our resources were thought to be unlimited this was an appropriate attitude but not today. No economic system, Marx concedes, has "been so successful in calling forth man's individual initiative and man's profit-making energies." Thus few would question the assumption that next year's income should be better than the last. This attitude has even penetrated into patriotism, democracy and religion so that any criticism is thought to be subversive. To change these ingrained attitudes will require a complex effort and education. The function of movements is the process of directing human energy to produce change. It is important to understand how movements operate in order to see how water conservation might be made acceptable to society (13:948).

One characteristic of movements is that they are segmented cells. Friends of the Earth is the result of a split from the Sierra

Club but both direct their efforts toward the ecology movement. Even though one cell may fail, the existence of a larger entity keeps the group viable. The death of Martin Luther King, for example, did not destroy the Black Liberation Movement. According to Gerlack and Hine (14:164) the power behind specific movements is best evaluated by the number of even small scale events as well as their geographic distribution.

The forces of movements sometimes are more effective in create ing behavioral changes than through the use of legislation. "Equality of races" policies were legislated in 1954 and still inequality exists.

Institutional Impacts

While cultural attitudes toward water conservation are often derived from individual or group influence, there exist a variety of private and public agencies or institutions which act as a constraint to potential water conservation. Most of these institutions have specific authority to grant approvals and implement policies which encourage or even discourage water conservation. These institutions are governmental agencies, building and plumbing codes, private institutions, and public utilities which include water distribution and sewage treatment components. Crain notes that the local political structure can have more influence on the public than institutions (49:10).

Governmental Agencies. Governmental agencies that potentially affect water programs include city councils, planning commissions and departments, local environmental protection agencies, and state and federal governments. Local governmental bodies such as city councils normally use ordinances that outlaw certain types of water use during a water crisis. For example, during the fuel crisis in 1973-1974 the Los Angeles City Council passed an ordinance imposing restrictions on the use of electricity based on the usage one year prior; severe penalties were called for. Consumption was reduced and with the end of the crisis, the ordinance was repealed. This implies that in the event of a crisis, government can successfully implement severe conservation measures.

While planning commissions have little ability to influence water use within the home, they do have the potential to influence builder-developers that could encourage or possibly require that water saving technology be used within the project, considering that the technology is available in the market place. Even so, zoning regulations are another tool which could be used to reduce water consumption within their respective jurisdictions. Zoning could also be used to restrict growth within the city which would have the effect of insuring a relatively steady rate of water consumption. It has been noted by Milne (15:121) however, that the legality of zoning to restrict growth has not been determined and that the reduction of water consumption depends on several variables including the overall residential density allowed within the city, the efficiency of watering open areas, and the demand for various types of dwelling units in the city.

Even though the concept of local environmental protection agencies in effecting resource conservation is relatively new, they do have significant potential in reducing water consumption. For instance, where environmental impact reports are required, the local agency could set priorities as to which costs are acceptable and which are not. In this way, the agency could ensure water conservation by making the cost of excessive or inefficient use of water unacceptable and one that must be resolved before project approval. There is a potential conflict for an environmental protection agency however since their views might agree with the idea of recycling water while a health agency is concerned about the dangers of reuse. But the overall environmental costs versus the benefits of water conservation should be resolved (15:121).

State and federal governments have the potential to reduce water consumption just as other local agencies. Since a tremendous amount of energy is required to pump water form place to place and to heat water, any efforts directed to energy conservation will obviously have some legislative effect on water conservation. The availability of water conserving fixtures could be influenced by the governments' procurement policies since these represent a vast potential market for manufacturers. With these fixtures in production, they could be made available to the general public.

Public Utilities. Public utilities such as water distribution and sewage treatment agencies could through similar methods support water conservation measures in the home. The use of conservation reminders or rating different appliances and practices with insertion of this information into the monthly water bill has had significant reduction effects on both water and energy use especially during crisis periods. Stroeh noted that in Marin County, California, the voters turned down bond issues to finance expansion of water supply and storage capacities. The local water district then launched a program which included a moratorium, public education campaign, rate restricting, and wastewater reclamation. The new effect was a reduction in consumption from 170 to 150 gallons per person per day. Sewage treatment agencies could also support water conservation efforts by giving price reductions to those homeowners who install water saving equipment as well as to owners of newly constructed or remodeled homes who do the same (16:19).

Building and Plumbing Codes. Within new or remodeled homes, the revision of building and plumbing codes could help reduce water consumption. While building codes are very general and are directed only to the inclusion of certain adequate household facilities such as kitchen sinks and bathroom facilities, revised plumbing codes have greater potential since they establish the operating characteristics which household plumbing facilities must meet. For instance, Los Angeles County has a severe restriction on the type of toilet that may be installed in a new home and the method of operation that a toilet must have with regard to seal and flushing of the water closet walls.

Private Institutions. Building trade unions are an example of a private institution that would only be concerned with efforts to reduce residential water consumption when those efforts incorporated the use of new technology. Since the main concern of a trade union is to ensure that their members are employed, any new technology that reduces the number of man-hours required for a particular job would most likely be resisted culminating in a strike or work stoppage, unless of course, union members are granted higher wages due to the new technology. Other opposition might come resulting from a redistribution of man-hours due to a vacuum toilet system. For example, if such a system required thirty less hours for a plumber but thirty more hours for an electrician, the plumbers union would probably oppose the use of vacuum toilets.

Milne notes that it is worth noticing that almost without exception institutional constraints operate during or prior to the time when a residence is in construction. However, once the occupant moves into his home, he is rarely disturbed by any of these institutions. Since new and remodeled houses are only a small fraction of the housing inventory each year, the vast majority of residents will not be affected by institutional impacts on water conservation, except possibly through economic coverage by means of the regular utility bill. Yet, it does seem that the advantage of institutional approaches to water conservation is that they are potentially the easiest to implement, most equitable, and most effective (15:117).

Economic Aspects

Aside from cultural attitudes and institutional factors with their potential constraints on residential water conservation, there are economic mechanisms that offer important possibilities to reducing water consumption and the behavior related to consumption. A brief analysis will consider water demand and price, and economic incentives to builders and homeowners. A summary of pricing systems is included in Table 2-1.

Water Demand and Price. Water metering is one of the most effective present water pricing mechanisms. This system links the price of water to the quantity of water consumed. Over 90% of the municipalities in the United States have residential water meters (17:302). Two incentives are associated with water meters. The first is the incentive of reducing the water bill by using less water, and the second is the awareness of being charged for each unit of water consumed. But most people think of water as a very cheap commodity, which it currently is, and the water bill is the smallest of all the household utility bills. It is this very low cost of water that shapes public attitudes.

Several studies have attempted to identify the variables that determine water consumption patterns. Hollman (18:20) using a statistical method of multiple regression, found that of the thirteen variables he believed explained variations in household water consumption, three explained 45% of variation in water consumption. They were (1) number of people, (2) market value of the home, and (3) price of water. Most other studies agree that variations in household water consumption are most strongly influenced by family size followed by some variable which is an indication of a family's socioeconomic status.

Table 2-1

Summary of Pricing Systems (43)

Type of System	Definition and Comments
Metering	1. Not generally thought of as a pricing mehtod, it is essential to effect most pricing programs. 2. Installation of meters in nonmetered areas usually results in decrease in consumption of at least 25%.
Flat Rate	1. Usually found in unmetered areas; each customer is charged the same regardless of the amount of water used. 2. Sometimes the rate is varied according to the size of delivery line. 3. Easy for utilities to manage.
Declining Block Rate	1. Customer is charged a certain amount for an initial quantity or "block" of water. The rate for succeeding blocks decreases with each block.
Uniform Rate	1. Each unit of water costs the same.
Increasing Block Rate	1. Customer is charged a certain amount for an initial quantity or "block" of water. The rate for succeeding blocks increases with each block.
Peak Load, or Seasonal, Rate	1. Customer is charged a uniform rate for a certain quantity of water. This quantity is usually based on the reduced lawn irrigation season use or on the average demands on the water distribution system. 2. Quantities used above the amounts determined in (1) are charged at a higher rate.
Lifeline Rate	1. State law requires that the rate for a certain amount of energy service ("lifeline" amount) cannot be increased until rates for amounts above the "lifeline" amounts are raised 25%.

It is often expected that consumer response to an increase in the price of water would lead to a decrease in the amount consumed. This hypothesis does not hold true for residential water consumption. Hollman concluded that reasonable increases in the price of water will not significantly affect residential water consumption; in fact, many people are willing to pay as much as 700 times the cost of tap water just to get bottled water. His studies further concluded that consumer responsiveness to price increases generally depends on the price elasticity of the demand for the commodity and the percentage of family income that is spent for the commodity. Price elasticity is one way of measuring or predicting how consumers will respond to changes in the price of water (18:21). Price is said to be inelastic when a large increase in the price of a commodity leads only to a small or insignificant decrease in the demand for that good; demand is elastic when a small increase in the commodity price leads to a large or significant reduction in the quantity demanded. The studies noted above do agree that the demand for water used outside the home, for example, in lawn-watering or for less essential uses is more elastic than the demand for water used inside the home for essential purposes.

Since affluent families, due to different values and social standards, may be compelled to have a large lawn, swimming pool, three bathrooms, and even two dishwashers, any increase in the price of water would probably not change their consumption since they would probably take the money spent on some item they considered less essential and spend it on water. A poor family already with a tight budget would have to absorb any increase in the price of water and therefore would have to decrease some of its essential uses of water.

Therefore, simple increases in price alone will probably not prove to be an effective means of reducing residential water consumption.

Incentives. Other types of incentives to homeowners could be a taxation policy to reduce water consumption or as a penalty for not reducing it. Using the incentive approach might take the form of the city giving a small percentage reduction in property tax rate to those homes that proved they had reduced their water consumption over a previous year. As a lump sum payment once a year, this incentive would probably have more meaning as opposed to reductions in the price of water over a period of twelve monthly payments. A taxation policy in the form of a penalty could be imposed for not reducing consumption. Neither of these approaches could be used in a new home which has no previous accounting record; but, the effectiveness of the approach would be increased if they were used together since property owners would be facing twice the tax rate differential; therefore giving a high incentive to conserve water in as many ways as possible.

To study the overall effectiveness of economic measures is interesting since there is a strong psychological component in consumer behavior; decisions of the consumer do not always appear to be logical from the economic point of view. Just as people would rather pay 700 times the cost of tap water for bottled water, others like to add products to the water closet to color the water and disinfect it.

These products cost almost twice what the water costs per flush. Thus some logical economic incentives may in fact have no effect on consumer behavior. Nevertheless, changes in water rate structures and other non-market economic incentives may be able to turn around the ever increasing consumption habits of the American household (15:136).

Technological Alternatives

A review of the literature has indicated to this author that there are no overwhelming and unsolved problems holding back technological development in this area. One could conclude from a review that of all these devices there are no technological problems preventing residential water conservation; there are hundreds of feasible and attractive alternatives available. Of course, it must be kept in mind that water conservation is much more than just a technological problem, as has been shown in the foregoing analysis.

Actually, the devices that affect the way water is used can be described in terms of four general categories: (1) those commercially available water-using fixtures and systems, (2) products that have been patented but are not in production, (3) residential recycling systems, and (4) devices currently used in aerospace technology and mass transportation systems (15:162). The latter three categories will be discussed briefly. A review of the commercially available water-using fixtures and systems selected for installation will be discussed in Chapter 5.

Patents. Patents offer some insight into the possible future developments in residential water conserving technology. Most claim to reduce water consumption either by more efficiently using water or by substituting waterless technology. The information on a patent application is general, all-encompassing, and somewhat vague which probably allows the inventor to better perfect his invention. Since most of these developments are not commercially available, no attempt was made to include them as a practical means of reducing water demands.

Recycling Systems. It was this author's original intention to illustrate that the use of residential recycling systems would provide a significant reduction in water consumption. Unfortunately, most of these systems are still in the developmental stages and their initial cost is extremely high for the residential homeowner. Nevertheless, these systems will be discussed as an alternative measure to reduce water demands.

Two reasons for recycling water within the home are less water required and less sewage produced. Water used in the home does not have to be of drinking water quality for all uses. The most cost effective way therefore to recycle water within the home is to minimize or eliminate the need for treatment between uses. An example would be to reuse the water in the same appliance as in a swimming pool filter; another example would be to use water from a shower in a washing machine and finally that from the washing machine in a toilet.

While these "example" concepts may seem simple, implementation as such is still new and infrequently done. While sewage and water can be currently treated on-site, the question of pollutant disposal after their removal is a problem. The previous review of cultural attitudes and the problem of social acceptance of recycled water poses another problem. Yet, it has been proven by Bailey that the recycling of water can produce significant reductions in the quantity of water discharged to the sewage treatment system (19:R62).

A consequence of recycling is that the sewage leaving the home will have a higher concentration of pollutants in it. It may be erroneously implied that this would pose problems for the municipal sewage treatment plant. However, since treatment costs are associated with the quantity of water treated and not the amount of pollutants removed, the decreased sewage output of the homes would reduce the per capita costs of treating sewage for the city (15:362). It also appears that with reduced flow the design life of the plant would be lengthened (20:53). It should be recognized that at some point the cutback of effluent poses the problem of maintaining solids transport or scouring, or the possible build up of gases because of retention in the system (21:155).

Grey water and black water recycling are two words currently being used in the literature to describe types of recycling systems. Grey water is all the waste water generated within a home except toilet waste water. Black water is any waste water containing toilet waste water and wastes from garbage grinders (46:53).

Grey water without treatment could be used for home irrigation where the phosphates from laundry water would act as soil and plants nutrients. It should be noted that only soap products that are not detrimental and are biodegradable should be used; in the long run this practice might save fertilizer and water. With filtration treatment, grey water could be used for lawn sprinkling, car washing, and in the water closet.

Assuming that grey water accounts for about 50% of the waste water produced inside a home, its resuse, in either the water closet or for irrigation, could result in a 50% reduction in indoor residential water consumption or a 25% reduction in total consumption (15: 374).

Because black water is so highly polluted and unsanitary and therefore requires extensive treatment before reuse, consideration of the concept as a residential water conservation measure is currently impractical.

Both Cohen (22:42) and McLaughlin (23:133) have designed and tested recycling systems on a residential basis. McLaughlin's system collected effluent from bathing and clothes washing in a pair of 55 gallon drums, then pumped it through a swimming pool filter for use in a conventional toilet. The system cost about $500, but he felt the initial cost could be reduced by eliminating the filter. The system reduced water consumption by 22.6%.

Cohen worked with three different systems for recycling wash water for use in toilets and in lawns. The initial costs for the systems were between $550 and $650 and resulted in a 26% reduction in total water consumption, with an annual operating cost of $20. Unless the cost of water is unusually high, or unless the owner pays for sewage treatment in proportion to the amount of water consumed, this type of system is unlikely to be cost effective (22:94).

Milne describes the potential for water reuse within the home through the use of a legend (Table 2-2).

The potential for recycling is greatest in new homes yet to be constructed since the costs of retrofitting a recycling system within an existing home have been found not to be cost effective. Recycling is one of the few ways in which it is possible to accomplish a large reduction in consumption.

Advanced Technology. The idea of recycling in the home is relatively new but is somewhat more critical and common in the air, sea, rail and aerospace industries. The objectives of less weight, in order to reduce fuel consumption and increase cargo capacity are predominant savings in the form of payload rates and cash profits. These industries indicate to us as consumers that not only do we use less water than at home but that we are able to cope with new design utilizing less than half the space to which we are accustomed. In the Skylab program, astronauts found it was possible to take a satisfying shower with only one gallon of water, by wetting down, soaping up with the water off, and then rinsing down (15:389).

While recycling of potable water has not been practiced on any spacecraft, the other developments noted exemplify the potential for savings in dollars and water and illustrate that individual behavior can be altered under particular circumstances.

Summary

The discussion of four potential constraints to water conservation has presented sufficient information to allow one to speculate as to how water conservation may come about in the future.

Table 2-2

Potential for Water Reuse Within the Home (15)

ORIGINAL USE	REUSE: Toilet	Irrigation	Sprinkler	Kitchen sink	Carwash	Laundry	Pool	Shower/tub	Bathroom sink	Dishwasher	Drinking	Cooking
1. Toilet[a]	2	-	-	-	-	-	-	-	-	-	-	-
2. Irrigation*[b]	1	1	1	-	1	-	-	-	-	-	-	-
3. Sprinkler*[c]	1	1	1	-	1	-	-	-	-	-	-	-
4. Kitchen sink with grinder	1	0	1	-	-	-	-	-	-	-	-	-
5. Carwash*	1	0[o]	1[o]	-	1	-	-	-	-	-	-	-
6. Laundry[d]	1	0[o]	1[o]	-	1	1	-	-	-	-	-	-
7. Pool (Chlorinated)	1	-	-	-	1	1	2	-	-	-	-	-
8. Shower/tub	1	0[o]	1[o]	-	1	1	-	1	-	-	-	-
9. Bathroom sink[e]	1	0[o]	1[o]	-	-	-	-	-	-	-	-	-
10. Dishwasher	1	0[o]	1[o]	0	1	-	-	-	-	0	-	-
11. Drinking*	1	0	1	0	1	-	-	-	-	-	-	-
12. Cooking	1	0	1	0	1	-	-	-	-	0	0	0

LEGEND

0 Reusable directly without treatment
1 Reusable with settling and/or filtering (primary treatment)
2 Reusable with settling, filtering, and chemical treatment usually chlorination (secondary treatment)

NOTES

* Very difficult to collect
o Special soaps required
a Small valves & underwater moving parts--clogging problem
b Large orifice: unpressurized open hose or channel
c Small orifice: pressurized
d Assumes no diapers with fecal matter
e Shaving and brushing teeth

First, with the emphasis on changing cultural attitudes, the public can be made aware of the need for protecting and conserving water resources through conservation movements and the various mass media. A gradual change in values may result from these forces. The educational procedure may be accelerated as prestigious or admired personalities begin to identify themselves with new concepts and water conserving behavior. With increased public interest in the need for conservation, they will be more cooperative with any legal measures which enforce it. It seems more likely, however, that cooperation and acceptance will result from financial benefits which will have to be associated with new behavior if it is to be adopted. The appeal of newness of gadget type water conservation devices will mean quicker acceptance, assuming the new devices closely resemble the existing ones.

Second, institutions and agencies are highly interconnected. The actions or policies of one can influence the actions or policies of the other agencies. With integration of their activities, their effectiveness should multiply.

Third, in regard to economic aspects, even though increases will not significantly reduce residential water consumption, changes in water rate structures and other non-market economic incentives may be able to reverse the ever increasing water consumption habits of the American household.

Fourth, technological alternatives are offered as a constraint only if they are not available to reduce consumption. The fact is, there are no technological problems preventing residential conservation;

there are hundreds of feasible and attractive alternatives available but few are in widespread use.

The following chapter will discuss the reasons for conserving water, domestic water use, and residential water usage patterns.

Chapter 3

THE CURRENT PROBLEM

Why Conserve Water?

It has been illustrated in Chapter 2 that significant reductions in water demand have been observed but only when temporary shortages or a period of drought required those reductions during a crisis. In Chinese, the word "Wei-jee" means "crisis creates opportunity." Ling notes that faced with coming crises, those in the water field must take advantage of their opportunities. He further states, "one cannot worship technology blindly, since it is a means and not an end. But when everyone understands its strengths and weaknesses, technology can be applied wisely. Once its limitations are comprehended, innovative and conservation-oriented technology developed through a well-planned, well-balanced research program offers the best opportunity . . ." (24:660). The education of the public and their understanding of the current problem are essential to the success of a well-balanced and phased program.

The continued current use of water in the home not only imposes a reduction in quantity of water available but in quality as well. The Law of Conservation says "matter cannot be created or destroyed but only converted to another form or moved to another place" (24:661). A reduction in demand consistent with a change in behavior and attitudes and a recognition of a water quality problem should have a positive effect of providing more adequate supplies in the future. Since the purpose of this paper is to develop a residential water conservation program, the question of quality water will not be considered.

Abel Wolman's studies conclude that "for many years beyond 2000 A.D. total water shortages for the U.S. as a whole are highly improbable." He predicts that, except for irrigation, consumptive use will always be negligible; consumptive use is defined by him as the amount of water withdrawn that subsequently becomes unavailable for reuse (25:30).

The total reason to conserve, however, in response to Wolman's studies cannot be answered in one sentence as one problem; rather, there is a series of interconnected small but complex problems. For example, the fact that residential water conservation will save energy and reduce loads on sewage treatment systems provides just two of the best reasons for effecting such a program. Appendix A is a list of reasons for reducing domestic water use.

The Hydrologic Cycle

The world's supply of fresh water is obtained almost entirely as precipitation resulting from evaporation of seawater (26:9). The hydrologic cycle, illustrated in Figure 3-1, is a collection of all the processes involved in the exchange of water among the atmosphere, the earth, and the oceans and other bodies of water. "In its most basic form, it can be described as the sequence in which water from the

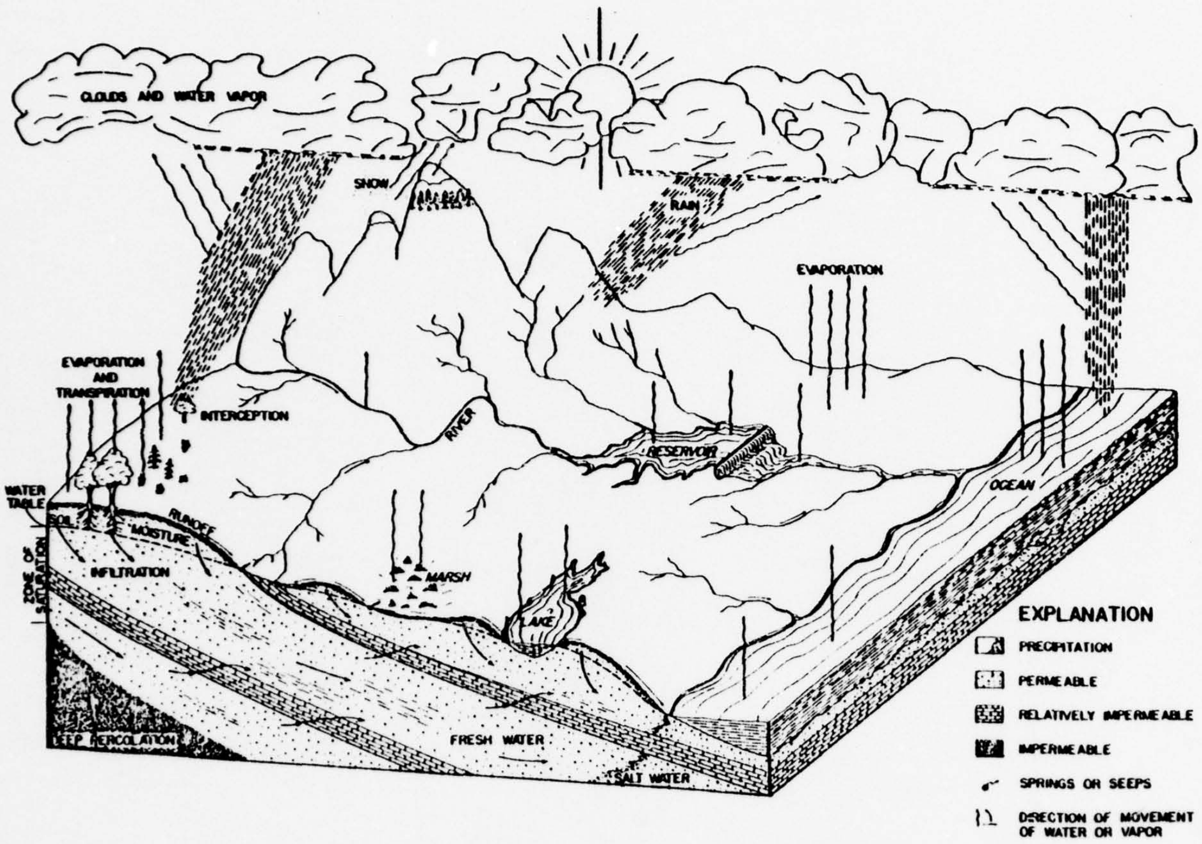

Figure 3-1. The Hydrologic Cycle (47).

oceans evaporates into the atmosphere, precipitates from the atmosphere as rain or snow, and eventually returns to the sea through the drainage systems of streams and rivers (15:23). A brief understanding of the hydrologic cycle should be a prerequisite of water management policy and should be presented to the public before expecting them to adopt conservation measures. It serves as a foundation for understanding the total perspective of the water supply problem.

Water circulates through a series of paths. The change of water from a liquid to a gaseous state occurs during evaporation to the atmosphere from oceans, soil, and vegetation. With increased lifting and cooling, water droplets form and result in cloud formations, with larger droplets forming around nuclei or dust particles. With increased weight, the droplets fall to earth.

Another path water might take would be into the tissues of plants where it is used as a vehicle for the transportation of nutrients throughout the plant. Animals may eat the plants and therefore store some of the water as well. Still, other water falls to the earth infiltrating or percolating into ground-water reservoirs and eventually moves toward streams, lakes, or oceans, thereby completing a cycle.

But there are other ways in which water is stored for longer periods of time and where the cycle is interrupted. Snowfields and especially icefields as well as underground reservoirs, may hold water for thousands of years.

While the total amount of water remains constant the quantity of water in a given area of the hydrosphere can vary according to climatic conditions. Cloudseeding, for example, may divert rainfall from given areas.

Some water is used directly in the stream as in navigation or hydroelectric use. Others is withdrawn from the natural course for human consumption and usage. Consider the residential homeowner's use of water. The city withdraws the water from the stream, distributes it to be customer, collects the sewage, and then returns the same water, in some cases untreated, to the same stream.

The consideration and understanding of the hydrologic cycle is important. From a residential viewpoint, the flushing of a commode or the washing of a car is not necessarily the last we have seen of that "particular water." Rather, we are inevitably using it over and over.

The terms withdrawal and consumption are often used in conjunction with a discussion of the hydrologic cycle. Withdrawal of water should not be confused with consumptive use. Withdrawal of water from its natural course implies the water may be used a number of times or it may even change physical state before it is returned to nature. It may be returned to its original source such as the case of city water withdrawn from a stream, distributed to the customers, collected in the form of sewage, and finally returned, possibly untreated, to the same stream. On the other hand, when water used by man is returned to nature in an altered state or needing some kind of treatment, it is considered to be consumed. The hydrologic cycle is closed and water can neither be created or destroyed. But the supply can be depleted as in the case of evaporated irrigation waters. The vapor cannot be used by man again until it returns to the liquid state.

Water Myths

Even though there is a public recognition of an imbalance of the quantity of water available, especially as a result of crisis periods, there are yet other reasons for lack of acknowledging that a shortage of water exists. Inherent in the cultural attitudes discussed in the previous chapter are actual myths that exist which influence public attitudes about water. Stults calls these myths the water-is-different images; they are often ascribed to water peculiarities that go far beyond its objective characteristics and appear again and again in water planning reports, issue papers, and everyday conversations. A brief description of each of the images follows:

Myth	Meaning
1. Scarcity	Almost every water study begins with the premise of scarcity. In the Denver area the price of dirt is about $2.00 per ton delivered; the price of water is 14 cents per ton.
2. Free Good	Since water is a free gift of nature it should cost its user no more than the net cost of its production and delivery. An implication of unlimited supply, free at its source, and complete absence of scarcity is prevalent.

3.	Survival	Water is necessary for life and essential for sanitation. It is a survival absolute. Without it, we die. The requirements of several quarts a day to survive are essential but not 200 gallons per day.
4.	Priceless Resource	Because water is necessary for survival and people would pay almost any price rather than go without, development of water is often viewed as providing this priceless resource to customers at a cost of 15 cents per ton.
5.	Irrigation Fundamentalism	Irrigation in the west is required for a viable society since agriculture is the cornerstone of a viable society. This was true in the past but not any longer. Only a fraction of economic growth is due to agriculture. Irrigation is not a necessary condition for viable growth in the west.
6.	Environmental Quality	The fastest growing image is that water is needed for green spaces, greenbelts, recreation, camping, and wild rivers. Therefore water requirements need to be "established" for these purposes and demand their share of water resources.

These myths, taboos, and traditions are interacting with each other akd with the realistic images reflecting the public policies and institutions that guide the control, development, and allocation of water resources. Each person in the home has perceptions and attitudes of what the water requirements are . . . however, these are not requiremetns but rather preferences (27:12). Preferences have become so idolized that this author senses and "I can't turn back" attitude toward re-evaluating the current situation or status quo.

Domestic Water Use

In 1970 it was estimated that total withdrawals amounted to 378 billion gallons each day (15:126). The water withdrawn in the United States from oceans, rivers, lakes and underground is used as follows:

1.	cooling water for power plants	45%
2.	agriculture	34%
3.	industry	13%
4.	municipal/domestic	8%
		100%

The figures indicate that domestic use is only a small part of the total (28:3). Why should anyone be concerned about conserving water? Water used for cooling is relatively unchanged as it comes out of the power plant except for increased temperatures of the water. It is the only withdrawal that does not essentially pollute the initial water withdrawn. Agricultural return flows often have high concentrations of minerals and nutrients and are considered polluted; but much of this "tail water" is dispersed over wide areas and is not considered to be a major priority in pollution clean-up programs. While agricultural return flows make up approximatley two-thirds of the total volume from a pollution point of view, industrial and municipal/domestic uses account for the remainder or almost 40% of the total. From a pollution standpoint, municipal/domestic water use is important.

Consideration of domestic water use from an economic point of view results in similar conclusions. A much higher degree of treatment is required for domestic water supplies than most other uses and the resulting sewage must also be given extensive treatment to reduce this concentrated source to harmless levels before return to the resource pool. Not only do treatment plants require extensive capital investments but they are expensive to operate and maintain. Distribution and collection systems are also expensive and require significant energy inputs to lift water to the various desired locations and overcome friction losses.

Although water for domestic purposes amounts to a samll percent of all water use purposes, it is one of the highest and most expensive use levels and certainly requires respect and attention if only from an economic point of view.

Residential Water Usage Patterns

Residential water requirements vary widely with many factors. These include property valuation, the number of occupants per household, type of dwelling, rate structure, climate, as well as educational status and age of the occupants. Property valuation and social status are directly proportional to per capita consumption, whereas the number of occupants per household shows an inverse relationship, with a peak for two occupants (29:218).

An understanding of residential water usage patterns can best be described by examining the interior and exterior uses and the factors which influence those particular patterns. Interior water use is defined as that part of the water delivery used within a home for such purposes as drinking, laundry, bathing and toilets. Exterior water use is the use of water for irrigation of gardens, lawns, and ornamental shrubs, and for replenishing swimming pools, car washing, and other related outdoor activities (43:49).

The principal past surveys of residential quantitative water requirements and household water budgets were performed by Anderson and Watson (1967), Reid (1965), Linaweaver et al. (1967), McPherson (1967), Olsson et al. (1968), Thomas and Bendixen (1962), and Watson et al. (1967) (29:218).

Figure 3-2 is a flow chart representing a picture of residential consumption. While no single household probably matches any of the figures shown, the pattern is good enough to allow comparison of the relative effectiveness of various approaches to water conservation. The flow chart indicates that toilets account for almost 50 percent of all indoor water consumption and about one-quarter of total residential consumption. In all the studies reviewed toilets were responsible for the bulk of wastewater flow. Each flush requires approximately four to eight gallons.

Because the activities of residential consumers are extremely

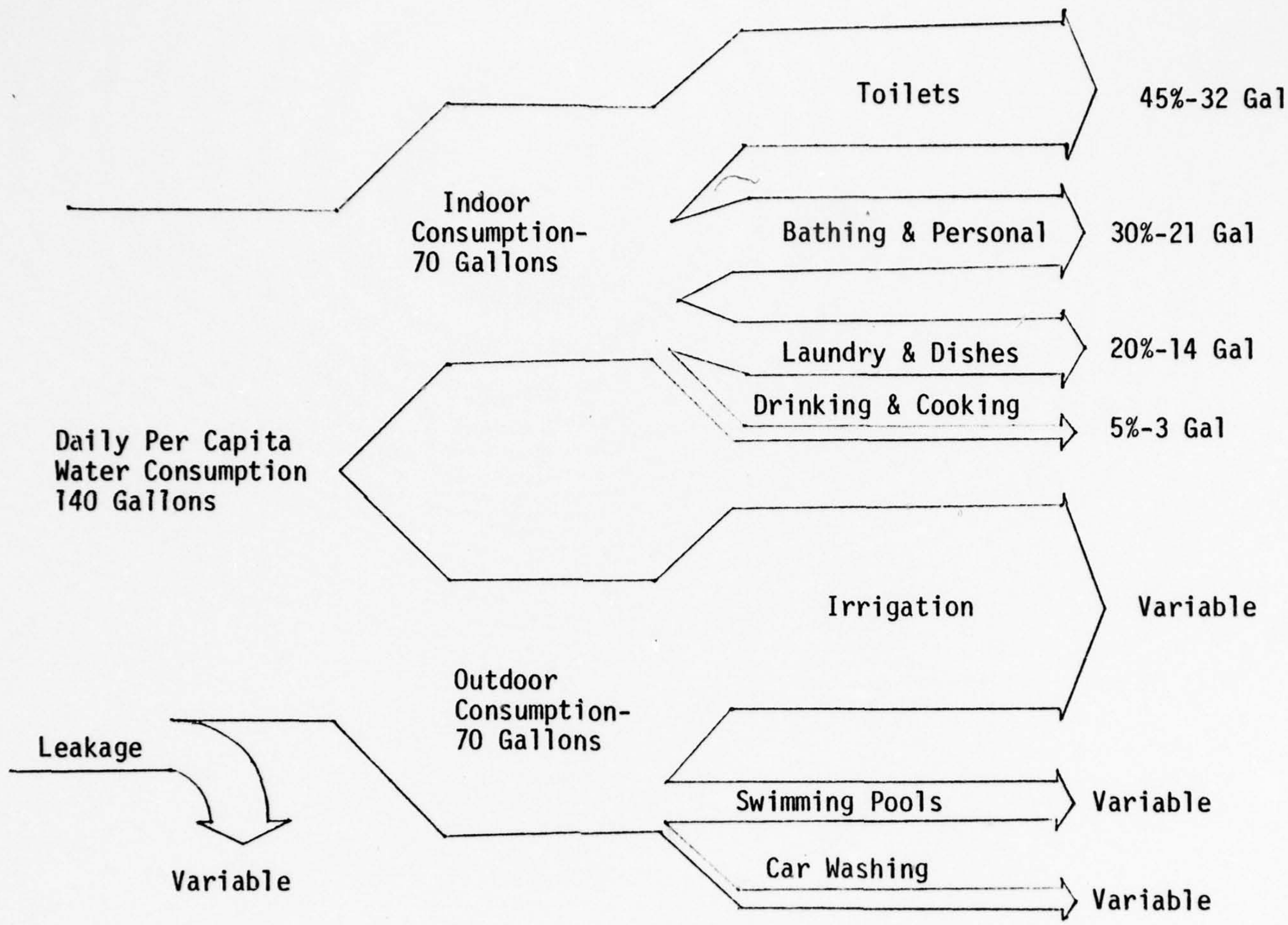

Figure 3-2. A Picture of Residential Consumption (15).

variable in regard to outdoor use of water, it is difficult to establish any accurate values. The literature indicates that Western residential living units use over twice as much water per capita for sprinkling lawns and gardens as do comparable eastern units (30:14). Two Los Angeles area studies indicate that on an annual basis roughly 50 percent of the water consumed daily per capita, or about 70 gallons, was used outdoors. Linaweaver found in the study of sprinkling use in 41 communities across the country that the ratio of average summer use to average annual use was 2.40. It can be concluded that outdoor use represents probably about half of total consumption.

Some of the factors which influence residential water usage patterns have already been discussed in an earlier chapter on the basis of cultural attitudes and institutional factors. Linaweaver identified several general determinants that account for the variations in water usage among residential users. First, he determined that within a given area, the level of water consumption can be explained primarily by the total number of residential units and by the population density in these units. A high-density population area consumed more water than a low-density area of similar size. A second factor responsible for the variation in water usage was the economic level of a water consumer, as estimated by home market value of his house or his income. The more affluent consumers generally have more water-consuming appliances, use these appliances more often, and usually have a larger house on a larger lot that requires more irrigation (30:52).

The billing method was also a factor accounting for variation in water usage. The Linaweaver study found that the amount of sprinkling in set price areas is more than double that in metered areas (30:66).

The determinants of outdoor usage are primarily climate and the number of multiple-family dwelling units. The irrigation demands of lawns and gardens are dependent primarily on climatic conditions such as precipitation while multiple-family dwelling units in comparison to single family units will use less water outdoors because there is less lawn area per capita.

There are several important secondary determinants of usage. Bogue's studies found that the age of a residential community can affect usage since new areas require more water for the establishment of new lawns and gardens (31:548). Evaporative coolers use more water than air conditioners. High water pressure causes increased consumption and waste when leaks are left unrepaired or taps left open.

The studies of Wolman and Cohen indicate that the use of public sewers results in heavier water consumption than the use of individual septic tanks, apparently since consumers attempt to avoid heavy demands on their septic tanks (22:40).

Summary

The reasons for conserving water are many and are in response to a series of many small but complex problems. An understanding of the hydrologic cycle is basic to an understanding that the quantity of water on this earth is fixed. The resource can only be changed in form, quality or location. These facts help to demonstrate that the myths associated with water are really just "myths." They reflect uninformed and immature thinking which, unfortunately, influence public policy and management in water resource decision making. The water myths are responsible in part for the excess domestic water use found in the semi-arid southwest. Even though domestic use is a small portion of all water use purposes, it is one of the highest and most expensive use levels. Residential water usage patterns vary primarily by location, population density, economic levels, billing method, and sewerage system. Outdoor water use, especially in the southwest, has been found to represent about one half of total household consumption.

The following chapter will discuss the conceptual framework and methodology used in this study.

Chapter 4

CONCEPTUAL FRAMEWORK AND METHODOLOGY

Introduction

Chapters 2 and 3 have provided both an insight into the cultural, institutional, economic and technological considerations of a residential water conservation program and a background and understanding of water and its domestic use characteristics.

The literature review has indicated that residential water conservation measures have been implemented successfully in emergency or crisis situations. Because of the immediate nature of these situations, little effort is made to define the societal aspects or to plan for a phased water conservation program. During a water crisis, the majority of water management efforts are directed toward mandatory rather than voluntary measures.

This author's hypothesis is that a phased residential water conservation program, taking into account the previous chapters' considerations, will result in more efficient and successful water conservation efforts than would attempts to implement crisis measures.

For instance, it must be recognized that cultural attitudes and institutional constraints vary from area to area. Some areas may be more economically advanced than others and conditions may provide for more available technological alternatives than others.

Certainly, residential water usage patterns are not the same on the east coast as compared with the west coast and even municipalities may differ not only in uses but in usage rates as well.

An engineering study performed by General Dynamics for the Federal Water Pollution Control Administration concluded that reduction of water usage appeared to be the most practical and economically feasible approach to both water conservation and waste treatment at the household level, and would not become obsolete as new treatment technology is developed. The study cited many household functions in which water is being used wastefully. In particular, the study indicated that water for toilet flushing and bathing could be reduced by approximately 35% by using presently available devices and technology (22:55).

An indirect approach to the problem of reducing residential water demands may have considerable impact on water management personnel as well as individual consumers. For example, if it could be shown that due to the application of selected water conservation measures and devices and the assumed removal of certain institutional, cultural, and economic barriers, considerable reductions in water and energy demands could be achieved, some incentive may be provided for changing attitudes, revamping institutions, alleviating economic constraints and accepting selected technological alternatives.

This chapter contains the framework within which the study was made. The sections to be discussed are as follows: (1) statement of hypothesis and delimitations, (2) description of geographical area, (3) sources of data and data selection, (4) definition of terminology, and (5) method of analysis.

Statement of Hypothesis and Delimitations

The application of selected interior water conservation measures to both existing and new residential housing units will result in a significant reduction of water demand. The delimitations required for the sake of clarity and understanding are:

1. The quantities of water used for lawn irrigation and other outside uses are difficult to quantify.

2. How water is used in the City of Mesa and particular trends were considered outside the scope of the study.

3. No attempt was made to prove or disprove that residential water use in Mesa is typical of the Phoenix Metropolitan Area.

Description of Area

The city of Mesa is located in the eastern portion of Maricopa County, sixteen miles east of Phoenix, Its location is shown on Figure 4-1, Vicinity Map. Six major highways now serve the city in addition to the main line of the Southern Pacific Company Railroad and two major bus lines. Mesa is situation on a broad alluvial plain adjacent to and bounded by the Salt River on the north and the Gila River ten miles to the south. The intermountain valleys and plains which comprise part of the watershed area are deeply filled with alluvium, consisting of poorly assorted, coarse sediments interspersed with silt and clay. The soil in the valley is fertile, and where water without a high saline content is available for irrigation, the crop yields are high.

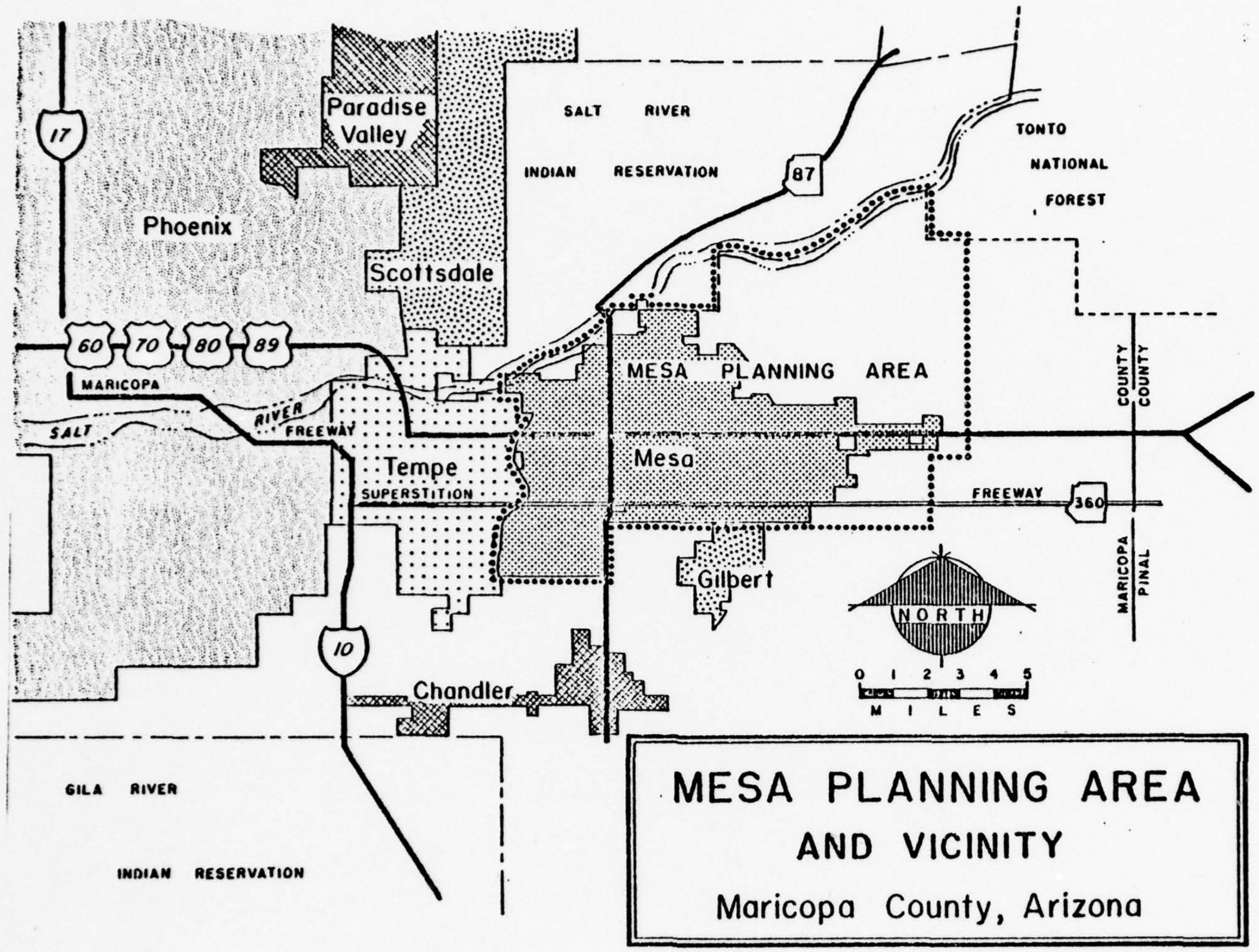

Figure 4-1. Vicinity Map.

Most of the area inside the corporate limits of Mesa is well-drained, with the exception of a small area in the southern part of the city subjected to occasional flooding due to lack of an improved storm drainage system.

Mesa's location in the Salt River Valley makes its climate very attractive to residents, tourists, and health seekers. The sun shines 85 percent of its possible daylight sojourn, along with a low average relative humidity of 20 percent. This results in a dry warm climate.

Summers are hot with an average July temperature of 87.8 degrees. Extremes during the summer often exceed 110 degrees. Winters are very pleasant with an average January temperature of 49.1 degrees. The record high temperature is 116 degrees as compared with a record low of 15 degrees.

Yearly rainfall averages 7.64 inches with maximum amounts usually occurring in two seasons: July through September, and December through March. In general, precipitation is small during spring and autumn (32:5).

Favorable location and climatic factors have been two of the reasons for the City of Mesa's rapidly increasing population. According to census data for 1960 and 1970, the City of Mesa had an 87 percent increase in population, the highest increase compared to the Phoenix Metropolitan Area (34:4-11).

Sources of Data and Data Selection

The City of Mesa Water Department has recorded, by month, water consumption according to different uses since 1 July 1949. Electric, gas and sewer statistics are also recorded on a monthly basis.

Water, electric and gas usage and consumption rates for various water saving appliances and fixtures were taken from a recent study by the U.S. Army Corps of Engineers and from a current report on domestic water use in Marin County, California.

Population and housing statistics were taken from the decennial census reports of 1960 and 1970 as compiled by the United States Bureau of Census. The same statistics on the special 1975 Census of Mesa were also obtained from this source. Statistics for 1976 were obtained from the Mesa Planning and Zoning Department.

Reliability of Data

Of the five data sources, namely: City of Mesa Water Department, U.S. Army Corps of Engineers, Marin County Water District of California, United States Bureau of Census, and the Mesa Planning and Zoning Department, only the Bureau of Census does not warrant a discussion.

The possibility of faulty metering and incorrect recording could be a source of possible error as to the actual amounts of residential water use. However, these potential sources of error are being monitored and provide little chance for significant deviations on a monthly basis.[1]

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[1] Expressed by Mr. Larry Lines, Utilities Director, City of Mesa in a personal interview.

Water and energy usage factors developed by the U.S. Army Corps of Engineers and the Marin County Water District for both existing and new water saving appliances and fixtures are current and are compatible with figures reviewed in the esisting literature. The figures used by these two agencies were developed solely from studies in Arizona and California and were therefore assumed to be typical for this study.

The housing and population statistics for 1976 and future projections provided by the Mesa Planning and Zoning department were assumed as accurate since they are the results of detailed planning estimates.[2]

Several assumptions have been made and noted in the study but are correlated as close as possible to the actual existing conditions based on the availability of actual data. All available data was analyzed as recorded.

Definition of Terminology

The various terms used in this report and their definitions are as follows:

Term	Definition
Residential Water Use	Water supplied to a single residential unit within city limits for both inside and outside use.[3]

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[2]Expressed by Mr. Norman Hall, Population Director, Planning and Zoning Department , City of Mesa, in a personal interview.

[3]Defined by Mr. Larry Lines, Utilities Director, City of Mesa, in a personal interview.

Consumptive Use (Urban)	Water transpired by urban-associated vegetative growth and used in building plant tissue; and water evaporated from soils, water surfaces, plant foliage, and impervious surfaces. It also includes water consumed inside homes and commercial establishments through evaporation in cooling, cleaning, and food preparation processes.
GPCPD	An averaged value of water consumption stated in terms of Gallons per Capita per Day.
Housing Unit	"A house, an apartment or other group of rooms, or a single room is regarded as a housing unit when it is occupied or intended for occupancy as separate living quarters . . ." (34:App. 6).
Interior Water Use	That part of the water delivery used within a home for any purpose.
Occupied Housing Unit	"A housing unit is 'occupied' if it is the usual place of residence of the person or group of persons living in it at the time of enumeration. Included are units occupied by persons who are temporarily absent . . . the count of occupied housing units is the same as the count of households . . . (34:App. 7).
Exterior Water Use	The use of water for irrigation of gardens, lawns, and ornamental shrubs, and for

	replenishing swimming pools, car washing, etc.
Service Connection	A metered unit; a customer account.
Year-round Housing Units	"All occupied units plus vacant units which are intended for year-round use" (34:App. 7).
Vacant Housing Units	"New units not yet occupied if construction has reached a point where all exterior windows and doors are installed and final usable floors are in place . . . (34:App. 8).
Complete Bathroom	"A housing unit is classified as having a complete bathroom if it has a room with a flush toilet and bathtub or shower for the exclusive use of the occupants of the unit and a wash basin, as well as piped hot water in the structure . . ."
Source of Water	"A public system or private company supplying running water to six or more housing units . . . A well supplies six or more housing units . . ." (34:App. 10).
Public Sewer	". . . is connected to a city, county, sanitary district, neighborhood, or subdivision sewer system. It may be operated by a governmental body or private organization."

Method of Analysis

The discussion in Chapters 2 and 3 indicated that attitude and behavioral changes, alleviation of institutional constraints, adoption of more efficient economic measures, and education towards understanding the water resource situation should be considered and planned prior to the actual "hardware" implementation of a water conservation program.

Because each of the above considerations may be peculiar to local areas and municipalities, this author has taken an indirect approach to residential water policy program formulation. In other words, while it can not be assumed that the water saving appliances and devices to be used in this study would be accepted in Mesa, it can be inferred from the results that some, all, or even other measures may suggest significant reductions in residential water usage. This author advocates a planned and phased program of residential water conservation which would make use of all the above mentioned aspects prior to the steps taken in the actual analysis. The consideration of these socio-economic, institutional, and educational measures has a direct bearing on the success or failure of the acceptance and adoption of water conservation facilities.

The City of Mesa, Arizona is selected for analysis since its rate of population growth has increased faster than any other city in the Phoenix Metropolitan area. The analysis begins with a brief summary on the growth of Mesa and a discussion of current household usage and fixture consumption. The development of the analysis continues with a review of the water saving devices and appliances to reduce consumption. There are hundreds of ingenious devices commercially available that somehow affect the way water is used in the home. Other sources of devices include those patented but not yet in production, and recycling systems. Of all the devices available, many can be eliminated due to high costs of installation, poor water reduction, or current public non-acceptance.

An acceptable list of water using devices and appliances is developed for consideration in both existing and new homes and each is evaluated for residential unit water savings and costs.

These savings and costs were then applied to the City of Mesa on the basis of retrofitting existing homes, and installing new devices on the basis of projected housing and population statistics to the year 1990. Total water savings and costs were formulated.

Since the water saving devices and appliances considered to use hot water, with the exception of the toilet, an analysis of energy used per fixture is evaluated against use of present household devices versus selected water saving devices and appliances.

The final portion of the analysis determines the overall implications of the residential water conservation program for the City of Mesa.

The next chapter analyzes the results of selection and installation of water conserving facilities.

Chapter 5

THE ANALYSIS

Introduction

This chapter contains the results of the investigation. In order to thoroughly examine the problem and to put the results in the proper perspective, it was necessary to consider many aspects. The areas of study, in the order of presentation, were as follows: (1) the growth of population and housing units in Mesa, (2) current household water usage and fixture consumption, (3) selection of water saving appliances and devices and related costs, (4) results of retrofit and installation in existing and new homes, and (5) implications of the program.

Growth of Mesa, Arizona

Mesa was founded in 1878 by Mormon settlers from Idaho and Utah. When it was incorporated in 1883, Mesa was a small community of the higher flat land overlooking the Salt River Valley. Population growth was relatively slow up to the pre-World War II years with Mesa having only 7,224 people in 1940. During the two decades following 1940, the growth rate increased rapidly. By 1950 the population had more than doubled to 16,790 people. From 1950 to 1960, population again more than doubled to 33,772 people and to 50,529 in 1965. This very high growth rate has continued and Figure 5-1

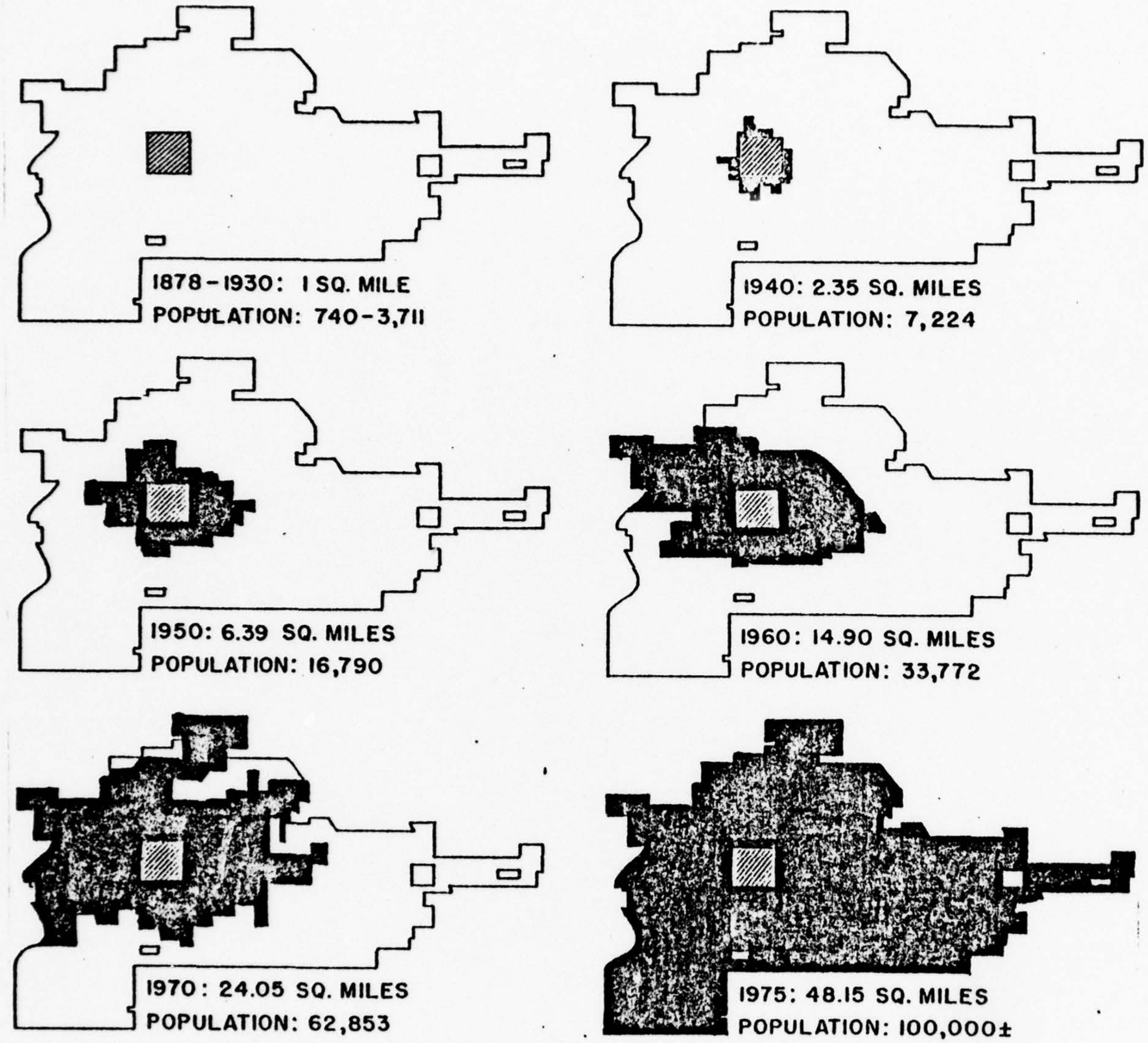

Figure 5-1. Growth of Mesa, Arizona.

illustrates how the City of Mesa has grown from 1883 to 1975.

Table 5-1 indicates a 60.3 percent increase in total population from 1970 to 1975.

Table 5-1

Percent Increase in Population Growth

For Mesa, Arizona

Year	Population	% Increase in Population
1950	16,790	--------
1960	33,772	100.01
1970	62,853	86.1
1975	100,763	60.3

This trend is expected to continue through 1980 but in decreasing percentages. A report in 1968 by Carolla engineers (35:14) of Phoenix (Figure 5-2) indicated that the population growth of Mesa would exceed that of the three other large cities of the Phoenix Metropolitan area which include Glendale, Scottsdale, and Tempe. While Carolla's report indicates even sharper increases in population growth from 1980 to 2000, the Mesa Planning and Zoning department[4] projects an increasing population but at a decreasing rate of growth (See Table 5-2).

[4]Information acquired in a personal interview with Mr. Norman Hall, Population Director, Planning and Zoning Department, City of Mesa.

Figure 5-2

Population Growth-Study Areas of Four Large Cities (35)

Glendale Mesa Scottsdale Tempe

Study Area Population Factors in Year 2000

	Glendale	Mesa	Scottsdale	Tempe
Population	181,000	320,000	221,000	278,000
Area, Acres	28,800	64,000	64,000	35,100
Density, p/a	6.3	5.0	3.5	7.9

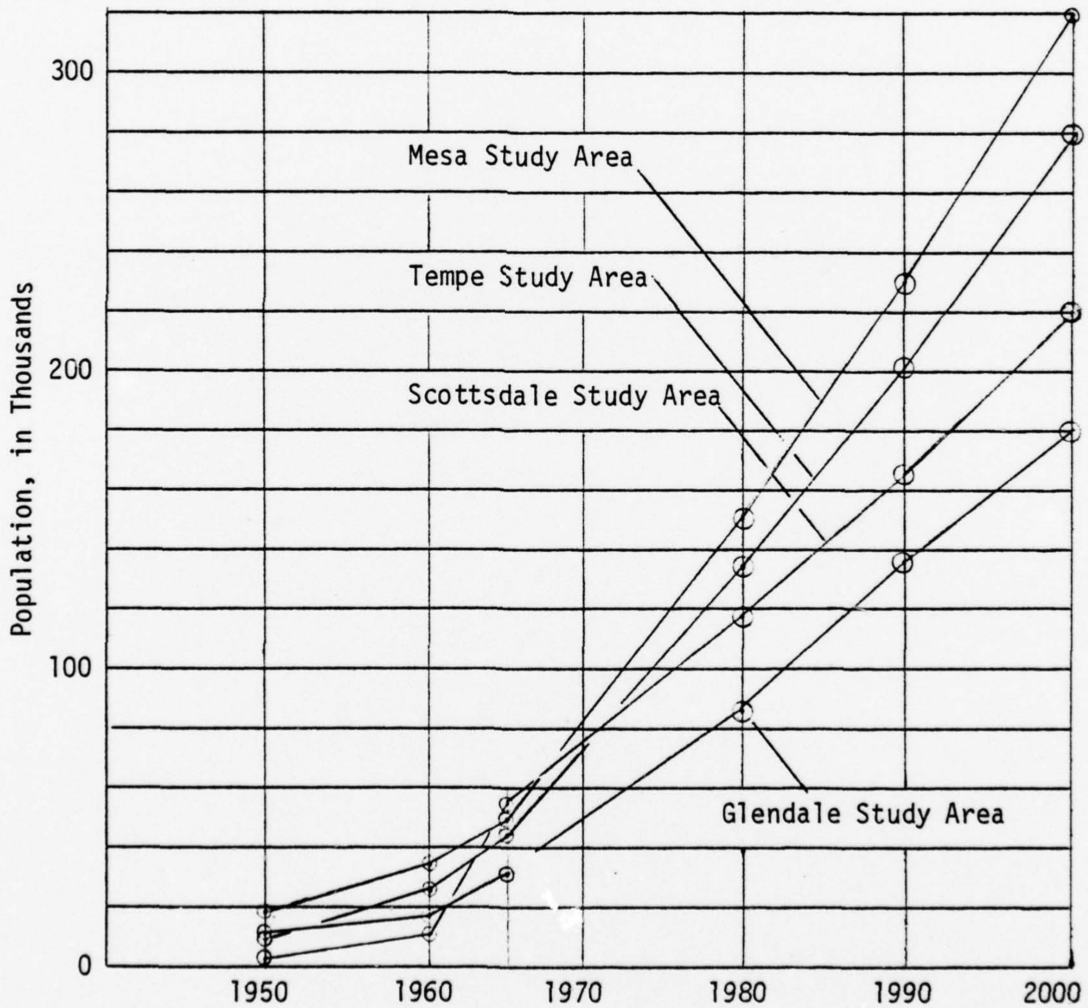

Table 5-2

Projected Population and Housing Statistics

For Mesa, Arizona

Item	Year 1980	Year 1985	Year 1990
Total Population	146,550	170,876	191,775
Total Housing Units	48,208	56,876	63,084
Occupied Housing Units[a]	47,275	55,122	61,863
Vacant Housing Units	933	1,180	1,227
Average Number of Persons Per Occupied Housing Unit[b]	3.1	3.1	3.1

[a]Assumed 3.1 persons per household based on study by Gruen Associates.

[b]Calculated by dividing population by number of occupied housing units.

Household Water Usage and Fixture Consumption

Domestic water use includes water used for household purposes--the bath, toilet, sinks, laundry, cleaning, cooking and drinking and water used on property outside of the house--irrigation of lawns and gardens, car washing, washdown, and pools. Per capita use requirements vary widely from place to place depending principally on climatic conditions, especially rainfall.

Various estimates of water use in the household for a typical family of four residing in a sewered, metered community are indicated in Table 5-3.

Table 5-3

Household Water Use (28, 29, 36)

Source	Gallons Per Day
Murawczyk & Ihrig	246
Linaweaver, Geyer & Wolff	247
Reid	246
Bailey	255
U.S. Geological Survey	260
Average of the above	251
Average divided by four	63 gpcpd

Estimates of interior water use according to the various water using activities are noted in Table 5-4. Virtually all the water used in the home ends up in the sewer and the chief personal use of water involves carrying away wastes. Approximately 72% of all household use occurs within the confines of the bathroom, primarily the toilet and shower.

Outside irrigation requirements add considerably to household use. In California where semi-arid conditions prevail throughout much of the state, total residential per capita use in metered communities averages 185 gpcpd. FHA studies in the Western United States indicate that outside (irrigation) requirements amount to 57% of total residential requirements. Others have shown that the outside irrigation component, though varying widely, averages from 30% to 50% of total residential requirements in the Western United States (28:8).

Table 5-4

Family of Four Daily Water Use Characteristics (36)

	Fixture Flow Rate	Water Use Gal/Day	Use Temperature	Energy[a] BTU/Day
Toilet	5 gal/use	100	Amb.	-------
Bathing	4 gal/min	80	107	55,998
Laundry	50 gal/load	35	120	30,624
Dishwasher	15 gal/load	15	140	17,163
Kitchen Sink		12	105	8,076
Lavatory		8	105	5,384
Utility		5	Amb.	------
			Fixed Loss	79,214
Total		255		196,460 Btu

Fixed loss is the amount of energy lost from a full sized water heater regardless of water use.

[a]Based on Ambient water temperature of 55F.

At this point, it is significant to compare the household water use in Europe with that in the United States. In a study by Konen (37:25) water consumption in Europe is estimated at 37 gpcpd (gallons per capita per day) compared to the consumption in the United States estimated at 60 to 64 gpcpd. A contrasting analysis of water consumption in Europe and the United States for a family of 4 consisting of two adults and two children is given in Table 5-5. These figures indicate the per capita water consumption in the United States is approximately sixty-two percent higher than in

Table 5-5

Water Usage For A Family of Four (37)

	England		United States	
	Percent	Gallons/ Day	Percent	Gallons/ Day
W. C. flushing	35	52	39	100
Personal bathing	35	52	31	79
Laundry	10	15	14	34
Washing up	10	15	3	8
Car washing, garden	6	9	-	-
Drinking, food preparation	4	6	11	26
Utility sink	-	-	2	5
	100	149	100	252

Europe. The significant difference is attributed to the higher volume used by American water closets. Other differences are attributed to personal habits, more widespread use of such appliances as dish washers and automotic washing machines, and lack of established minimum flow rates for plumbing fixtures and fittings based on function.

The 1970 census (38:4-69) provides an indication of the number of water consuming activities which are responsible for overall residential water consumption in the City of Mesa. Table 5-6 shows that the percentage of households having private bath, toilet and hot and cold piped water has reached the point where further percent increases should no longer influence changes in unit residential demands.

Almost 100% of the population receives water from the City Water Department and approximately 97% of all households are connected to the public sewer. Based on the number of total occupied housing units, 93% of the population has a private automobile, with 69% having a clothes washer and approximately 18% with a dishwasher. The latter three commodities would account for water consuming activities as well. Greater than three times as many households use gas for water heating fuel as those using electricity. Table 5-7 presents the national 1970 census statistics on water heating efficiency (39:94) and suggests that the City of Mesa is consistent with the national average.

Little information is available on the use of water in Mesa households. Gross use figures or rough estimates are available but no measurements have been made of water use for cooking, washing clothes, bathing, cleaning and flushing toilets. Neither swimming-pool nor car-washing requirements have been evaluated.

Appendix B is a summary of utility data for the City of Mesa during calendar year 1976. Referring again to Table 5-6, the average number of persons per occupied housing unit in 1975 was 2.87 (40:2). Assuming this figure was the same for 1976, the total daily average consumption for the City of Mesa is about 182 gpcpd. This figure, however, does not account for lawn irrigation usage.

Table 5-6

Population and Housing Statistics on Mesa, Arizona As Recorded
In The United States Census of 1970
And Special Census of 1975 (38)

Item	Census Year 1970	Census Year 1975
Total Population	62,853	100,763
Total Housing Units	19,927	39,596
Occupied Housing Units	19,181	35,125
Vacant Housing Units	447	4,471
Average Number of Persons Per Occupied Housing Unit	3.27	2.87
% of Total Housing Units		
With Private Bath	99.0	N.R.[b]
With Source of Water From Public System or Private Company	99.9	N.R.[b]
With Connection to Public Sewer	96.8	N.R.[b]
% of Total Occupied Housing Units		
With Private Automobile	93.4	N.R.[b]
With Gas As Water Heating Fuel	76.2	N.R.[b]
With Electricity As Water Heating Fuel	22.0	N.R.[b]
With Clothes Washing Machine	69.3	N.R.[b]
With Dishwasher	17.5	N.R.[b]

[a]Calculated by dividing population by number of occupied housing units.

[b]Not recorded.

Table 5-7

Water Heating Efficiency (39)

Fuel Type	% of Occupied Households	Overall Thermal Efficiency
Electricity	25.4%	24. %[a]
Natural Gas	55.1	45.5
LPG	5.0	45.5
Fuel Oil	9.8	43.5
Other or None	4.7	45.5
Total	100. %	36.9%

[a]Based on 80% efficiency at heater and 30% fuel conversion and transmission efficiency of electrical energy supply.

The city does provide water for irrigation from the regular drinking water system but the quantities are small. Water for lawn care is available to all residents of Mesa from a canal system operated by the Salt River Project.

While city residential water consumption due to lawn sprinkling is not recorded, the use of water from the Salt River Project used exclusively for lawn irrigation was determined by Sadusky (45:39) to be 92 gpcpd. As mentioned previously, outside irrigation requirements amount to 57% of interior usage which could mean approximate irrigation usage of 104 gpcpd for Mesa. A combined total household usage figure of 286 gpcpd is somewhat higher than those reported in the literature. Studies conducted by Carolla (41:7) and Thiele (43:20) for the Phoenix Urban Area determined average gpcpd calculated on total water consumed as 191 gpcpd and 315 gpcpd, respectively.

Selection of Water Saving Appliances and Devices

There are many ways to reduce residential water consumption. Conservation practices might be implemented by any of three basic methods: (1) voluntary action by individual users, (2) institutional action by government or water agencies such as pricing, educational programs, and leakage repair programs, and (3) the imposition of laws and regulations. Appendix C lists methods of urban water conservation including implementation, advantages, and disadvantages.

It is beyond the scope of this report to consider all the different methods of urban water conservation that might be evaluated. Since the importance of residential water conservation has already been discussed, emphasis is directed toward the selection of water saving devices and appliances which will reduce water demands in existing and new homes.

While there are numerous plumbing fixtures and appliances commercially available, only a few significantly reduce water consumption and are within the economic grasp of the average household.

Several agencies including the California Department of Water Resources and the Corps of Engineers have developed a list of practical water conserving facilities which are addressed toward improvement or replacement of new facilities in remodeled or new construction. Tables 5-8 and 5-9 are a compatibility matrix for selected water conserving facilities.

Table 5-8

Compatibility Matrix for Water-Conserving Facilities--Existing Homes (44)

	Water Saving Toilet	Dual-Flush Toilet	Vacuum Toilet	Reduced-Flush Devices	Flow-Limiting Showerheads	Flow-Limiting Faucet Valves (Kitchen/Bath)	Faucet Aerators	Pressure Reducing Valves	Insulation of Hot Water Pipes	Water-Saving Clothes Washer	Water-Saving Dishwasher	Premixed Water Systems	Repair of Faucet and Toilet Leaks	Wash Water Recycle Systems
Water Saving Toilet	X	N	N	I	C	N	C	N	N	C	C	N	C	N
Dual-Flush Toilet	N	X	N	N	N	N	N	N	N	N	N	N	N	N
Vacuum Toilet	N	N	X	N	N	N	N	N	N	N	N	N	N	N
Reduced-Flush Devices	I	N	N	X	C	C	C	N	N	C	C	N	C	N
Flow-Limiting Showerheads	C	N	N	C	X	C	C	N	N	C	C	N	C	N
Flow-Limiting Faucet Valves (Kitchen/Bath)	N	N	N	N	N	X	N	N	N	N	N	N	N	N
Faucet Aerators	C	N	N	C	C	C	X	N	N	C	C	N	C	N
Pressure Reducing Valves	N	N	N	N	N	N	N	X	N	N	N	N	N	N
Insulation of Hot Water Pipes	N	N	N	N	N	N	N	N	X	N	N	N	N	N
Water-Saving Clothes Washer	C	N	N	C	C	C	C	N	N	X	C	N	C	N
Water-Saving Dishwasher	C	N	N	C	C	C	C	N	N	C	X	N	C	N
Premixed Water Systems	N	N	N	N	N	N	N	N	N	N	N	X		N
Repair of Faucet and Toilet Leaks	C	N	N	C	C	C	C	N	N	C	C	N	X	N
Wash Water Recycle Systems	N	N	N	N	N	N	N	N	N	N	N	N	N	X

Legend

I Control measures are incompatible and cannot be used simultaneously; e.g. water-saving and dual-flush toilets.

C Control measures are compatible; e.g. water-saving toilets and flow-limiting showerheads.

N Measure would apply primarily to new homes.

Table 5-9

Compatibility Matrix for Water-Conserving

Facilities--New Homes (44)

	Water Saving Toilet	Dual-Flush Toilet	Vacuum Toilet	Reduced-Flush Devices	Flow-Limiting Showerheads	Flow-Limiting Faucet VAlves (Kitchen/Bath)	Faucet Aerators	Pressure Reducing Valves	Insulation of Hot Water Pipes	Water-Saving Clothes Washer	Water-Saving Dishwasher	Premixed Water Systems	Repair of Faucet and Toilet Leaks	Wash Water Recycle Systems
Water Saving Toilet	X	I	I	E	C	C	C	C	C	C	C	C	E	C
Dual-Flush Toilet	I	X	I	E	C	C	C	C	C	C	C	C	E	C
Vacuum Toilet	I	I	X	E	C	C	C	C	C	C	C	C	E	C
Reduced-Flush Devices	E	E	E	X	E	E	E	E	E	E	E	E	E	E
Flow-Limiting Showerheads	C	C	C	E	X	C	C	C	C	C	C	C	E	C
Flow-Limiting Faucet Valves (Kitchen/Bath)	C	C	C	E	C	X	C	C	C	C	C	C	E	C
Faucet Aerators	C	C	C	E	C	C	X	C	C	C	C	C	E	C
Pressure Reducing Valves	C	C	C	E	C	C	C	X	C	C	C	C	E	C
Insulation of Hot Water Pipes	C	C	C	E	C	C	C	C	X	C	C	C	E	C
Water-Saving Clothes Washer	C	C	C	E	C	C	C	C	C	X	C	C	E	C
Water-Saving Dishwasher	C	C	C	E	C	C	C	C	C	C	X	C	E	C
Premixed Water Systems	C	C	C	E	C	C	C	C	C	C	C	X	E	C
Repair of Faucet and Toilet Leaks	E	E	E	E	E	E	E	E	E	E	E	E	X	E
Wash Water Recycle Systems	C	C	C	E	C	C	C	C	C	C	C	C	E	X

Legend

- I Control measures are incompatible and cannot be used simultaneously; e.g. water-saving and dual-flush toilets.
- C Control measures are compatible; e.g. water-saving toilets and flow-limiting showerheads.
- E Measure would apply primarily to existing homes.

These facilities have been selected on the basis of reducing waste flow as well. The percent reduction in waste flow, costs, benefits, advantages, and disadvantages are summarized in Table 5-10.

It appears that the greatest reduction in waste flow and water demands is in the use of the various water closet facilities.

A summary of potential water savings as a result of installing selected water conserving facilities in existing and new homes is compiled in Table 5-11.

A further summary of dollar savings in both water and electrical energy is provided in Table 5-12.

This author has noted that retrofitting of existing homes may be extremely costly; in fact, the present price of water in some cases may not justify implementing the retrofitting of any water conserving facilities in existing homes. However, Table 5-13 indicates that two of the proposed water conserving facilities for existing homes are cheap, save a considerable amount of water, and can be easily installed. Therefore, the use of plastic bottles or water dams in the toilet reservoir and the installation of a flow restrictor will be the two devices considered in this report for use in existing homes.

Because installation of water conserving facilities in new or remodeled housing permits greater flexibility, this author has chosen the following water conserving facilities based on costs, benefits, energy/water savings, and reduced waste flow for new homes: (1) water-saving toilet, (2) flow-limiting shower head, (3) flow-limiting faucet valves, (4) insulation of hot water pipes,

Table 5-10

Water Conserving Facilities (44)

Control Measure	Estimated % Reduction in Waste Flow[1]	Incremental Unit Cost[2]	Incremental Unit Benefits[3]	Major Advantages	Major Disadvantages
Water-saving toilet	9%	$10/toilet	$0.90/mo.	Easy to purchase	Expensive to replace existing toilet
Dual-flush toilet	21%	Negligible	$2.10/mo.	Reduces flush	Not readily available
Vacuum toilet	27%	$100/toilet	$2.70/mo.	Major reduction	Expensive in water use
Reduced-flush devices	12%	$0 to $14	$1.20/mo.	Easy to install	Inconsistent effectiveness
Flow-limiting showerheads	12%	$5	$4.00/mo.	Easy to install	No obvious disadvantage
Flow-limiting faucets (kitchen/bath)	2%	$5	$0.55/mo.	Minimizes water use	Requires skilled installation
Faucet aerators	2%	$2	$0.32/mo.	Easy to install	No obvious disadvantage
Pressure reducing	5%	$25	$1.70/mo.	Reduces excessive household pressure	Should not be used in older homes
Insulation of hot water pipes	4%	$1.00/ lineal ft.	$1.40/mo.	Water & energy savings	Primarily for new homes

Table 5-10 (cont.)

Water Conserving Facilities (44)

Control Measure	Estimated % Reduction in Waste Flow[1]	Incremental Unit Cost[2]	Incremental Unit Benefits[3]	Major Advantages	Major Disadvantages
Water-saving clothes washer	6%	$25	$2.00/mo.	Water & energy savings	Expensive to replace existing machine
Water-saving dishwasher	4%	Varies	$1.20/mo.	Water & energy savings	Expensive to replace existing machine
Premixed water systems	8%	$100	$2.70/mo.	Water & energy savings	Expensive
Repair of faucet and toilet leaks	Varies	Varies	Up to $5/mo.	Water savings can be substantial	Expensive if plumber required
Washwater recycle systems	30%	$640 for prototype	$3.00/mo.	Major reduction in wastewater flow	System needs refinement

[1]Estimated percent reduction in household wastewater flows resulting from implementation of the control measure.

[2]The estimated additional cost per unit associated with implementing the control measure.

[3]Computed as the estimated monthly savings per household in water and energy costs that would occur if the control measure were to be implemented.

Table 5-11

Potential Water Savings From Residential Interior Fixtures (43)

Fixture/Action	Water Use		Percent Savings Total Interior		Incremental Cost	
	Standard	Improved	New	Retro	New $	Retro $
Tank toilet	5-7 gallons per flush	3.5 gallons per flush	18	10-18	$0-$10	$0-$6
Shower	up to 12 gallons per minute	3.0 gallons per minute	9-12	9-12	$0-$5	$1-$5
Kitchen and lavatory faucets	up to 5 gallons per minute	1.5 gallons per minute	2[2]	0-2[2]	$0-$5	$1-$5
Pressure reducing valve	80 pounds per square inch	50 pounds per square inch	0-10	0-10	$0-$25	$25
Hot water pipe insulation[5]	Not insulated	Insulated	1-4[2]	0-1[2]	$0.50-$100 per foot	$0.50 per foot
Automatic clothes washer[6]	27-54 gallons per load	15-19 gallons per load	0-5	---	$20-$30	Not practical
Automatic dishwasher[6]	7-5-16 gallons per load	7.5 gallons per load	0-4[4]	---	0	Not practical

Table 5-11 (Cont.)

Potential Water Savings From Residential Interior Fixtures (43)

Fixture/Action	Water Use		Percent Savings Total Interior		Incremental Cost	
	Standard	Improved	New	Retro	New $	Retro $
Total			30-55[2]	19-43[3]		

[1]Attachments marketed with 0.5 gallon per minute flow. Residential acceptance unknown but commercially proven.

[2]No field quantification.

[3]Educate to only wash full loads, turn off water faucets unless actually used, etc., could add another percent or two to the totals.

[4]Based on one load per day.

[5]Insulation of certain continuously circulating hot water piping is already required.

[6]59% of the households in Los Angeles area have washing machines and 24% have dishwashers.

Table 5-12

Costs and Savings For Installing Water-Conserving Facilities In A Typical New Home (44)

Facility	Estimated Percent Waste Flow Reduction[1]	Costs Per Unit[2]	Monthly Savings Water[3]	Monthly Savings Energy[4]	Monthly Savings Combined
Water-Saving Toilet	9	$ 60	$0.90	$0.00	$ 0.90
Flow-Limiting Showerhead	12	10	1.20	2.80	4.00
Flow-Limiting Faucet Valves	2	10	0.20	0.35	0.55
Insulation of Hot Water Pipes	4	50[5]	0.40	1.00	1.40
Water-Saving Clothes Washer	6	200	0.60	1.40	2.00
Water-Saving Dishwasher	4	250	0.40	0.80	1.20
Total	37	$580	$3.70	$6.35	$10.05

[1]Estimated percent reduction in overall household wastewater flows.

[2]Approximate cost of installing the fixture in a typical new home.

[3]Estimated monthly savings per household in water costs assuming as average monthly cost for water of $10.00.

[4]Based on an assumed energy consumption of 400 kwh per month for heating hot water at a rate of $0.04 per kwh.

[5]Assuming a cost of $1.00 per lineal foot.

Table 5-13

Potential Residential Interior Water Savings

In Existing Homes (43)

Feature	Added Cost Per Unit ($)	Water Savings as a % of Interior Use
Plastic bottles or water dams in toilet reservoir	0-6	18
Replace showerheads with low-flow variety or install flow restrictors	1-5	12
Place low-flow aerators on kitchen & lavatory faucets or replace entire unit	1-5	2
Presure reducing valves	25	5
Insulated hot water lines	0.50 or more per foot of line	1

(5) water-saving clothes washer, and (6) water-saving dishwasher, Appendix D is a summary of characteristics of the selected water conserving facilities.

With the exception of the water-saving toilet, the selected water-conserving facilities use hot water. Both a reduction in water usage and energy consumption would be realized. Table 5-14 notes the energy costs of using hot water for household fixtures. Muller (39:90) noted that best estimates indicate that residential water heating accounts for an energy consumption of 1.1 million barrels per day oil equivalent. Heating of water is the second largest energy use in the home and accounts for 3 percent of America's total energy consumption. By way of comparison, automobiles account for 12 percent of our total energy use.

Table 5-14

Energy Costs of Using Hot Water For Household Fixtures (44)

Fixture	Wastewater Flow (gpcpd)	Percent of Hot Water Used	Energy Used (kwh/month)	Monthly Energy Costs
Faucet (Kitchen/Bath)	5	7.2	29	$ 1.16
Shower	20	29.0	116	4.64
Dishwasher	14	20.3	81	3.25
Clothes Washer	30	43.5	174	6.95
Total	69	100.0	400	$16.00

Results

The results are presented as follows: (1) Retrofit of existing homes, (2) installation of water conserving facilities in new homes, and (3) energy savings for both retrofit and existing homes using water conserving facilities.

Retrofit of Existing Homes. Since toilet flushing and bathing account for about 75 percent of all use inside the home, the devices selected aim at reducing water use in this area. The devices can easily be installed by the average resident. The cost of these devices would be approximately $1.15 per household, and their life expectancy is indefinite. The assumptions were approximated to the existing residential households in Mesa.

The use of the water closet displacement bottles and the shower flow control insert would result in a water savings of 9852 gallons per year or 0.027 million gallons per day per 1000 households. For the City of Mesa this would result in savings of approximately .594 million gallons per day.

According to the City of Mesa water department data for 1976 the average use per residential customer was 16,160 gallons per month. The savings would approximate half of an average month for that particular year.

The dollar savings in water at current water rates is $4.92 per year with a savings in energy on reduced shower consumption of $5.76 per year. A total savings of $10.68 per household per year is realized with a retrofit program.

Installation of Water-Conserving Facilities in New Homes. The installation of the facilities in new homes would have considerable impact on the overall savings of water to the city. The cost of the new facilities would be approximately $580 but it is assumed that these items would be included in the total cost of a new home.

Since the Mesa City Water Department does not make any projections on the number of future connections, this author has estimated the number of future connections based on estimated housing units and projected population. Table 5-15 indicates that by 1990 there will be approximately 33,340 residential water connections to the water system or a 11,340 increase from 1976. This figure includes single and multiple dwelling units.

Table 5-15

Present and Projected Water Connections

For The City of Mesa, Arizona[a]

Year	Connections	Housing Units	Population
1976	22,000	41,396	109,163
1980	25,478	48,208	146,550
1985	29,756	56,302	170,876
1990	33,340	63,084	191,775

[a]Projections expressed by Mr. Larry Lines, Utilities Director, City of Mesa in a personal interview.

An average of 872 water connections could be expected per year. With an 86 gallon per day savings, 75,081 gallons per day or 27,381,570 gallons per year could be conserved in water alone. Losses in the system were not considered.

For the new homeowner, the water savings in dollars is $1.38 per month and energy savings is $2.04 per month. Combined savings are $3.42 per month or $41.08 per year.

The following chapter concludes this Research Report with a summary, conclusions, and some implications and recommendations for further study.

Chapter 6

DISCUSSION

Summary

The purposes of this study were to determine the constraints and mis-understandings associated with residential water conservation and to determine the actual savings in dollars, water and energy that would be achieved by the selection and installation of water conserving facilities.

The considerations in Chapters 2 and 3 (Potential Constraints to Residential Water Conservation, and The Current Problem) were included in the study since they constitute a sound and logical basis upon which to formulate and design a timely and phased residential water conservation program. Public education requires an understanding of its attitudes. Water planners need to consider revision and change of existing institutional and economic arrangements to accommodate the expected changes in attitudes and values.

The assumed revision of institutional and economic arrangements and an expected acceptance of water conservation facilities lead to Chapter 5 (The Analysis) which considered the selection and installation of water conservation facilities in existing and new homes. The savings to the residential howowner achieved at the current price of water and energy are not significant. The economic relationship between these two resources, however, will cause them to be extremely significant considerations to the homeowner with increased prices of water, gas and electricity. Further savings are realized via the sewage treatment collection and treatment operations. The homeowner should be made aware of the value he is contributing to the sewage entity by saving water.

Conclusions

The nature and the magnitude of a residential water conservation program will vary on a case-by-case basis depending on such factors as the measures implemented, location, water supply source, and water quality. However, it is beyond the scope of this study to identify all the specific impacts of this program. A few of the implications on water supply, quality, waste reduction and economics will be briefly discussed.

In regards to impacts on water supply, a residential conservation program would help to alleviate the "shortage" of water as it is presently perceived. A reduced demand, in addition to possibly delaying the need for additional major water projects, might permit greater use of some of the existing supplies for such other purposes as groundwater basin recharge, quality improvement, salinity control, and in-stream uses.

In the area of water quality, reduced demands and a corresponding reduced imported water supply could also reduce the total amount of salts brought into an area over a given period of time. However, in the case of inland water discharges used to replenish ground water basins, higher salt concentrations may occur with reduced discharges but the quantity of salts remain the same (43:40).

There could be similar effects on surface water supply systems but a thorough analysis of each situation is necessary before evaluating beneficial or detrimental impacts of reduced residential water use.

Reduced demands for water would also contribute to effects on existing and future sewage treatment systems. The overall effect should be to extend the capacity of sewage treatment facilities. Figure 6-1 indicates that the design life of a treatment plant could be extended by the use of 3.5 gallon per flush toilets only. Another effect of reduced flows is on the capacity of existing gravity-flow sewage collection systems to carry solid wastes. If the existing carrying capacity of a system is already marginal, stoppages could occur; but where the existing system is overloaded, the effect would be beneficial. One other effect is the higher concentration of salts and other materials in the sewage effluent. This could be a problem at the point of discharge but according to Dryden, the total salt loading would be reduced (50:83).

In considering the direct consumer monetary benefits resulting from a reduced water demand in response to a residential water conservation program, the benefits may be offset by increases in water prices required to make up for the decrease in water utilities revenue. The impact on water sales are the basis for scheduling the repayment of debts and other long-term obligations. However, considering the projected population increases and the corresponding utility revenue derived from a larger number of services increases, water rates

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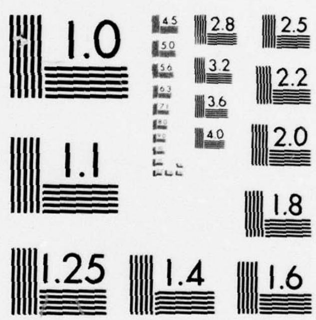

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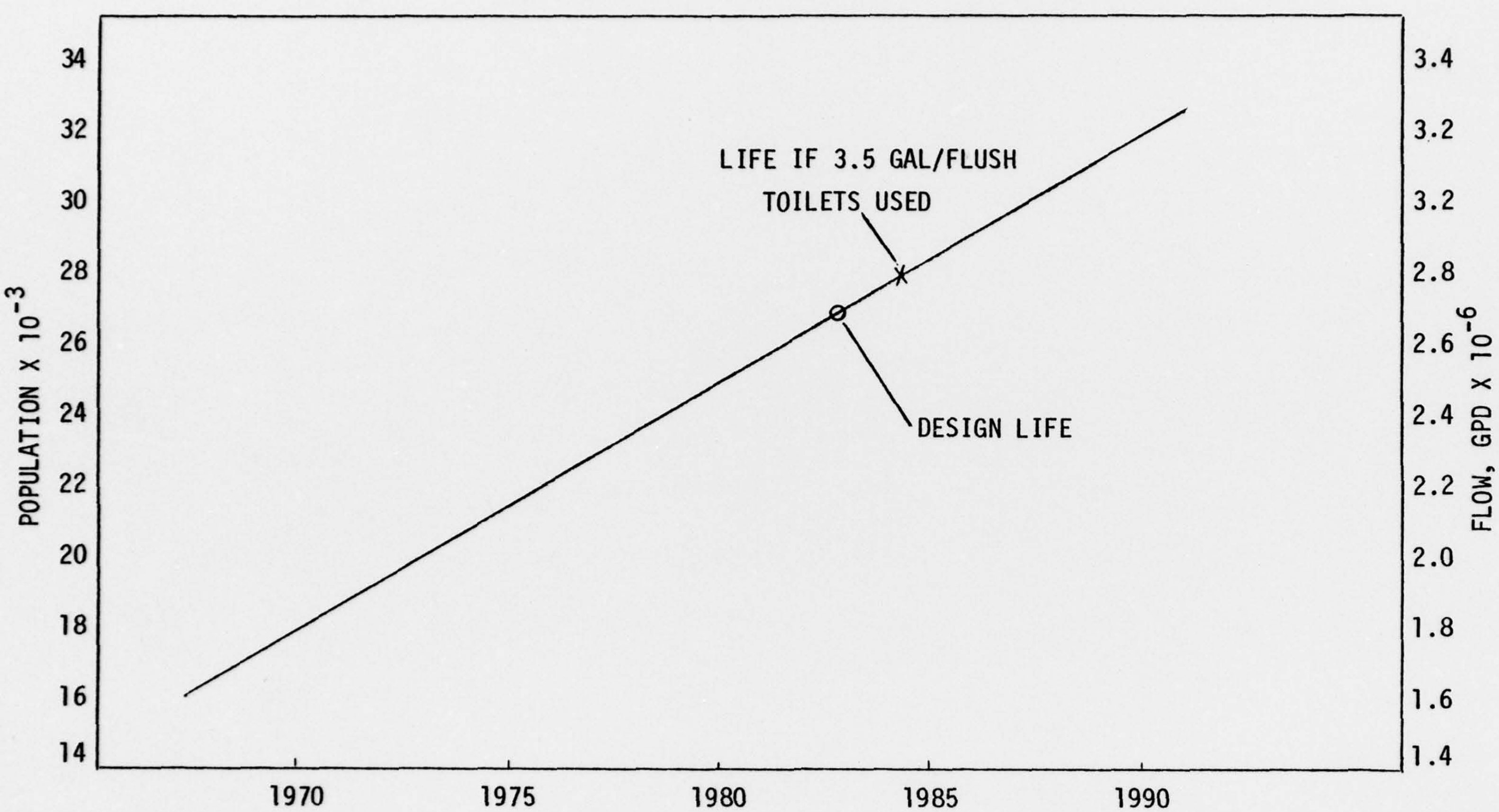

Figure 6-1. Effect of Reduced Flow Toilets on Useful Life of Sewage Treatment Plants (20).

should eventually stabilize.

The major beneficial economic impact of water conservation will be to delay and reduce expenditures for development of additional water supplies. Additional supplies will be extremely costly, in both terms of facility development cost and the energy to transport the water. These long-range economic benefits of maximizing the beneficial use of the current available supplies should be emphasized in public education programs on residential water conservation.

Implications and Recommendations For Further Study

Both the savings in dollars, energy, and water are insignificant in relation to the residential customer. But as the costs of water distribution, energy for pumping,and possibly the price of water increase, the importance of water conservation will be realized. On an aggregate scale these savings become significant.

There is yet one other area where water conservation will have tremendous impact. When public water is consumed, the customer generates a like amount of "used" water, which goes down the drain as sewage and is transported through pipelines to a wastewater treatment plant for careful processing. Since "sewage" is more than 90 percent water, the reduction of water use in the home or business can greatly decrease the volume loading of sewage-handling facilities. Table 6-1 reflects the household wastewater flow generated by conventional household fixtures.

Table 6-1

Household Wastewater Flow Generated By Conventional Household Fixtures (44)

Fixture	Wastewater Flow (gpcpd)
Toilet	30
Faucet (Kitchen/Bath)	5
Shower	20
Dishwasher	14
Clothes Washer	30
Total	99

By broad customer acceptance of water conservation as a family-household responsibility, the per capita demand on pollution control system will diminish and both public health and the environment will benefit.

While the reduction in the use and demand for water appear inevitable for the future, there are monetary benefits and costs that should not be overlooked in planning for the "big picture."

The principal monetary benefits of reduced water usage and the consequent wastewater flow reduction lie in the lowered demand for water and wastewater treatment and sewer capacity and the concomitant reduction in the demand for energy. A reduction in residential water requirements will result in a lowering of both fixed and variable costs of new facilities, but of only the variable costs of existing ones.

Table 6-2

Waste Flow Reduction Achieved By Installing Water-Conserving Facilities In A Typical New Home (44)

Facility	Estimated Percent Waste Flow Reduction[1]
Water-Saving Toilet	9
Flow-Limiting Showerhead	12
Flow-Limiting Faucet Valves	2
Insulation of Hot Water Pipes	4
Water-Saving Clothes Washer	6
Water-Saving Dish-washer	4
Total	37

[1]Estimated percent reduction in overall household waste-water flows.

The monetary costs of achieving the reduced demand comprise the costs of promoting, acquiring, installing and operating the flow reduction devices, as well as the costs of promoting and implementing voluntary water conservation practices. The costs are obviously lower in new construction if the same water conserving facilities were to be installed.

Suggested related topics for further study include the following:

1. Definition of the actual indoor and outdoor residential uses of water, especially lawn irrigation.

2. An evaluation of water-conserving facilities in Mesa on flow reduction and the corresponding effect on sewer solids transport capacity, sewer flow handling capacity, and the treatment processes capacity.

3. A study of the existing institutional and economic constraints on water conservation in the Phoenix Metropolitan area.

4. A survey of how people feel about domestic water and its use during shortage or emergencies.

5. An analysis of the total resource utilization to achieve a residential water conservation program including resources used in the manufacture of the water covserving hardware.

6. Detailed research into the many variables requiring consideration for formulation of a residential water conservation program.

7. Analysis of the potential cost savings both for household plumbing with smaller sized pipes and for water and sewage units.

8. Determination of the local availability of water conserving devices and survey of local housing contractors to determine their acceptability of these devices.

9. Determination of the practicability of installing a dual system of water distribution for new developments since many household tasks to not require water of drinking quality.

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APPENDIX A

REASONS TO PRACTICE WISE WATER USE (25:11)

The following is a list of facilities and suggested impacts that a residential water conservation program will have on each.

I. Source of Supply Facilities:

   A. Reduced groundwater pumping costs and increased reserves.

   B. Leaves more water for longer periods of time in surface sources (lakes, streams, rivers) and hence increases source related fish and wildlife, recreation and esthetic benefits.

II. Import Facilities

   A. Increases the number of services that can be supplied from existing over-land aqueducts and canals.

   B. Reduces out-of-pocket operating costs (energy is most significant).

   C. Ultimately, reduces per capita capital repayment costs since same facility is spread over a larger user base.

III. Treatment Facilities

   A. Increases the number of services that can be supplied from existing facilities.

   B. Reduces out-of-pocket costs for energy and chemicals.

   C. Reduces residual sludge volumes and disposal costs.

   D. Ultimately reduces per capita capital repayment costs.

IV. Distribution Facilities

   A. Reduces out-of-pocket costs to operate distribution system pumps (mainly energy).

   B. Will alleviate distribution capacity problems if existing system is over-taxed during the summer season.

V. Homeowner's Facilities

A. Where devices are installed in new growth only, new growth enjoys substantially lower water costs.

B. Where devices are also retrofitted to existing development, water cost savings enjoyed diminish to savings associated with out-of-pocket costs experienced by the utility for energy and chemicals.

C. Utility may have to adjust water rate upwards to maintain fixed income requirements level but end result is that the consumer's total water bill will not increase and in fact should be slightly less due to energy and chemical cost savings.

VI. Other Hidden Homeowner Benefits

A. Reduced energy bills if hot water use (i.e. shower, kitchen and lavatory faucet, etc.) is reduced.

B. Reduced fertilizer costs since careful irrigation will wash less applied fertilizer to gutters and drains.

C. Reduced pesticide costs since good irrigation practice goes hand-in-hand with healthier turf.

D. Increased lawn pleasure as turf areas will be more attractive, more uniformly green, etc.

E. Lower ground water levels in some cases due to reduced tailwater runoff and waste, hence less drainage problems.

VII. Sewer Collection Facilities

A. Equal performance in properly designed and installed systems.

B. Reduced out-of-pocket costs for energy to operate pumps.

VIII. Sewage Treatment Plants

A. Reduced out-of-pocket costs for energy and chemicals

B. Increased number of services that can be accommodated during the dry weather period.

C. Probably little capacity advantages during wet weather periods unless indiltration inflow levels are under control.

IX. Storm Water Runoff

Reduced levels of nutrients and pesticides reaching receiving waters due to application load reductions which result from more efficient irrigation practice.

APPENDIX B

SUMMARY OF UTILITY DATA FOR CITY OF MESA (1976)

Service Classification	Residential Customers	Consumption	Revenues	Average Use Per Residential Customer	Average Revenue Per Residential Customer
Electric	7,726	70,557,874 kwh	$1,972,702	9,354 kwh[a] 780 kwh[b]	$261.34[a] 35.79[b]
Gas	18,515	10,259,746 therms	2,077,225	564 therms[a] 47 therms[b]	114.29[a] 9.52[b]
Water	22,000	4,131,644 gallons	2,144,792	193,922 gallons[a] 16,160 gallons[b]	100.65[a] 8.39[b]
Sewer	23,001	N.A.[c]	802,306	N.A.[c]	34.88[a] 2.91[b]
Irrigation	351	5,025 hours	13,186	14.32 hours[a] 1.19 hours[b]	37.57[a] 3.13[b]

[a]Per Year

[b]Per Month

[c]Not Applicable

APPENDIX C

METHODS OF URBAN WATER CONSERVATION IMPLEMENTATION, ADVANTAGES, AND DISADVANTAGES (43)

Means to Reduce Water Consumption	Implementation	Advantages	Disadvantages
Water saving plumbing fixtures in new and replacement construction.	Proscriptive	1. Mechanical devices render savings despite user habits. 2. Reduce waste water conveyance and treatment load.	1. Possible resistance to redesign and retooling to manufacture water conserving devices. 2. Drain pipe slope tolerances are more critical. 3. Initially, consumers may resist acceptance. 4. Initially, higher unit cost of water saving devices until demand increases production and reduces cost. 5. May cause blockage problems in marginal sewage collection systems.
Modification (retrofit) of existing plumbing fixtures.	Proscriptive Voluntary Institutional	1. Many devices are nominal in cost. 2. Enables water and energy conservation in existing facilities and therefore has potential rapid, widespread savings. 3. Water savings mechanically effected.	1. Inconsistent effectiveness of retrofit devices because of variable design and construction of existing fixtures. 2. Consumer removal or tampering with retrofit devices because of suspected poor performance.

Means to Reduce Water Consumption	Implementation	Advantages	Disadvantages
		4. Reduces waste water conveyance and treatment load.	3. Some devices require skilled installation and/or follow-up adjustment. 4. May cause blockage problems in marginal sewage collection systems.
New technology.	Voluntary Institutional	1. Greater water and energy savings than conventional designed devices. 2. Reduce waste water conveyance and treatment load.	1. Uncertain long-term effectiveness. 2. Consumer and institutional resistance to innovations. 3. Higher initial costs. 4. Conformance with existing codes and regulations; may require changes or variations. 5. May cause blockage problems in marginal sewage collection systems.
Efficient irrigation using automatic devices	Voluntary	1. Healthier plants. 2. Decreased maintenance. 3. Mechanical type savings.	1. Periodic adjustments required. 2. Expensive initial cost.
Native and other low-water-using plants in landscaping.	Voluntary Institutional	1. Established native and other low-water-using plants and need little or no irrigation. 2. Established plants need little care.	1. General preference for exotic plants. 2. Narrow selection of native plants in nurseries. 3. Difficult to establish some low-water-using plants and general lack of knowledge on care.

Means to Reduce Water Consumption	Imple-mentation	Advantages	Disadvantages
			4. Somehwat higher costs because native and other low-water-using plants are not readily available.
Leak detection and repair of water agencies' distribution systems.	Institutional	1. Reduces unaccounted water losses. 2. Reduces undermining damage to streets, sidewalks, and other structures.	1. Because leaking water often percolates to usable ground water, water agencies sometimes ignore losses. 2. Low cost of lost water may not equal cost of detection and repair.
Leak detection and repair of consumers' systems	Voluntary Institutional	1. Can reduce other home repair costs such as those from wood rot. 2. Many leaks simple and inexpensive to repair. 3. Reduces operational costs.	1. Difficult to induce flat-rate consumers and apartment dwellers to repair leaks. 2. Could be expensive to consumer if he needs professional service.
Metering	Institutional	1. Easier to implement than some of the other suggested methods. 2. May induce consumers to begin conserving water.	1. Consumer objection. 2. High capital cost. 3. Requires changes in rate structure and billing procedure.
Pricing	Institutional	1. May be relatively easy to implement. 2. Can affect all customers.	1. Consumer objection. 2. Requires well designed pricing structure to achieve effective, equitable pricing.

Means to Reduce Water Consumption	Imple-mentation	Advantages	Disadvantages
		3. Can be strong inducement to effect consumer savings.	3. Often require changes in rate structure, meter reading, and billing procedures.
Sewer service charges based on water consumption	Institutional	1. More equitable than flat-rate basis to pay operational cost of sewage treatment. 2. Achieve dual benefits of reduced water consumption and waste water flow.	1. Requires well designed rate structure. 2. Need to segregate inside and outside water consumption.
Education	Voluntary Proscriptive Institutional	1. Induces voluntary water conservation. 2. Changes long established, wasteful consumer habits. 3. Achieves long-lasting results by influencing younger generation. 4. Ensures greater success and acceptance of other water saving means.	1. Effective program requires coordinated efforts of local and state agencies.

APPENDIX D

SUMMARY OF THE CHARACTERISTICS OF SELECTED WATER CONSERVING FACILITIES (44)

I. Water-Saving Toilet

A. Description. Water-saving toilets (also known as "shallow-trap" toilets) are similar in appearance to standard toilets except for a noticeably smaller tank. Less water is required for flushing due to a modified bowl and trap design.

Water-saving toilets use about 3.5 gallons per flush which is approximately a one-third reduction in the amount of water required per flush for a standard toilet.

Water-saving toilets have a lower wastewater flow reduction potential than dual-flush toilets. However, shallow-trap toilets are more socially acceptable than dual-cycle toilets because they are operated similarly to standard toilets and have the same appearance.

B. Circumstances Under Which It May Be Applied. Water-saving toilets can be installed in new residential and commercial buildings. They can also be retrofitted in existing homes as existing toilets wear out and need to be replaced.

C. What Authorities It Requires. Applicable plumbing and building codes will have to be revised to require the installation of 3.5 gallon "water-saving" toilets in new residential and commercial development. Water utilities could also require installation of these toilets in agreements to provide new service.

D. Estimated Reduction In Waste Flow. Assuming a 30 percent reduction in wastewater flow generated per flush, the use of water-saving toilets would reduce residential and commercial sanitary wastewater flow by approximately 9 percent.

E. Incremental Unit Costs Associated With The Control Measure. Water-saving toilets cost approximately $60 or about $10 more than conventional toilets.

F. Incremental Unit Benefits Associated With The Control Measure. The use of water saving toilets would reduce a monthly water bill by approximately $0.90.

II. Flow-Limiting Showerheads

A. Description. Flow-limiting showerheads restrict and concentrate water passage by utilizing orifices that limit and divert shower flow so that it may be optimally used by the bather. These orifices restrict water flow through the shower head to about 3 gpm as compared to typical consumption rates of 5 to 10 gpm.

B. Circumstances Under Which It May Be Applied. Flow-limiting showerheads can be easily installed by a homeowner in existing and new homes.

C. What Authorities It Requires. Applicable plumbing and building codes will have to be revised to require the installation of flow limiting showerheads in new residential development. Water utilities could also require installation of these devices in agreements to provide new service. The use of these devices in existing homes can be encouraged by an effective public education campaign on the use of these devices for water conservation and by a mass public distribution of these devices.

D. Estimated Reduction In Waste Flow. Assuming a 60 percent reduction in shower flow, the use of flow-limiting showerheads will reduce total household wastewater flow by approximately 12 percent.

E. Incremental Unit Costs Associated With The Control Measure. Flow-limiting showerheads cost about $5 more than conventional showerheads or about $10 per unit.

F. Incremental Unit Benefits Associated With The Control Measure. The use of flow-limiting showerheads would reduce a monthly water bill by approximately $1.20. Monthly energy costs would be reduced by approximately $2.80.

III. Flow-Limiting Faucets and Faucet Valves

A. Description. Flow-limiting faucets and faucet valves restrict water flow to a certain maximum rate which is dependent on the system pressure. For lavatory and kitchen sink fittings, the flow is generally restricted to about 1.5 gpm for each valve.

Flow-limiting valves for showers function similarly to sink flow-limiting valves by limiting flows to as low as 2.5 gpm.

Faucets that deliver only 0.5 gpm have been used successfully in commercial buildings. However, their acceptability for residential use has not been tested.

B. Circumstances Under Which It May Be Applied. Flow-limiting faucets and faucet valves would be expensive and difficult to install in existing systems but can be easily incorporated into new facilities.

C. What Authorities It Requires. Applicable plumbing and building codes will have to be revised to require the installation of flow-limiting faucets and faucet valves is new residential construction. Water utilities could also require installation of these devices agreements to provide new service.

D. Estimated Reduction In Waste Flow. Use of flow-limiting faucets and faucet valves in the kitchen and bathroom will reduce faucet flows about 30 percent and will reduce total household wastewater flow by about 2 percent. However, if flow-limiting valves are also used for showers, shower flow will be reduced by approximately 30 percent and overall household wastewater flow will be reduced by approximately 8 percent.

E. Incremental Unit Costs Associated With The Control Measure. Flow limiting faucets cost about $5 more per faucet than conventional faucets or about $10 per unit.

F. Incremental Unit Benefits Associated With The Control Measure. The installation of flow limiting faucet valves in the kitchen, lavatory, and shower would reduce a monthly water bill by approximately $0.80. Monthly energy costs will be reduced by approximately $1.70. The installation of flow-limiting faucet valves in the kitchen and lavatory only will result in monthly water and energy savings of $0.20 and $0.35, respectively.

IV. Insulation Of Hot Water Pipes

A. Description. Insulation of hot water pipes would reduce the amoung of time a householder waits for the flow of hot water at the tap when the hot water faucet is opened. The California State Housing Code now requires that ". . . all continuously circulating domestic . . . hot water piping which is located in attics, garages, crawl spaces or unheated spaces other than between floors or in interior walls shall be insulated to provide a maximum heat loss of 50BTU/hour per linear foot for larger sizes."

Hot water heaters can also be centrally located to reduce the distance from the heater to hot water taps.

B. Circumstances Under Which It May Be Applied. Insulation of hot water pipes and guidelines for location of hot water heaters can apply to all new construction. Hot water pipes in existing homes could be insulated when surrounding wall and ceiling panels would be removed for other reasons during remodeling.

C. What Authorities It Requires. Applicable plumbing and building codes will have to be revised to require specified insulation of hot water pipes in new residential construction. Guidelines for locating hot water heaters should also be provided.

D. Estimated Reduction In Waste Flow. Insulation of hot water pipes would reduce total household wastewater flow by approximately 4 percent.

E. Incremental Unit Costs Associated With The Control Measure. Insulation of hot water pipes will cost an estimated 50 cents to $1.00 per lineal foot.

F. Incremental Unit Benefits Associated With The Control Measure. Insulation of hot water pipes will reduce a monthly water bill by approximately $0.40. An overall household water use reduction of 4 percent would result from a 6 percent reduction in hot water use. This 6 percent reduction would result in household energy savings of approximately $1.00 per month.

V. Water-Saving Automatic Clothes Washer

A. Description. For the same wash load, some automatic clothes washers use as much as 70 percent less water than others. Other automatic clothes washers have a level control that allows the individual operating the washing machine to match the amount of water used to the amount of clothes to be washed. This reduces the volume of water required to wash a small or medium size load of clothes.

B. Circumstances Under Which It May Be Applied. Water-saving washing machines can be installed in new homes and apartments. As older machines are phased out in existing dwellings, they can be replaced with models designed to use less water.

C. What Authorities It Requires. Manufacturers of clothes washing machines should be required to prominently display the water use characteristics of their machines. This action should be accompanied by educating the public on the benefits of using washing machines that require less water.

D. Estimated Reduction In Waste Flow. If a new installed clothes washing machine reduces water consumption by 20 percent as compared to a conventional machine, total residential wastewater flows will be reduced by approximately 6 percent.

E. Incremental Unit Costs Associated With The Control Measure. An automatic clothes washing machine with a level control would cost approximately $25 more than a conventional washing machine.

F. Incremental Unit Benefits Associated With The Control Measure. Using an automatic clothes washing mahcine with a level control that reduces water use by 20 percent will reduce a monthly water bill by approximately $0.60. A 20 percent reduction in the amount of hot water used will result in monthly energy savings of approximately $1.40.

VI. Water Saving Automatic Dishwasher

A. Description. There is a large variation in the amount of water used per load for different models of automatic dishwashers. Some models use 50 percent less water than others.

Overall, total household wastewater flows are increased by about 3 percent by the use of automatic dishwashers as compared to manual dishwashing.

B. Circumstances Under Which It May Be Applied. Water-saving dishwashers can be installed in new homes and apartments. As older dishwahsers are phased out in existing dwellings, they can be replaced with models designed to use less water.

C. What Authorities It Requires. Automatic dishwasher manufacturers should be required to prominently display the water use characteristics of their machines. This action should be accompanied by educating the public on the benefits of using automatic dishwashers that consume less water.

D. Estimated Reduction In Waste Flow. If an automatic dishwasher designed for 25 percent less water consumption is used, total residential wastewater flows will be reduced by approximately 4 percent.

E. Incremental Unit Costs Associated With The Control Measure. The cost for a dishwashing machine that would use less water is highly variable and is determined by factors other than water consumption.

F. Incremental Unit Benefits Associated With The Control Measure. Using a reduced water consumption dishwashing machine with a 25 percent reduction in water use will reduce a monthly water bill by approximately $0.40. A 25 percent reduction in the amount of hot water used will reduce monthly energy costs by about $0.80.

BIOGRAPHICAL SKETCH

Donald E. Warner was born in Hanover, Pennsylvania on September 20, 1947. He received his elementary and secondary education in the Spring Grove Area School District, Spring Grove, Pennsylvania. In September 1965 he entered the Pennsylvania State University from which he graduated in June 1969 with a Bachelor of Science degree in Landscape Design and a commission as Second Lieutenant, Army Corps of Engineers. His military education includes the Engineer Officer Basic Course, Construction Planning and Operations Course, Atomic Demolitions and Munitions Course, and Engineer Officers Advanced Course. Cpt. Warner has served in both Germany and Korea. Included in his military decorations are the Army Commendation Medal and the Meritorious Service Medal. A member of the Society of American Military Engineers, he presently holds the rank of Captain with a Regular Army Commission. Having been selected by the Army for graduate schooling, Cpt. Warner entered Arizona State University in January 1976 to study for the degree of Master of Science in Facilities Engineering. He is married and the father of a son and two daughters.