NAVAL POSTGRADUATE SCHOOL
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THESIS

WATER CONSERVATION
AS A WAY TO LESSON THE IMPACT
OF NEW CONSTRUCTION
AT THE PRESIDIO OF MONTEREY

by

Michael Henry Kennedy

June 1983

Thesis Advisor: Leslie J. Zambo

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This thesis considers ways to conserve water at the Presidio of Monterey with reference to the general applicability of the study to other bases. Chapter One describes the current need for water conservation as potable water becomes more of a scarce resource. Chapter Two presents six methods of water conservation: reclamation and reuse, rainwater

capture, flow reduction devices for inside application, metering of usage, planting of drought-resistant vegetation, and public education campaigns. Chapter Three evaluates each of these for the Presidio of Monterey. The most beneficial, determined by cost/benefit analysis, is the installation of two particular flow reduction devices--reducers for showers and faucets, and pressure reducing valves--and the institution of public education campaigns. Several suggestions are made for further study since rising costs may make some of the currently nonrecommended options, such as reuse and rainwater capture, more viable.

Water Conservation as a Way to Lessen the Impact of New Construction at the Presidio of Monterey

by

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This thesis considers ways to conserve water at the Presidio of Monterey with reference to the general applicability of the study to other bases. Chapter One describes the current need for water conservation as potable water becomes more of a scarce resource. Chapter Two presents six methods of water conservation: reclamation and reuse, rainwater capture, flow reduction devices for inside application, metering of usage, planting of drought-resistant vegetation, and public education campaigns. Chapter Three evaluates each of these for the specific situation at the Presidio of Monterey. The most beneficial, determined by cost/benefit analysis, is the installation of two particular flow reduction devices--reducers for showers and faucets, and pressure reducing valves--and the institution of public education campaigns. Several suggestions are made for further study since rising costs may make some of the currently nonrecommended options, such as reuse and rainwater capture, more viable.

TABLE OF CONTENTS

LIST OF TABLES

I. INTRODUCTION

I will make rivers flow among
barren hills
And springs of water run in
the valleys.
I will turn the desert into pools
of water
And the dry land into flowing
springs.
Isaiah 41:18 (TEV)

A. OVERVIEW

The United States is a country with abundant natural resources, including a seemingly never ending supply of water. In reviewing the history of water usage in the United States, Eugene W. Weber said:

> Most of the nation was endowed with a generous supply of this vital resource. For many years it was not necessary to plan how to use it but merely to exploit it and reap the blessings of the endowment. From the beginning of our history as a nation, there have been prophetic warnings at infrequent intervals of the need for planning ahead. Most of these warnings went unheeded locally and nationally until recent years. [Ref. 1: p. 3]

In the current period, no single water pollution problem has caused as large a stir as the contamination and "death" of Lake Erie. This was one of our

first environmental alarm bells, sounded in the late 1960's. The nation was shocked to hear that agricultural, municipal, and industrial wastes had 'killed' one of our Great Lakes. Public indignation spurred bordering states and provinces to spend several billion dollars to clean up their effluent. After a decade of work, the public was elated to read that Lake Erie had been 'brought back to life!' [Ref. 2: p. 52]

But it is not that easy, it seems. "Scientists at Ohio State University's Center for Lake Erie Area Research (CLEAR) had found no decline in the pollutants already in the lake. . . . Once pollutants are in the lake they are almost impossible to remove." [Ref. 2: p. 53] As concern focused on Lake Erie, the overall problem of water use and planning also came to the fore.

When viewed in the aggregate, the water resources available are clearly defined by the famous line from the Rhyme of the Ancient Mariner: "Water, water, everywhere, but nary a drop to drink." The total quantity of water on the earth is approximately 326,000,000 cubic miles. But only 2.5 percent of this is fresh water and 75 percent of that fresh water is locked in the polar ice caps. Of the total water on the earth, only about 0.6 percent is in the form of liquid fresh water [Ref. 2: p. 45]. Although this still amounts to almost 2 million cubic miles of water, the World Bank estimates that there are in excess of one billion people in the world with insufficient access to drinking water, due to its unequal distribution around the globe [Ref. 2: p. 45]. A UNICEF report speaks, for example, of a woman in the Sudan who spends 8 hours per day fetching water with a four gallon pail on her head [Ref. 2: p. 45].

1. Groundwater

Among the largest sources of water are the aquifers[1] that underly vast areas of land. The largest in the United States is known as the Ogallala aquifer, that stretches from southern Nebraska through Colorado, Kansas, Oklahoma, and Texas. The first wells were drilled about 100 years ago and now in some places the water table has dropped drastically, as much as 100 feet [Ref. 3: p. 148]. Since aquifers refill slowly, at a maximum of about 2.5 inches per year, it would take, in some places, a thousand years of no drawing at all for the Ogallala aquifer to regain its orignal position [Ref. 2: p. 47].

In fact, Alan Anderson, in [Ref. 2: p. 47], predicts that "Kansas alone will lose 500,000 acres of irrigated farm land every five years." This is due to the overdrafting of the Ogallala aquifer. Because of the falling water table and the increasing cost of gasoline to run the pumps, it is becoming less and less viable, financially, to pump the water. In some cases the water level has even fallen below the well depth causing the well to go dry. In Pecos, Texas, some "70,000 wells have gone dry, and sagebrush rolls again, coming to rest against rusting irrigation equipment and abandoned barns." [Ref. 2: p. 47] Overdrafting is not just a problem in the central United States. "Farmers already pump so much groundwater in the San Joachin that an area the size of Connecticut has subsided as much as 30 feet." [Ref. 2: p. 49]

The total amount of groundwater in this country is "vast--about 50 million acre feet[2] (AF)." [Ref. 2: p. 47] Even so, the "western cities and farms are pumping it out faster than it can be replenished. They are overdrafting."

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[1] Please see appendix for definition.

[2] Please see appendix for definition.

[Ref. 2: p. 47] But, "overdrafting is not necessarily bad--any more than mining coal or pumping oil is bad. But it is essential to understand that some groundwater supplies, such as the dwindling Ogallala, are irreplaceable. In much of the Southwest, especially California, Texas, and Arizona, today's overdrafting is leading inexorably to tomorrow's crisis." [Ref. 2: p. 47]

Jean A. Briggs, a Fellow at the National Humanities Center in Research Triangle Park, N.C., stated:

> We are a water-intensive people, perhaps the most water-intensive the world has ever known. We cherish our benefits, but nevetheless 45% of the fresh water we use in our homes goes for flushing toilets and sewage. Another 30% goes for bathing and cleaning. Only a tiny percentage is used for drinking and cooking. [Ref. 4]

In order to reach a balance so that there will be water for the future, "we must initiate a conservation ethic--a notion still foreign to Americans who view water, not as a gift, but as a constitutional right, if not a God-given right." [Ref. 2: p. 53]

2. <u>The Necessity for Conservation</u>

We are entering an era that will be characterized by the requirement for the conservation of water resources. Conservation is

> an obvious key component in solving the water crisis and avoiding future problems. It is the obvious way to provide the equivalent of a vast untapped reservoir of clean, potable[3] water. It is as obvious as elementary school mathematics: halving the demand for water is equal to doubling the supply. Every serious examination of what is happening to water today, and of what threatens to happen to it tomorrow, comes to the conclusion that conservation is of extreme, possibly of premier, importance. [Ref. 5, p. 715]

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[3] Please see appendix for definition.

New sources of water supplies, such as deeper aquifers, are being sought [Ref. 3: p. 149], but they cannot be depended upon to provide the water needed to meet the demands in the coming several decades. Briggs also stated:

> What I'm not advocating is the notion that we are going to solve the problem by discovering more water. We must examine what resources are available in given regions of the country over a 25-to-30 year period to see where there's no more water to draw from and to establish some national planning. [Ref. 4]

National planning will help redirect resources, but in the near-term (five to ten years), the only way to make an impact on the water supplies is to decrease usage and developing a reuse capability [Ref. 5].

> There are really only two alternatives: the choice must be made between either increasing supplies or decreasing demand. In the United States at least it has been demonstrated that the option of reducing consumption is not only feasible, it is ecologically and economically superior. [Ref. 6]

3. The California Water Situation

California has been particularily hard-hit in terms of water problems. Hal Rubin of California State University at Sacramento, said that "water has broken more alliances and friendships in California than alcohol." [Ref. 2: p. 48] When California became a state in 1850, the "frontier was still open. California had few people, vast open spaces, and large amounts of natural resources." [Ref. 7: p.1] Those early miners and farmers had no need to account for the impact their use of resources made.

But as California developed, from a frontier to a modern society, many of the ways of the frontier were replaced by "complex systems that attempt to maximize total net benefits obtainable from a given set of resources." [Ref. 7: p. 1]

Part of the problem stemmed from the conflicting types of laws that have "historical roots reaching back into English common law, Mexican pueblo law, and western mining law. These bodies of law were developed under very different principles and for different reasons." [Ref. 7: p. 1] The courts have resolved various conflicts from these laws, but there has been "no systematic restatement of water law through the legislative process. The result has been that California water law decisions have been made primarily to protect specific private water using rights, rather than to provide maximum benefit to society as a whole." [Ref. 7: p. 1]

The distribution of water supplies and the concentration of demand complicates this picture even further.

> Nature provides the largest proportion of California's water during winter and spring, whereas the largest demands occur in the summer and fall. Fifty-five percent of California's water supply comes from the northern one-third of the state, but 75 percent of the use occurs in the central and southern two-thirds of the state. Thus, the water system must store water across time and transport it across space to meet the demands of water users. [Ref. 7: p. 2]

Currently, California is able to meet the demand for water except during periods of drought. But, part of the way this need is being met is through overdrafting ground water reservoirs. Statewide water demands by the year 2000, could exceed dependable supplies by as much as 6.6 million acre feet per year

> if agricultural and urban water use continues to increase, groundwater supplies are not better managed, and no new supplies are developed. The [California] Department of Water Resources plans to meet these demands through a program that uses a balance of new water facilities, water reclamation, and groundwater storage of water supplies. [Ref. 8: p. 3]

4. The Monterey Peninsula Water Situation

Focusing on the Monterey Peninsula, a coastal area with usually adequate rainfall, problems in the water supply are a possibility in the future. "This is an area of recurring droughts. Water conservation on a reasonable level should be practiced or we may run short of water in little more than a decade." [Ref. 9]

What amount of short-fall is being talked about on the Monterey Peninsula? Tree ring studies indicate that California has alternated between droughts and moderate to heavy rainfall. There have been exceptionally dry years in its history, ranging back over a thousand years [Ref. 9]. The Monterey Peninsula has experienced four droughts in its recorded 77 year history. A possibility of a drought is strong in any given year [Ref. 9]. The Monterey Peninsula recieves 14 to 22 inches of rainfall yearly.

> Ten or fewer inches constitute a dry year. In one such year, normal stream flows are diminished and the aquifer does not become fully recharged. Two dry years in a row use up much of the water in the reservoirs, drawing heavily on the groundwater and depleting the reserve buffer of water in the aquifer. [Ref. 10]

5. Sources of Water for the Monterey Peninsula

There are three basic sources of water for the Monterey Peninsula: (1) runoff from rainfall via the Carmel River Basin; (2) the Carmel Valley aquifer; and (3) the Seaside aquifer. The Monterey Peninsula Water Management District has estimated that the

> supply of water currently available is 18,000 acre feet (AF) annually. By using the ground water available from the Carmel Valley, that yield could be increased to 22,000 AF in a normal year. . . . The 22,000 AF estimate is based on drawing 9,000 AF from the reserviors at the Los Padres and San Clemente dams on the Carmel River, 11,000 AF from Carmel Valley wells, and 2,000 AF from Seaside wells. [Ref. 10]

The water utilities' deliveries, historically, have increased at an "average rate of 3% per year. Current District projections indicate that by the year 2000, demand will exceed the 22,000 AF estimated supply, and the Peninsula is expected to have a serious water supply problem." [Ref. 10]

With this serious a situation facing all the residents of the Monterey Peninsula, the consideration of ways to cut water consumption are needed.

Americans have been brought up to think of water as a free resource. We, "to a degree inconceivable to many of the world's other inhabitants, are accustomed to having unlimited supplies of inexpensive, clean water" [Ref. 5: p. 703] at our disposal. "We can, and often do, allow a gallon or so of pure drinking water to run down the drain while we brush our teeth and we think nothing of it." [Ref. 5: p. 703]

6. <u>The Military Presence on the Monterey Peninsula</u>

Among the residents of the Monterey Peninsula are three major military installations: Fort Ord, the Naval Postgraduate School, and the Presidio of Monterey. These three installations account for a large percentage of the Monterey Peninsula population and the impact they make warrants evaluation.

For the military members living in government-provided quarters on the Monterey Peninsula, the concept of water being a free resource is reinforced, since there is no metering or monthly bill for any utility, including water. Consequently, water conservation is not something that happens by consumers' cutting back so that they can lower their water bill. But as fresh water becomes more scarce and more expensive, the problem of the lack of water conservation measures and the continued notion of water being a free good must be addressed.

One of the lessons learned during the California drought of 1976-77 was that individuals and families could cut down their consumption of water greatly without destroying or even seriously rearranging the rest of their lives. 'It is clear,' said a state report on the drought,'that Californians can carry on nearly all domestic activities with little more than a minor crimp in lifestyles, [and] with a rather substantial reduction in water consumption.' [Ref. 5: p. 716]

Water conservation can work.

A learning process is required because water has been a free good for so long, a substance so easily taken for granted, used and then splashed unceremoniously onto the ground or into the nearest stream. . . . If there is one thing we should know about water now, it is that it is important. It is not free. [Ref. 5: p. 716]

B. OBJECTIVE

The objective of this thesis is to evaluate water use on military installations, and to determine ways to conserve, if necessary, which could be implemented DOD-wide.

C. SCOPE

The focal point will be new construction on the Presidio of Monterey, as an example of the impact made by a small military installation on a civilian community. From this evaluation, generalizations will be made, if applicable, to other military installations.

D. RESEARCH HYPOTHESES

The research will be guided by two research hypotheses:

(1) Water consumption on military installations is proportionally higher than consumption in civilian communities.

(2) Conservation techniques can be implemented which will result in significant cost savings for the United States government through decreased water consumption.

E. FORMAT

Chapter Two is a review of the literature concerning various conservation techniques that are appropriate to military installations. It includes a study of the reuse potential of waste water generated in the home; the possibilies of cisterns both in individual units and base-wide; internal flow-reduction devices for cutting down water use inside the house; metering as a way of making the housing occupants aware of the cost of the water they are using; the possible water savings in landscape irrigation by the use of drought-tolerant plants; and the effects of public education in raising the consciousness level about water use.

Chapter Three addresses each of the research hypotheses and considers the techniques outlined in Chapter Two from a cost/benefit perspective, paying special attention to combinations of alternatives. Chapter Four is the conclusion of the study, making specific recommendations for use at the Presidio of Monterey.

II. POTENTIAL CONSERVATION APPROACHES

A. INTRODUCTION

The literature in water conservation recognizes four primary ways of making more efficient use of existing supplies--through operational, economic, structural, and socio-political means [Ref. 11: pp. 85 - 95].

Operational methods of demand reduction are chiefly under the control of the utility and include leak detection and repair and the implementation of use restrictions. Economic means of demand reduction can be accomplished solely through utility company actions, in terms of pricing policy, incentives, penalties, and demand metering. These two methods, operational and economic, are beyond the scope of this thesis.

Structural and socio-political means, however, hold much promise as ways that could be implemented by military installations to make a dramatic impact on water use and cost. Structural methods relate to recycling and reuse systems, cisterns for rain water capture, water-saving flow controllers, metering, and low water-use plants and ground cover. The socio-political method is basically public education to explain the necessity of water conservation and to elicit support from the users. The development of this conservation ethic is essential to any successful water management effort.

B. BASELINE CONDITIONS

Various combinations of the above mentioned ways of conserving water can be made. All are interrelated and so are not strictly additive; that is, the total impact cannot

be measured by adding together all of the individual effects.

To evaluate a program of water conservation, a baseline has been adapted from the Journal of Water Resources, Planning and Management Division published by the American Society of Civil Engineers and is presented as Table I.

TABLE I

Baseline Water Use

Function	Gallons per Capita per Day	Percent of In House	Percent of Total Use
In-House use			
Toilet	25	40	13
Bath/Shower	20	30	11
Lavatory/Sink	3	5	2
Laundry	10	15	5
Dishwasher	3	5	2
Culinary	3	5	2
Subtotal	64	100	35
Outside-Yard	125		65
Total Use	189		100

[Ref. 11: pp. 88-89]

Water use figures were based on studies done in Denver, Colorado, in 1969. They are very similar to amounts obtained in other studies as noted in [Ref. 12: p. 210].

C. RECLAMATION AND REUSE

One way of cutting down on potable water use while at the same time reducing the amount of discharge into the sewage system is through reclamation and reuse. This has become a more viable alternative as the cost of fresh water has increased and its availability has decreased. There has been extensive study of the technological and health-related aspects of water reuse.

In 1979, a Water Reuse Symposium was held in Washington, D.C., with the theme "Water Reuse--From Research to Application," co-sponsored by the American Water Works Association Research Foundation; the Office of Water Research and Technology, U. S. Dept. of the Interior; the U. S. Army Medical Research and Development Command; the U. S. Environmental Protection Agency; the National Science Foundation; and the Water Polution Control Board. Several thousand pages of reports and studies were presented at the symposium.

One of the papers presented dealt specifically with the State of California and the ongoing reclamation and reuse project of Las Virgenes Municipal Water District [Ref. 14: pp. 1629 - 1647]. The paper pointed out that the State of California Water Code, Chapter 6, Article 2, encourages the reuse of wastewater.

> It is hereby declared that the primary interest of the people of the State in the conservation of all available water resources requires the maximum reuse of wastewater in the satisfaction of the requirements for beneficial uses of water. [Ref. 14: p. 1629]

Also, the California Department of Water Resources has declared "the reuse of water to the maximum extent feasible" to be one of the elements of its water management policy [Ref. 14: p. 1629].

1. Water Reuse in Southern California

The Las Virgenes Municipal Water District (LVMWD) has prepared itself to be a leader in the rapid expansion in reclamation and reuse of wastewater in Southern California. LVMWD covers 78,500 acres in western Los Angeles County, sitting astride the Santa Monica Mountains. Its population is close to 30,000. LVMWD has been providing reclaimed water[4] for agricultural and institutional landscape use since 1971. However, in 1977, the California Department of Parks and Recreation acquired a large part of the Las Virgenes Valley and designated that the land be kept in its native state, unirrigated. LVMWD was faced with what to do with the water it now had available. Also, new filters were installed to bring the water up to non-potable standards.[5] The district, thus, proposed to provide this water to the only source capable of using this supply over a large part of the year, the residential homeowner [Ref. 14: p. 1632].

As was pointed out in Table I, 65% of the domestic water consumption was for outside water use. Another 13% was used in toilet flushing. These are the two primary uses for recycled water. LVMWD proposed using recycled water for toilet flushing, but the health authorities ruled it out. However, the amount of water used in landscape irrigation made the proposal worth persuing on its own right.

The LVMWD developed a dual-water delivery system, with separate lines for potable and non-potable water. Appropriate safeguards were built-in to minimize accidential ingestion of the non-potable supply by the user. It is worth mentioning that the non-potable water met the so-called 'body-contact' standards of the State of California. In other words, "swimming in water of this

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[4] See appendix for definition.

[5] See appendix for definition.

quality, or irrigating lettuce, is permitted." [Ref. 14: p. 1633]

LVMWD developed extensive guidelines for the non-potable water system, the basic concepts of which are broadly described as follows.

> The non-potable water system will be operated at a lower pressure that the potable water system. (Should a cross-sconnection occur, flow will be from the potable to the non-potable system.)
>
> All non-potable facilities will be easily identified and differentiated from the potable facilities. (This will be accomplished by special markings and/or use of different materials.)
>
> The installation and operation of non-potable facilities will be closely monitored by LVMWD, who will keep accurate records of the form and location of each on-site system.
>
> LVMWD has adopted the necessary Resolution to provide for District control of the non-potable system through a permit system, and for enforcement of the rules and regulations relative to the use of the non-potable supply.
>
> LVMWD will develop and implement an on-going education program for users of the nonpotable system. [Ref. 14: p. 1633]

LVMWD received a qualified endorsement from the health authorities, and was able to begin the program in 1978. What is most significant is the the

> concept of piping reclaimed water to the point of use has the advantage, when compared to ground water recharge and/or river or lake discharge, of sidestepping the residual organic question. By this means, virtually all beneficial uses, short of drinking, are within reach of present day knowledge and technology. [Ref. 14: p. 1633]

The experiment tried by LVMWD has, so far, been successful, even though the health authorities insisted that irrigation water for private homes be used only on the front yards, using a District-controlled timer to limit the hours that the non-potable water could be used.

When the health authorities allow the use of non-potable water for all landscape irrigation and for use in toilets, LVMWD feels it will be meeting the spirit of the California law, which requires maximum use of wastewater,

and will be "taking advantage of the beneficial economics of a socially-acceptable program, resulting in lower short and long-term total cost to the customer for water and sewer service." [Ref. 14: pp. 1637-1638]

This case has been presented in detail to show that the technology now exists to reuse wastewater in ways that can make an impact in the total demand and cost for water. Since the test was conducted by installing the system in new houses, there may be a direct applicability to the military housing at the Presidio.

2. Department of Defense Concerns about Reuse

The military was well represented at the Water Reuse Symposium. One of the first speakers was George Marienthal, Deputy Assistant Secretary of Defense (Energy, Environment and Safety). Mr. Marienthal stated that the "Department of Defense is fully committed to conserving our nation's resources. We view wastewater recycle and reuse as a means to further this basic commitment." [Ref. 15: p. 6] He expressed the concern that DOD, as well as private industry, was finding water just too valuable to throw away.

> Used water is becoming, in fact, a practical source of good water. We see water reuse as just plain wise management. If fully developed, water reuse should be cost effective, should increase our operational capability, and should ease all our installation demands for fresh water. [Ref. 15: p. 6]

Mr. Marienthal reminded the participants that the 1977 amendments to the Federal Water Polution Control Act have added an additional emphasis to wastewater reuse considerations.

> All federal agencies must, after September 30, 1979, use innovative treatment processes and techniques for water pollution abatement facilities. This includes, but is not limited to, methods utilizing recycle, reuse, and land treatment. Innovative treatment must be used when its life cycle cost is no more that 15 percent greater than the most cost effective alternative. [Ref. 15: p. 7]

In tracing the Army's recycling experiments at Ft. Detrick, Maryland, Mr. Marienthal pointed out how Army, Navy, and Air Force research is creating expertise that the civilian institutions can draw on. He concludes by saying: "All in all, we view wastewater recycle and reuse as a viable alternative in wastewater treatment, water source development, and our overall resource conservation program." [Ref. 15: p. 9]

3. United States Air Force Water Reuse

The United States Air Force has been conducting water reuse research since 1973 [Ref. 16: p. 1877]. A comprehensive study of the possibility of water reuse was conducted at McClellan AFB, Sacramento, California. McClellan AFB was viewed by the Air Force as having good potential for water reuse since the on-base wells were lowering the water table by at least two feet per year, 85 percent of the non-potable water use would be for cooling towers and irrigation, and the base was faced with a high surcharge for discharging to a regional system [Ref. 16: p. 1877].

After the analysis was completed, a recommended water reclamation and reuse system was developed to handle reclaimed wastewater.

> Ten million gallons of storage are being provided to supply over 10 miles of a dual distribution system. Main uses of the reclaimed water will be landscape and athletic field irrigation, cooling tower makeup water and air pollution control scrubber makeup water. The total construction cost for the system is $2.5 million, a savings of several million dollars in the life cycle costs over the alternative of joining the regional system. An equally important savings is the approximately 400 million gallons annually of fresh water which will not be withdrawn from the groundwater basin. [Ref. 16: p. 1879]

As the example demonstrates, the Air Force is providing a working model of how to apply water reuse technology to a military installation and make it work.

4. United States Army Water Reuse

The U. S. Army also has an interest in developing a water reuse potential. A paper was presented at the Water Reuse Symposium entitled "Water Reuse and Water Conservation at U. S. Army Installations." The introduction to the paper stated:

> Wastewater reuse has become a viable alternative water resource in the abatement of a number of stressing environmental problems. It offers a new means of extending water supplies and reducing fresh water demands. In regions where high sewer surcharge fees or stringent discharge requirements exist, reuse has the potential to reduce treatment costs by reducing or eliminating the discharge. As our water resources become stressed and pollution potential increases, effective low energy resource conservation methods must be explored; wastewater reuse is one such method. [Ref. 17: pp. 1865 - 1875]

The U. S. Army was interested in studying the possibility of savings to be generated by wastewater treatment and reuse on its installations in the water short areas of the United States--the west and the southwest [Ref. 17: p. 1865].

> Wastewater reuse can have several benefits for army posts: fresh water supplies can be conserved by substituting the reclaimed water for subpotable[6] uses; problems with pollution control can be alleviated by internal recycling and reuse at specific activities; treatment performance can be enhanced by reusing water and reducing the hydraulic load on the treatment plant; nutrients in the wastewater can be utilized as fertilizer in irrigation waters; zero discharge reuse schemes can eliminate the problem of routine stringent effluent or pre-treatment criteria; and by reducing wastewater through the reuse, bases can reduce the cost of sewer discharge fees. [Ref. 17: pp. 1865 - 1866]

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[6]This is equivalent to 'non-potable' defined above. See the appendix for definition of 'non-potable.'

In order to make an adequate study of the water reuse potential at permanent army posts, a model was developed to assess that potential. "The model was directly applicable to those installations where new water and wastewater construction is planned and, thus, formal evaluation of reuse potential is federally mandated." [Ref. 17: p. 1866] The model was set up to deal only with subpotable (non-potable) water reuse on a permanent, fixed army posts.

"This model was designed as a three-tiered evaluation to aid the Army in evaluating reuse potential at fixed installations." [Ref. 17: pp. 1866 - 1867] In order to evaluate more than 130 Army installations of interest in the United States, it was necessary to develop, as the first tier, a straightforward, easy to apply model that could be evaluated in approximately one man day of effort [Ref. 17: p. 1867].

Those U. S. Army installations that ranked highest in Tier I, would then be considered for evaluation under Tier II. This tier would provide a "cookbook-type approach, leading the evaluator to an eventual comparison of total cost for various reuse scenarios, including non-reuse options, at each installation." [Ref. 17: p. 1867]

Tier III, a more detailed approach, "incorporates a sophisticated mathematical model supported with a computer program to aid Army engineers in the selection and cost of conceptual reuse systems at installations with the best reuse potentials." [Ref. 17: p. 1867]

This whole process is aimed at sifting through the population of possible target posts to arrive at a rank ordering of those that would provide the best potential for savings through recycle and reuse. Using Tier I rankings a substantial number of Army posts that have little potential for water reuse could be eliminated from further consideration, thus reducing the cost for analysis at the more extensive Tier I and Tier II stages.

5. U. S. Army Reuse Model--Tier I

Tier I is composed of five general categories that were developed as indicative of the water reuse potential at Army installations. "The major criteria were rank ordered as to importance for wastewater reuse as follows: water supply, wastewater, activities, institutional aspects, and climate, from high priority to low priority." [Ref. 17: p. 1867]

The first criterion, water supply, is of primary importance since it is the cost and availability of a water supply, both current and expected, that drives the need for wastewater reuse [Ref. 17: p. 1868]. Some of the questions and responses that are considered under this criterion are:

Question 1. Is the base water supply available from a reliable source for the next 20 years?

Remark: A negative response signals possible long-range supply problems, a plus for reuse.

Question 2. Is there possible significant depleation of the water supply within the next 20 years?

Remark: A negative response means future planning and possible design of new water supply facilities--a good time to evaluate reuse.

Question 3. Is there a new future anticipated problem with the water supply?

Remark: Negative response implies a high rating for reuse as evaluation and planning for new and additional water supplies should include reuse possibilities.

Question 4. What is the present cost of water procurement and treatment per 1,000 gallons?

Remark: High water costs are a driving force for reuse as the economics of reuse become more attractive.

Question 5. Is there a forseeable event that could markedly increase water costs in the near future?

Remark: Although costs may be reasonable now, many areas are realizing increased costs as water sources are depleted and quality degrades. Future cost increases benefit reuse economics.

Question 6. Is expansion or upgrading of the water supply/ treatment systems planned for the near future?

Remark: Reuse can provide savings in reduced plant capacity. Planning should include reuse feasibility. [Ref. 17: p. 1868]

The second criterion, wastewater, is evaluated in terms of the quality and type of wastewater generated by the installation. If the wastewater is good quality already, it may be an excellent candidate for reuse. However, if the installation is

> currently in a situation where outdated and/or overloaded treatment facilities are unable to meet requisite quality requirements and, therefore, an update of current facilities is under consideration by virtue of the mandate of Public Law 95-217, they must consider water reclamation or wastewater reuse as an alternative within their decision-making process. Thus, when considering the overall concept of wastewater management, the treatment facility's effluent quality, effluent criteria costs, and discharge volumes are all important factors. [Ref. 17: p. 1869]

Several questions in this section are relevant:

Question 11. Will additional treatment facilities be required within the next 5 years?

Remark: A positive response indicates planning, design, and construction of new facilities. Reuse could have positive cost impact, or conceivably alleviate the problem so new facilities would not be necessary.

Question 12. What quality is the plant effluent in terms of suspended microorganisms?

Remark: Good quality effluent is a bonus for reuse in that little extra treatment is required for reuse and, therefore, the economics look more advantageous.

Question 18. If the base discharges to a municipal or regional sewer system, what is the discharge fee per million gallons?

Remark: High discharge fees have a positive effect of reuse economics.

Question 19. Are future changes likely that would markedly increase the discharge fee?

Remark: Again, future increases in discharge fees can have a positive impact on current reuse planning. [Ref. 17: p. 1870]

The third criterion considers the demands that exist for non-potable water. These demands are referred to as 'activities.' In order for a water reuse system to function effectively, there must be places that the generated non-potable water may be used. "In the classic approach, agricultural or recreational irrigation has been a primary sink for reclaimed wastewater." [Ref. 17: p. 1870] The key question in this area is question 22, "How many acres of landscape and athletic fields could be irrigated if reclaimed water were available?" [Ref. 17: p. 1871]

Institutional aspects, criterion number four, draws attention to the fact that "legal constraints or negative attitudes toward reuse have stopped programs that were technically feasible and economically justified." [Ref. 17: p. 1871] Several of the questions and remarks is this area are:

Question 36. Is the base free of any long-term water purchase agreements that would prohibit the base from cutting back on water usage?

Remark: Constraints on the ability to reduce water usage are obviously detrimental to reuse programs.

Question 38. Is wastewater reuse occuring now or being planned in surrounding communities?

Remark: Reuse in surrounding areas portends of legal pressures and a favorable legal/institutional climate for reuse.

Question 40. Is there a potential large civilian water user near the base (i.e., golf course, power plant, agriculture)?

Remark: Large civilian water users near the base can offer a sink for reclaimed water if the quality is sufficient and the economics of transport are feasible.

Question 41. Do key base personnel feel that the effluent is a high quality source being wasted?

Remark: The attitude of key personnel towards wastewater reuse is a prime factor in the success of a program. [Ref. 17: p. 1871]

Climate, the fifth criterion, deals with irrigation as a primary sink for reclaimed water. Since the value of water for irrigation purposes is dependent upon climatic conditions,

> the bases located in arid or semi-arid areas have a substantial advantage over installations located in areas of high rainfall. Furthermore, bases that are located in semi-arid or arid regions also are potential candidates for severe potable water shortages, thereby increasing the interest in reduction of total raw water demand. [Ref. 17: p. 1872]

Two questions aim at obtaining the basic preliminary information needed to make a decision about the climate.

Question 42. What is the average yearly rainfall on the base in inches/year?

Remark: Areas with low rainfall are rated more positive for reuse.

Question 43. What is the average yearly evaporation on the base in inches/year?

Remark: Areas with high evaporative loss are apt to have a higher demand for reclaimed water. [Ref. 17: p. 1872]

The Tier I model was applied to three Army installations: Fort Ord, California; Fort Jackson, South Carolina; and Anniston Army Depot in Anniston, Alabama [Ref. 17: pp. 1872 - 1873]. The study indicated that Fort Ord ranked the highest for water reuse potential of these three.

6. U. S. Army Reuse Model--Tier II

Tier II is a model used to evaluate those installations that scored well in the Tier I phase. It is estimated that Tier II would require 10 to 15 man days [Ref. 17: p. 1873], performing a variety of tasks, including: base investigation composed of interviews of key personnel, record evaluation, current treatment works, cost of water procurement and treatment; the implementation of the Tier II model; and the decision as whether or not to proceed with a Tier III evaluation [Ref. 17: p. 1873].

The Tier II model is made up of four distinct sections that progress from one to the next. "The four sections of evaluation in their order of evaluation include: activities, spatial relationships, conceptual reuse systems, and economics." [Ref. 17: p. 1873] The activity section would include a listing of all activities that might be included in the reuse system; whereas, the spatial relationship section would consider each of those activities and their distance from each other and the source of the reclaimed water, with the purpose of eliminating the ones that are too far removed from the main system.

The most important part of the Tier II evaluation is the third section. "Conceptual reuse networks are laid out for eventual cost-comparison and treatment requirements are addressed, including the upgrading of existing facilities." [Ref. 17: p. 1874] These are then subjected to a cost analysis which is used for comparative purposes as to its "validity and potential for the installation concerned in terms of its water reclamation reuse potential." [Ref. 17: p. 1874]

This three-tiered approach provides a logical, systematic way to analyze the potential for water reuse.

> Important outputs of the model are the quantity and quality of the supply water required by each activity, quanity and quality of wastewater generated by each activity, treatment required, storage requirements, results of blending various wastewaters and/or fresh water, pipeline transport, and estimated system costs. [Ref. 17: p. 1874]

By combining these outputs in a comparative analysis, Army installations that require water for irrigation become "primary candidates for comprehensive water reuse and conservation analysis. These installations include those in areas of below average rainfall" [Ref. 17: p. 1875], or the installations with possible restrictions on fresh water flows due to drought or supply reductions.

The analysis indicates that "wastewater reuse and conservation can provide a cost savings over fresh water usage at locations with extensive irrigation or industrial demands, potential water supply programs or high discharge fees." [Ref. 17: p. 1875] The three-tiered approach provides a way to get a handle on the potential reuse capabilities of various installations.

7. Individual Unit Reuse

Heretofore, the emphasis has been on water reuse in base-wide terms; the used water from selected base activities is treated and reused in irrigation or industrial settings. This could be considered the macro-use concept of water reuse.

There is also a micro-use sense, in that water collected from individual units can be recycled through those units for uses that require non-potable water. This would require two different plumbing systems, one for potable, the other for the non-potable water. "During the 1976-77 drought [in California], a double water system of sorts was used by some water consumers in Marin County who disconnected their kitchen drainpipes and collected dishwashing water to water their plants or to flush their toilets." [Ref. 8: p. 36] This type of water, referred to as graywater[7] can be found being used today to water plants in many countries where the water supply is restricted, such as in Bermuda and in developing third world countries.

> A normal plumbing system takes the water from various outlets to a dirty water line and then, in the city, to the sewer or, in the country, to a septic line. Kitchen water used for rinsing a head of lettuce or washing dishes is not polluted in the same way as water that comes out of the toilet. Even shower water can be treated with a chemical and reused, at least for maybe a second shot through the toilet. So you have to think about doubling your plumbing lines. Take the water from the sink and shower

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[7] See appendix for definition.

drains and keep it in a collection tank. The toilet, as always, goes straight to the sewer. [Ref. 8: p. 37]

Graywater recycling provides one way to cut down potable water usage in areas where it is not really needed to accomplish the task at hand. It is not something, however, that can be used immediately since the health authorities are not convinced that it would be safe [Ref. 8: p. 36].

D. CISTERNS

A cistern is merely a basin of some sort for capturing rainfall on a local scale. All water used is, of course, captured rainwater. Whether our water is from a lake, a stream, or an artesian well,[8] it was all rainwater or snow once. The water that is used in homes is water that has been captured elsewhere, stored, treated for pollutants, and delivered.

The family cistern was commonplace in the Midwest and West before World War II and was usually a barrel placed under the downspout to catch the rainwater as it came off the roof [Ref. 8: p. 5]. "Cisterns were a standard feature of just about every California mining town (including San Francisco) and are a major part of the water system in the Caribbean, Korea, Japan, and the State of Israel." [Ref. 8: p. 5] A cistern can be anything from a simple barrel to a new 5,000 gallon redwood tank to a 2500 year old basin carved into soft rock in the Negev Desert [Ref. 8: p. 5].

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[8]See appendix for definition.

1. The 1975-1977 Drought

California was made painfully aware of the need for alternative sources of water by the 1975-1977 drought. After the drought, ways were sought "to augment a public water system that could not meet even normal demand during periods of low supply. Rainwater collection systems that can capture and store precipitation have been considered as [a] possible source of [an] alternative water supply." [Ref. 18: p. 1]

Studies, such as [Ref. 18], are providing data about usage, costs, and the viability of cistern programs in California, especially as consideration is given to the possibility of problems in the future.

> If population or water demand increases at a faster rate than increases in water supply, required reductions in the use of potable water for irrigation purposes can be foreseen. Even in normal rainfall years it may not be possible to meet the entire household demand from public sources and in dry years severe shortages may develop, as evidenced by the 1975-77 drought. . . . It is not inconceivable that all outside uses of water may someday come from delivered recycled water, thereby releasing limited potable supplies for more critical domestic uses. It is precisely this pattern of reasoning that leads to the consideration of rainwater collection systems as means of displacing public water supply in the home. [Ref. 18: p. 15]

2. Catchments

A rainwater collection system is quite basic. It could be built for a private residence and would require a

> surface which collects rainfall (catchment), channels it (gutters and downspouts), and stores it (tanks and cisterns). In addition, some form of pumping system [would] be necessary if water is not stored above the point of use and fed by gravity, or if it must be distributed to remote sites. If rainwater is used for human consumption, a filtration or purification system may be needed, which could range in complexity from a simple screen or sand filter to one of the modern chemical treatment systems. [Ref. 8: p. 7]

A catchment area can also be developed by using the natural contours of the land to funnel the water to where it is needed. This system was highly developed by the Incas of South America.

> The Inca Empire created a sophisticated catchment system underground to collect rainwater coming off the mountains, a system only just being rediscovered now. They terraced the hills to slow down the water flow, giving the water a chance to percolate into the underground drainage area, where it was gravity-fed to the fields. [Ref. 8: p. 7]

Another source of a catchment area are the surfaces that are constructed of impermeable materials, such as roofs and streets, that, if properly guttered, could capture rainfall. Roofs are ideal for small systems as explained in [Ref. 8: p. 8]. Also, patios and driveways could provide the surfaces needed to catch the rainwater and guide it to storage areas. Cisterns should be located as close as possible to the supply and demand points, to reduce costs of material as well as to reduce any pumping costs.

3. <u>Purification Stages</u>

Depending on the ultimate use of the water from the cistern, there are stages of purification that the water must pass through to be drinkable. Rainwater is basically clean, but "its interaction with environmental catchment surfaces limits its use as drinking or food crop irrigation water." [Ref. 8: p. 4] Roofs can be "polluted by bird droppings, decaying vegetable matter, air polution and in some cases, substances used in the construction of the roof itself, leachates like lead or tar." [Ref. 8: p. 9] The purification process applied to this captured water involves four sequential stages: screening, settling, filtering, and sterilizing [Ref. 8: p. 9].

The first stage is merely filtering out the larger particles and debris, i.e., leaves, feathers, rocks, branches, via increasingly finer guage screens. The filters must be cleaned occasionally. This is very often as far as many cistern systems go in preparing the rainwater for landscape irrigation use.

The second stage, settling, "removes the gross turbidity (cloudiness) of the water and aids in the reduction of bacteria." [Ref. 8: p. 9] Water should be allowed to sit in the cistern for a while before it is used so that any suspended particles can sink to the bottom.

Stage three, filtration, calls for "percolating the water through a filtering medium with the help of either gravity or pressure." [Ref. 8: p. 11] The filtering medium can be sand, a mixed collection of wood chips, stones, and sand, a ceramic, or a solar still type filter.

The fourth stage is disinfection or sterilization. "Water can be sterilized by boiling or disinfected by the addition of bactericidal chemicals such as chlorine or iodine." [Ref. 8: p. 11]

As the water purification level required becomes higher, the cost goes up accordingly. But the rainwater collected and purified at the lowest level would still be clean enough for toilet flushing and landscape irrigation. There are golf courses in Orange County and Monterey County that are currently being irrigated with treated sewage instead of potable water [Ref. 8: p. 11].

4. <u>The Volume of Water Collected</u>

Rainwater collection systems can be influenced by four specific factors that determine the particular system's effectiveness.

> The amount of rainfall and its annual distribution along with the volume demand and its annual distribution are the inputs and outputs of the system. The roof or collection

area determines the amount or volume of water that the system can provide. The storage volume will determine how much water is captured and how much water is lost to spillage. In any given area where the rainfall characteristics will be relatively constant, the comparative analysis of system performance can be reduced to the examination of the effects of varying collection area, storage volume and seasonal demand. [Ref. 18: p. 3]

The volume of water that can be collected from the roof is proportional to the surface area of the roof. A roof with twice the surface area of another will collect twice the water. Cistern capacity is a volume measurement, with the amount of water in the cistern determined by the amount of the surface area feeding into the cistern and the rainfall depth.

If for any general roof area a tank is provided whose volume is equal to the total volume of rain shed from the collecting area, 100% of that volume can be captured and stored. If the cistern volume is less than the runoff volume, losses to spillage will occur. Cistern size can then be described as being some percentage of the annual rainfall. Also, it should be noted that the maximum volume of runoff per year from any roof is equal to the depth of annual rainfall times the roof area. [Ref. 18: p. 3]

The design of a rainwater collection system is a function of the demand for water. Large enough collection areas and cisterns would need to be provided to meet part or all of the specified demand that occurs during the year.

The main factor behind the need for this analysis of the potential for stored rainwater is the reliability of the public supply of water. "Even an occasional failure to deliver adequate quantities of water can cause massive losses in landscape investment." [Ref. 18: p. 25] Collection systems can reduce "a customer's absolute dependence on municipal supply and in the event of partial water rationing, provide insurance for the landscape investment." [Ref. 18: p. 25]

Determining the proper size of the cistern to meet the predicted demand is

> largely a question of correctly anticipating future events. If a completely reliable public water supply is forecast, reduced levels of cistern rainwater use would be anticipated. If interruption in the water supply or any on-going rationing plan is foreseen, the applicability of rainwater collection is greatly enhanced. [Ref. 18: p. 27]

5. Cistern Collection Systems

There are two ways of approaching cistern use. They can be made a part of the individual dwelling and, thus, supply water only to that unit, much like the graywater systems discussed earlier. Or they can be built as community-wide installations, collecting rainwater from common areas and distributing it to benefit the community as a whole. In considering these larger scale institutional rainwater collection systems, the "primary objective is again to develop relationships between the collection area, tank size and system reliability" [Ref. 18: p. 30] so that the applicability of this approach to water conservation at the Presidio may be determined.

A pilot study was done in [Ref. 18] using Pacific Grove High School to examine the

> feasibility of collecting and storing rainwater runoff for irrigational uses. The basis of analysis was the same as that used in the residential study; the roof collection areas were assumed to be impervious, no significant evaporation occurs from the covered cistern, and the rainfall record established at Forest Lake is representative of the precipation pattern actually occuring at the pilot project site. Thus, all water falling on the collection areas is at least potentially usable for irrigation purposes. [Ref. 18: p. 30]

Extensive study of the possible contamination of rainwater runoff was conducted by the Monterey County Health Department, which showed that "rooftop runoff, whether from a shingle roof or a tar and gravel roof as found at Pacific

Grove High School would probably not require treatment for use as irrigation water." [Ref. 18: p. 31]

The school was evaluated to have a total roof area of 50,000 square feet [Ref. 18: p. 33], with a tar and gravel composition. The runoff would be gathered by diverting the downspouts into lateral collection pipes leading via gravity feed to two storage tanks of 50,000 and 300,000 gallon capacity. "The irrigation areas for Pacific Grove High School were determined to be about 400,000 square feet." [Ref. 18: p. 35]

Using available figures for the average annual rainfall, it was calculated that if 100 percent of the mean annual rainfall is collected and stored from the 50,000 square feet of collection area, then 539,495 gallons of rainwater can be stored annually [Ref. 18: p. 37]. Even this total amount of water would not go very far in irrigating the fields at the school.

> The total irrigation area for the Pacific Grove High School is about 400,000 square feet including the Boys' and Girls' Athletic Fields and the Football Field. Irrigation to a depth of 10 inches annually would require about 2,500,000 gallons. The largest feasible tank for the Pacific Grove High School would irrigate only 539,495/2,500,000 = 22 percent of the total area. Even the Boys' Athletic Field, at 182,000 square feet, would require 1,135,000 gallons annually. The largest feasible tank would irrigate about 44 percent of the field. The 50,000 gallon tank would irrigate 12 percent of the Boys' Athletic Field while the 300,000 gallon tank would irrigate 32 percent of the same area. Is is obvious that the proposed 50,000 square foot rainwater collection system can meet only part of the total irrigation demand at Pacific Grove High School. [Ref. 18: p. 45]

Even considering the restrictions as noted above, there exists the possibility of creative out-of-doors use of captured rainwater as Selfridge indicates in the conclusion of the study:

> municipal watering of landscape areas not equipped with irrigation systems might conceivably be done with rainwater collected off of [sic] government buildings and trucked to the use point. Construction site watering could also be done with collected rainwater. Tennis courts could be washed with stored rainwater.

Agricultural enterprise might use barn runoff to augment irrigation supplies. Golf courses, large users of public water for irrigation, could benefit from partial use of collected rainwater. Rainwater collection should also be attractive for commercial greenhouse use as larger runoff areas are available and near constant annual demand improves the system yield. [Ref. 18: p. 47]

E. FLOW REDUCTION METHODS

Table I shows that approximately 64 gallons of water are used per capita per day (gpcd) in residential buildings. Most of that water is used in the bathroom, with a typical home using about 40 percent for toilet flushing and 30 percent for showers or baths. Another 15 percent is used to do the laundry and 5 percent each for sink use, dishwasher and food preparation.

From these figures, it can be seen that efforts to improve the efficiency of water use within the home need to concentrate on the water used for the toilet, the shower and bath, and for appliances.

Use of more water-efficient plumbing fixtures, devices, and appliances is one of the most practical and effective ways to conserve water. The passive nature of water saving devices is one attractive characteristic; with a more efficient faucet, shower, or toilet the water user can be saving water without even thinking about it. [Ref. 19: p. 71]

1. Toilets

The largest water-using item in the house is the toilet. The conventional tank toilet requires five to six gallons per flush, with "quiet" models requiring as much as nine gallons per flush [Ref. 19: p. 73]. A recent study [Ref. 20: p. 5-3] has found that the "weighted average number of toilet flushings per person per day was 4.3" which accounts for the 25 gallons indicated in Table I.

There are many types of toilets available on the market including some exotic systems that use little or no water, such as oil flush, composting, incinerator, or vacuum types. These are often "not recognized in the codes due to their recent development and to uncertainities as potential health hazards." [Ref. 19: p. 74] They are also very expensive when compared to conventional systems.

For these reasons, the conventional systems are the most promising, especially the water saving tank trap known as the "shallow trap". This toilet uses about 3.5 gallons per flush resulting in an approximate 1.5 gallon per flush saving, or about 7.3 gallons per capita per day [Ref. 20: p.5-5]. This type of toilet has a smaller tank and a modified design for the bowl itself.

> The flushing rim and priming jet have been designed to start the siphonic action in a smaller diameter trapway with less water than conventional fixtures. The shallow trap means that less water is retained in the bowl, which in turn means there is less inertia for the siphonic action to overcome. . . . The cost of a shallow trap toilet is comparable to that of a conventional model. [Ref. 19: p. 73]

2. Showers and Faucets

The shower is also a prime contender for water use reduction.

> Conventional shower heads are usually used at water delivery rates of approximately 5 to 6 gallons per minute. Maximum flow rates sometimes exceed 12 gallons per minute. Several different types of low flow shower heads are available which reduce the maximum possible flow rate to between 0.5 and 4.5 gallons per minute, the average being approximately 2.5 gallons per minute. [Ref. 19: p. 71]

Most low flow shower heads incorporate both a flow restrictor and aerator to cut down water use. Some are equipped with a cutoff valve that allows the water to be shut off without affecting the hot/cold water mix while soaping [Ref. 19: p. 72]. The average shower duration is

4.6 minutes [Ref. 20: p. 5-6]. Therefore, the average water savings is approximately 12 gallons per person per day, or a more than 50 percent reduction in usage.

Using redesigned faucets can provide savings in water used, also. Conventional domestic faucets provide a "maximum discharge of 4 to 5 gallons per minute. Low flow faucets deliver a maximum flow of 0.5 to 2.5 gallons per minute depending on the flow control type and specific design." [Ref. 19: p. 72] This would reduce by up to a half the amount of water used in the categories of lavatory/sink and cullinary in Table I.

3. Appliances

Water use reduction is also possible in two major appliances that are heavy water users--the clothes washer and the dishwasher. Conventional full-sized clothes washers use between 40 and 50 gallons of water for a full washer load [Ref. 19: p. 74], and "most manufacturers now provide models that are designed with water savings in mind." [Ref. 19: p. 74] The study done in [Ref. 19] indicates that new water and energy conserving washing machines would save 4,400 gallons annually per household. That works out to about 3.2 gallons per capita per day savings.

Dishwashers are used at an average of once every other day [Ref. 20: p. 5-5]. Conventional machines use from 12 to 18 gallons per full cycle. Low water use machines use as low as 7 gallons per full cycle [Ref. 19: p. 74]. That difference works out to about 1 gallon per capita per day less with the low water use dishwasher.

4. Pressure Reducing Valves

The last internal method of reducing water use to be considered is the pressure reducing valve. Although [Ref. 19] presents this as a very real water-saver, [Ref. 20] has questions about the viability of this method.

> Results collected to date indicate that water pressure has much less of an influence on water than previously believed. Findings in Denver, Colorado, and Los Angles, California, indicate that a 38 to 40 psi reduction results in only 4 to 5 percent reduction in water use. . . . New subdivisions could be designed for lower water pressure, instead of the usual 80 psi, resulting in a 4 to 5 percent decrease in water consumption. [Ref. 20: p. 6-15]

If that figure were applied to the total per capita inside use of water from Table I, there would be an approximate savings of 3.2 gallons per capita per day.

5. Double Counting Problems

When measuring the savings from conservation efforts, there is some concern about double counting. The total savings cannot be just the sum of all the individual water conservation measures "because some of the practices affect consumer response in the same way." [Ref. 11: p. 93] This can be especially true when pressure reducing valves are used, since

> the pressure reducer and the faucet or shower device save water by reducing the flow rate; thus the savings they produce in combination is somewhat less than the sum of their individual savings. Precise measurements of the combined effect of these devices do not exist in a generally applicable form. [Ref. 19: p. 87]

F. METERING

The installation of "water meters is designed to sensitize customers to water use and water price." [Ref. 19: p. 29] This particular method is examined here to identify that in the civilian community, the moving from a flat-rate to a usage rate causes the amount of water consumed to decrease.

Flack, in [Ref. 11: p. 89], indicates that "metering should reduce usage somewhat," mostly in terms of irrigation. The study done in the Denver, Colorado, area in [Ref. 20: p. 1-2], indicates that "metered households used

15 percent less water than unmetered households." This figure is somewhat less than Flack, [Ref. 11: p. 89], who found a reduction of 21 percent in total demand. When applied to the total of 189 gallons per capita per day found in Table I, between 28 and 40 gallons per capita per day could be saved. Of course, this might be a moot point in a military community since utilities are not paid for by the individual user. However, it could be an "effective consciousness-raising measure which [could] enhance [the] effectiveness of other flow reduction measures." [Ref. 19: p. 30]

G. DROUGHT-RESISTANT VEGETATION

As noted in Table I, 66 percent of the water used each day is used outside the home, for yard and plant irrigation, car washing, etc. Anything that would reduce that consumption could have a significant impact on the total amount of water used. Water reuse and cistern installation have already been suggested as possible ways of reducing the quanity of fresh water used outside the home. One device considered above, the pressure reducing valve, could also have an impact on the amount of water demanded.

One other way that would decrease the amount of water needed would be to use drought-resistant plants. These are plants and trees that are able to take long periods without much water. The ultimate example would be the desert cactus that might have to store water within itself for months between rainfalls.

There are three types of drought-tolerant plants identified in [Ref. 21: pp. 2-4]. The first includes most landscape plants. They are called "water spenders." They have "extensive root systems and as long as some of their roots are in moist soil they can survive drought; but they still

use relatively large amounts of water. Examples are eucalyptus and black walnut trees." [Ref. 21: p. 3]

A second type, "drought-evaders", become "virtually dormant during dry periods. Examples are California buckeye and bermudagrass." [Ref. 21: p. 3] The third type are called "water conservers" and they have ways to reduce water loss.

> Their leaves may be small, gray-colored, leathery, and arranged to reduce the amount of sunlight that strikes them or structured in other ways to save water. Many California native plants and plants from similar climates are of this type. Examples are ceanothus, manzanita, and olive. [Ref. 21: p. 2]

The "drought evaders" and the "water conservers", under normal circumstances, use somewhat less water that other plants. When in a drought, they can survive on far less [Ref. 21: p. 2].

H. PUBLIC EDUCATION

The preceeding sections have all dealt with structural methods of reducing water use. The one socio-political method referred to in the introduction is that of public education, the raising of the issue of water conservation in the public forum.

In order for these programs mentioned above to work, the public must be informed about the overall problem of water use and then be educated about ways they can help in program implementation; it is especially necessary to "achieve habit changes." [Ref. 19: p. 31] A small amount of conservation effort can often result in significant savings. "By modifying ordinary behavior, large volumes of water can be conserved. . . . Examples include not letting the water run while brushing one's teeth or while shaving; turning off the shower while lathering up." [Ref. 13: p. 403]

There are four general categories of a public information campaign found in [Ref. 19: p. 35]. First is direct mailing of information packets to the consumers. Second is news media coverage of the general problem of water conservation and of the specific projects being done so that support will be generated for those projects. Third, personal contact, includes public meetings and guest speakers at local clubs and schools. And fourth, special events and/or exhibits, i.e., displays at central areas or schools, could be planned.

Education via these approaches can

> produce a conservation consciousness as a continuing means of demand reduction. . . . Emergency programs developed in many communities in California during the 1976-7 drought are no longer in effect, but have given way to an ongoing conservation program. Education to be most effective, should be geared to the elementary and secondary school level--it is apparently much less effective for long-term benefits at the adult level. [Ref. 22: p. 232]

Expected water savings from public education is difficult to determine, although [Ref. 19: p. 31] indicates that "estimated water savings of 5 to 10 percent" may be achieved. In the final analysis however, it is hard to differentiate the effects that education and information would have from the other methods of water conservation.

I. SUMMARY

This chapter has been a review of six techniques of water conservation--reclamation and reuse, rainwater capture, flow reduction devices, metering, drought-resistant vegetation, and public education. These were evaluated on the basis of the amount of water that each could conserve as well as the specific way to apply each technique. This chapter lays the foundation for the consideration of each technique for the Presidio of Monterey in the next chapter.

III. SPECIFIC CONSERVATION TECHNIQUES

A. INTRODUCTION

This chapter addresses the hypotheses stated in Chapter One. The water usage for the military installations on the Monterey Peninsula is compared to that of the civilian community to determine the accuracy of Hypothesis One. Before the second hypothesis is examined, the water costs, projected to the completion date of the barracks at the Presidio of Monterey in 1985, are determined. It is this cost that is used for cost/benefit analysis later in the chapter.

The impact on water conservation of sewage being billed to the Presidio of Monterey at a fixed monthly fee is also examined. The Presidio of Monterey's current level of conservation is outlined as well as the current baseline water usage.

An examination of the conservation methods proposed in Chapter Two is made and applied to the specific situation of the Presidio of Monterey. In this way, Hypothesis Two is evaluated.

Finally, this chapter concludes with a description of how the results of the research could be applied by other DOD installations.

B. WATER CONSUMPTION IN MONTEREY COUNTY

Hypothesis One was: "water conservation on military installations is proportionally higher than consumption in civilian communities." Table II shows the data collected from the military installations in the Monterey area and compares it to the total consumption in Monterey County and to Table I.

TABLE II

Water Use Comparison in Gallons per Capita per Day

Location	FY-1981	FY-1982	FY-1983	Source
Ft. Ord		155		MPWMD
Presidio	82	72	89	Brown & Caldwell
La Mesa	131	118	87	PWD, NPS
Urban Monterey County		159		MPWMD
Table I (no year):		In House	64	
		Outside	125	
		Total	189	

Table I in Chapter Two was based on data obtained in a study of Denver, Colorado [Ref. 11]. In comparing those water usage amounts to the ones obtained on the Monterey Peninsula, there is a significant difference. All of the Monterey usages in gallons per capita per day (gpcd) are at least 30 gpcd less than the Denver amounts. The La Mesa housing area usage is 81 gpcd less and the Presidio's usage is 117 gpcd less, using the data for 1982.

Several factors may account for this significant spread. One is that there is a difference in annual rainfall between Denver and Monterey. The average annual rainfall in Denver is 14.6 inches [Ref. 23], whereas, the average rainfall in Monterey is between 16 and 20 inches annually [Ref. 8: pp. 18-19]. The heavier precipitation on the Monterey Peninsula means that less water is needed for outside use, and so less water is consumed per capita. A thirty gallon per capita per day difference would not be unlikely considering not only the rainfall differential but also the cooler climate and water-carrying fog that Monterey has during its spring

and early summer. Water use amounts per capita vary considerably, from a low of about 20 gpcd to 190 gpcd, as indicated in the literature review in [Ref. 12: p. 210], who considers 13 sources. So, a variation of thirty gpcd is certainly within the range of water usage from studies throughout the United States.

The low consumption figure for the La Mesa housing area could be explained by reference to the transient nature of the occupants who are not in residence long enough to develop extensive water-using gardens. Also, there are no large grassy, park-like common areas that require watering. The only outside watering done is around each home as the occupant feels so inclined.

The Presidio of Monterey has the lowest per capita usage of the four areas investigated for 1982. Several reasons could exist for this low amount. One is that there are only 93 family housing units on post, with most of the 2,900 residents living in barracks. Personnel who live in barracks do not water yards nor use water as freely for food preparation, dish washing, or baths, since showers use less water and are the normal mode of bathing in barracks.

The toilets used in barracks and classrooms are of the efficient flush valve type that use only 3 to 4 gallons of water per flush, compared to 5 to 6 gallons with a conventional tank toilet [Ref. 19: p. 73]. Laundry water use may also be lower since it can be done off post and uniforms are usually done at a commercial laundry. Also, there are no large common areas, such as golf courses, that would require large amounts of water. Although the water usage is low at the Presidio of Monterey, there are mitigating factors that could account for the difference.

Considering the above data, Hypothesis One, that "water consumption on military installations is proportionally higher that consumption in civilian communities," must be

rejected, since in all three military installations examined for water usage, each one was below the daily per capita rate for urban Monterey County. Although this was a small sample, it was composed of all three major military installations on the Monterey Peninsula and it was compared to the usage for urban Monterey County.

Since the study concerns the Presidio of Monterey and the possibility of water conservation on that facility, the use of military installations in the Monterey area only allows a comparison within that locale. Therefore, for the Monterey area and the military installations on the Peninsula, Hypothesis One must be rejected.

However, in terms of all military installations and the per capita water use, the data collected for this study is too small a sample to generalize from and Hypothesis One, nationwide, can be neither accepted nor rejected. It is perhaps possible that with a larger sample over wider and more varied geographic locales, the results could prove different. Further study in this area is warranted.

C. PROJECTED WATER COSTS AT THE PRESIDIO OF MONTEREY

Even though hypothesis one must be rejected, the need to conserve is still present, since the cost of water is increasing. Records maintained by the Naval Postgraduate School show that water costs have gone from $0.27 per 100 cubic feet in 1975 to $1.09 per 100 cubic feet in January, 1983, a four-fold increase in eight years, and costs continue to grow.

Hypothesis Two was: "Conservation techniques can be implemented which will result in significant cost savings for the United States government through decreased water consumption." The price increases experienced in the Monterey area lead to the evaluation of this second

hypothesis. The specific techniques of water conservation will be developed after an exploration of the cost and population projections for the Presidio and the presentation of a baseline water use amount.

Water costs at the Presidio of Monterey were shown to average $0.766 per 100 cubic feet in 1981, $0.864 per 100 cubic feet in 1982, and $1.146 per 100 cubic feet in 1983 [Ref. 24]. This amounts to a 149 percent increase in two and one half years. The water usage for the Naval Postgraduate School and the Presidio of Monterey are somewhat different due to the rate charts used by the California-American Water Company (Cal-Am), the only metered water provider on the Peninsula. Cal-Am has three zones that determine water price. The higher in elevation the consumer is, the more he must pay for water, due to pumping costs to reach that elevation. The differential of about $0.05 between the Presidio and La Mesa unit cost of water is due to the Presidio being higher in elevation than La Mesa.

Cal-Am has forecast its proposed rates to 1 January 1985, shown in table III.

TABLE III

Projected Rate Increases of Cal-Am Water Company

Base Rate, 1983	$1.154 per 100 cubic feet
Increase, 1 Jan 1984	0.045 per 100 cubic feet
Increase, 1 Jan 1985	0.027 per 100 cubic feet
Two year increase	$0.072 per 100 cubic feet
Total on 1 Jan 1985	$1.226 per 100 cubic feet

[Ref. 28]

A report prepared for the U. S. Army Corps of Engineers concerning the proposed facilities construction at the Presidio of Monterey projects the population in 1985 to be 4,100 effective and 6,200 design [Ref. 25 :p. 2-9]. The effective population is determined by adding together the resident population (actual numbers living on the post) and one third of the nonresident population (commuters). The resident population is forecast to be 3,600 by 1985, a growth of 1,300 from the 2,300 resident population in 1982, due to the construction of new barracks. The nonresident population in projected to be 1,400 by 1985, less than the 1982 figure of 1,900 due to personnel moving on post as housing becomes available.

> The design population is defined as the effective base population multiplied by a capacity factor that is dependent on the size of the effective population. For an effective population of less than 5,000 people, as is the case with the Presidio, the capacity factor is 1.5, which will account for unforeseen increases in activity demands. [Ref. 25: p. 2-8]

This means that the design population is 4,100 X 1.5, or 6,200.

The projected water use and cost can be computed using either the effective population or the design population. The more useful figure would be the effective population, since that is what the best estimates predict the population to actually be in 1985. The design population is a useful engineering concept, in that it provides the maximum population that the system should be designed to handle.

There are also two different rates of consumption that can be used. First, the historic three-year average for the Presidio can be used, which is 80 gallons per capita per day (gpcd). Second, the "Department of the Army requires that water distribution systems be developed in conformity with design criteria," [Ref. 25: p. 3-20] found in technical manuals. One manual, TM5-813-1, <u>Water Supply, General</u>

Considerations, states that "water systems shall provide for a domestic demand based on an average daily per capita consumption of 150 gpcd for the design population." [Ref. 25: p. 3-22]

Using the historic average water use of 80 gpcd for both the effective and design populations, and a conversion factor of 748.4 to convert gallons to units of 100 cubic feet, the following quantities are derived:

Effective population: 4,100 @ 80 gpcd = 328,000 gpd
328,000 gpd / 748.4 =
438.3 units of 100 cubic feet each per day

Design population: 6,200 @ 80 gpcd = 496,000 gpd
496,000 gpd / 748.4 =
662.7 units of 100 cubic feet each per day

Using the Department of the Army water usage amount of 150 gpcd for the same populations results in the following:

Effective population: 4,100 @ 150 gpcd = 615,000 gpd
615,000 gpd / 748.4 =
821.75 units of 100 cubic feet each per day

Design population: 6,200 @ 150 gpcd = 930,000 gpd
930,000 gpd / 748.4 =
1,242.65 units of 100 cubic feet each per day

To project costs, the lowest and the highest use figures provide a range, with the most likely amount occuring near the low middle, since there are no factors to suggest that the addition of more people will cause the per capita consumption to double in just two years. It is likely that

in the near-term (two to three years) the water usage will approximate the historic usage, since the new plumbing to be installed will not have the leak problems that the older pipes have been experiencing. [Ref. 25: p. 3-2] Leaks would, of course, drive up the usage quantities as water is lost into the ground.

The range for the cost is:

Low: 438.3 cubic feet per day X $1.226 = $537.3 per day
This is $196,120 per year.

High: 1,242.65 cubic feet per day X $1.226 = $1,523 per day
This is $556,100 per year.

These two computed yearly costs compare to the 1982 cost of water at the Presidio of Monterey of $72,700. That is an increase of from $123,420 to $483,400 per year, which equates to an increase of from 269 percent to 765 percent in water cost in two years. Even if the lower estimate proves more accuate, an increase of that magnitude implies that there is a need for water conservation at the Presidio of Monterey.

D. SEWAGE

Sewage cost, until March 1983, was tied to the amount of water that was demanded from Cal-Am by the Presidio of Monterey. The assumption by the billing authority was that all water that came in must go out via the sewer; an assumption that was not necessarily accurate since some water never made it into the sewer, i.e., that used to water the yard. But it did allow for a costing formula based on a known amount, water that was put into the system, since sewage is hard to meter.

As of March 1983, the contract covering sewage was renegotiated, retroactive to 1 September 1981, to institute a flat fee for sewage billing. This flat fee is $152,040 per year or $12,670 per month. The sewage is treated at the Monterey Sewage Treatment Plant, located north of Highway 1 near the Naval Postgraduate School. There is an additional flat fee of $3,170 per month to the City of Monterey for the transportation of the sewage to the treatment plant. Sewage costs are, thus, $15,840 per month, or $190,080 per year, compared to the total sewage cost for FY 1982 of $53,802. The FY 1982 total sewage cost will be adjusted upward since the contract is retroactive to 1 September 1981 [Ref. 24].

Since sewage cost is now based on a flat fee, conservation techniques that would reduce inflows of potable water would have no impact on the cost of sewage to the Presidio of Monterey. Thus, the savings that could be realized by reductions in sewage amounts will not be included in this analysis. It is realized that a major impact could be made by considering the amount of sewage cost reduction that is possible by the conservation techniques outlined earlier.

E. CURRENT LEVEL OF CONSERVATION AT THE PRESIDIO OF MONTEREY

Chapter Two presented six techniques that could be employed to reduce water consumption at the Presidio of Monterey. These were graywater reuse, rainwater capture, flow reduction methods, water metering, use of drought-resistant plants, and public education. Currently, there is no reuse or cisterns employed at the Presidio. There are some flow reduction devices in place, such as flush valve toilets. Metering of individual residential units does not take place. Much of the vegetation is indigenous and may or may not be of the drought-resistant varieties. Public education about water consumption is sporadic.

This current situation provides many opportunities for the implementation of water conservation techniques at the Presidio of Monterey.

F. BASELINE WATER USE FOR THE PRESIDIO OF MONTEREY

Before considering the conservation methods presented in Chapter Two, it is important to outline the data which was used for the cost analysis. Table I presents a baseline water use analysis of Denver, Colorado. These amounts were compared with other studies [Ref. 12] and they were very similar, especially for the inside water use data. The outside usage was much more difficult to determine. In [Ref. 6: p. 776], Milne states that "there are tremendous variations in the value for outdoor use reported in the literature." For this analysis, Table IV showing the water use breakdowns for the Presidio of Monterey was used.

TABLE IV

Baseline Water Use for the Presidio

Function	Gallons per Capita per Day: Presidio	Gallons per Capita per Day: Table I
In-House Use		
Toilet	17	25
Shower	16	20
Lavatory/Sink	3	3
Laundry	8	10
Dishwasher	3	3
Cullinary	3	3
Total In-House	50	64
Outside Usage	30	125
Total Usage	80	189

The inside usage is based on the following: toilets are flushed an average of 4.3 times per person per day [Ref. 20: p. 5-3], with the flush-valve toilet using about 4 gallons per flush; showers run an average of 4.6 minutes per person per day at approximately 3.4 gpm, [Ref. 20: p. 5-4], lavatory/sink usage stays at the same 3 gpcd, as do the dishwasher and cullinary usage of 3 gpcd each, since these functions are either done by the individual or on his or her behalf in the mess hall, etc.; and the laundry figure would be about 8 gpcd, rather than 10 gpcd, to reflect the use of off-post laundromats and the use of dry cleaning shops for uniform cleaning.

The 30 gpcd for outside use is determined as the difference between the total average used of 80 gpcd, which is known, and the projected inside amount of 50 gpcd. Some water is obviously used outside, but as indicated earlier it does not equal the total in Table I for many reasons.

These modified quantities that apply specifically to the Presidio of Monterey are used in the cost analysis sections which follow.

G. CONSERVATION MEASURES ON THE PRESIDIO OF MONTEREY

There are two ways to improve water use at the Presidio of Monterey, either decrease consumption and/or lower cost. There can be either an improvement in supply or a reduction in consumption. Hypothesis Two will be evaluated on the basis of these conservation techniques.

1. Supply Improvement

Reuse can improve the supply of water by providing graywater where before potable water was necessary. This would, in effect, decrease demand for potable water and increase the amount available to other users.

Cistern-provided captured rainwater would accomplish the same goal by using rainwater to decrease the demand for potable water. For either or both of these to be effective, up-front costs for construction of piping systems and holding facilities would be necessary. There would also need to be an analysis of current health regulations with the view toward changing or adapting them to allow for reuse or cisterns. Modified public attitudes via education would be needed to gain acceptance for the use of non-potable water. Either of these sources of water would best be used for irrigation or fire protection first, with the possibility of providing water for flushing at some time in the future.

a. Water Reuse

Water reuse, as discussed in Chapter Two, is a viable way to decrease potable water usage and is currently used successfully in Tokyo [Ref. 26]. The major benefit comes from decreased demand for potable water. It would be possible to route shower and laundry water into a holding tank after initial filtering of pollutants. Table IV indicates shower usage of 16 gpcd and laundry usage of 8 gpcd, which combined yields 24 gpcd for reuse. From the holding tank, the graywater could be used for outside purposes such as irrigation or car washing. No matter what the graywater would be used for, the potable water consumption would be decreased by the total amount recycled, or by 24 gpcd.

The new construction of barracks at the Presidio will add 1,232 new residents to the post. This population figure is based on a 528-person barracks being constructed in 1983 and a 704-person barracks to be built in 1984 [Ref. 25: pp. 2-5,6]. Therefore, the total daily saving by 1985 by using recycled water would be 24 gallons per day times 1,232 people, or 29,568 gallons. That equates to

10,792,320 gallons per year or 14,420,500 cubic feet. At $1.226 per 100 cubic feet, that would be a yearly savings of almost $17,700.

The total cost of water for the additional personnel in the new barracks amounts to $58,900 per year, which is 1,232 people at 80 gpcd for 365 days at $1.226 per 100 cubic feet. The savings generated from reuse is, therefore, 30 per cent of the total water cost for the added personnel.

If sewage were included, there would be a reduction in the flow of sewage of 24 gpcd, which over a year would also contribute to the savings generated. However, the flat fee for sewage disallows a savings in this way.

The costs of constructing the reuse system are more difficult to determine, since detailed engineering studies are needed to set the parameters of treatment and define the physical components of the system. Nevertheless, rough estimates can be determined to aid in the analysis.

Dr. Asano, in [Ref. 26], discusses the various reuse techniques currently being used in Tokyo. One of the areas studied is an apartment complex with 888 rental units, recycling 160 cubic meters per day, or about 42,000 gallons per day. The barracks at the Presidio of Monterey will generate about 30,000 gallons per day, based on 1,232 people at 24 gpcd. Although the Japanese system is somewhat larger, the two outputs are close enough to each other to allow a general comparison.

The costs used for the Japanese construction were in 1978 dollars and included treatment, indoor and outdoor dual piping systems, and a storage tank and pump system for delivery of the reclaimed water. Table V shows the costs for each of these individual systems and the total cost of the project.

TABLE V

Reuse Facility Costs--Japan

System	Cost
Wastewater reclamation	$403,624
Indoor piping and facilities	83,534
Outdoor piping and facilities	174,038
Reclaimed water tank and facilities	114,162
Total in 1978 dollars	$775,358
Converted to 1983 dollars	$1,031,700

[Ref. 26: p. 172]

The data for conversion to 1983 dollars is from the Materials and Components for Construction of the Producers Price Index. The ratio to be applied to convert 1978 dollars to 1983 dollars is 1.33 (298.6 divided by 224.4) [Ref. 29: p. 43] and [Ref. 31: p. 4]. This ratio multiplied times the 1978 dollar total cost results in the converted total in 1983 dollars.

This total is only a very gross approximation, since construction cost differentials between the two countries are not considered, the types of filtering/treatment can be altered, and the amount of water to be treated is different. The attempt is to consider the general approach and the approximate added costs needed to allow the savings in potable water cost and consumption.

One way of evaluating projects such as this is by the payback period, the length of time it takes for the cash savings to equal the amount paid out to generate those savings. In this example, it would take approximately 58 years for the savings stream of $17,700 per year to equal

the cost of $1,031,700. If construction costs could be cut by 50 per cent, it would take 29 years to payback the initial cost.

The payback period is not a very sophisticated technique since it does not consider the time value of money. Another technique that has more theoretical justification is the present value approach in which the stream of savings is discounted to arrive at the present value of that flow over the useful life of the system. The problem, of course, is to determine the discount rate and the length of time over which to apply the discount.

Army Regulation (AR) 11-28 states that the

> discount rate specified by OSD [Office of the Secretary of Defense] is 10 percent. AR 11-28 also notes that decisions concerning water resource projects under the jurisdiction of the Corps of Engineers are specifically exempted from the requirement to use discounting. [Ref. 27: p. 2-13]

There is also a discussion in [Ref. 27] about the economic life of equipment, pipelines, and structures for water reuse. The length of time used was 35 years. Even though AR 11-28 exempts water resource projects from discounting, it is a useful tool when considering the cost and benefits of a particular project and it will be used in this study for comparison purposes. In this case, if $17,700 is discounted at ten percent for 35 years, the factor used is 9.6442, and the result is $171,000, or $17,700 times 9.6442. If the reuse system can be built for $171,000 or less, it would be economically feasible, since that is the value of the flow of savings over 35 years.

There are, however, factors other than economics to be considered. As the price of water increases, the savings generated by a reuse system also increases, making both the payback and discounted present value more attractive. Scenarios can be constructed where cost would become

a secondary concern and availability would become primary. Another drought where water is not available to be bought at any price would be such a scenario.

The technology and experience exist to make water reuse a viable system. Even though it does not appear to be economically feasible at this time, increased water costs and heightened environmental considerations combine to make the future of reclaimed water look bright. An argument in favor of acting now would be that the costs would increase for retrofitting a reuse system to already constructed buildings. If it is at all a possibility, it should be considered during new construction.

b. Rainwater Capture

A second major area covered in Chapter Two was the use of cisterns to capture rainwater for future use. The amount collected depends on the surface area dedicated to capturing the rainwater. In order to estimate a range, two analyses were made, the most likely, using the runoff from the new construction, and the most ambitious, creating a catchment to capture a significant portion of the outside water needed at the Presidio of Monterey.

The new barracks to be constructed will have a total roof area of about 40,000 square feet, as shown in the plans of the new construction. If 17.5 inches of rain is the average rainfall per year, [Ref. 18: p. 11] then approximately 58,400 cubic feet of water could be collected each year, or 436,300 gallons. Earlier it was estimated that 30 gpcd is used for outside irrigation. If the effective population of 4,100 is used, then 44.89 million gallons per year would be required for irrigation and other outside purposes.

It is obvious that all the water from the roofs could be used for irrigation. It would, in effect, be used in place of potable water supplied by the

California-American Water Company. The savings would, then, be figured in the same way as it was for the reuse option, multiplying the saved water by the cost. The result is 584 units of 100 cubic feet each times the rate of $1.226 per 100 cubic feet, or $716 per year.

A study referred to in Chapter Two [Ref. 18], discussed the amount of water gathered from the roof of Pacific Grove High School as a pilot project for institutional rainwater collection. The water thus collected was of a good quality, not needing treatment except to filter out leaves and debris. However, the captured water was not of good enough quality to use indoors without secondary treatment, so it was decided to use it only for irrigation purposes. The costs would be kept low since only piping from the roof, the storage, pumping, and distribution facilities would be needed.

The Pacific Grove High School study was for a roof area of 50,000 square feet, so the data are close to that generated for the Presidio of Monterey. The study states that the

> total installed rainwater system costs include the cost of an installed tank plus the capital expenditures required to convey the runoff water to the storage tank and the costs of a distribution system. For the proposed pilot project, these capital costs have been estimated at $10,000 at 1980 cost levels. [Ref. 18: p. 40]

Taking into account the price index change for construction costs from 1980 to 1983, the current cost would be approximately $11,000. The index for converting 1980 dollars to 1983 dollars is 1.11, which is 298.6 divided by 268.3 [Ref. 30: p. 2] and [Ref. 31: p. 4]. This ratio multiplied times the 1980 dollar cost of 10,000 yields the approximate 1983 cost of 11,000.

Applying a discount factor to the savings of $716 per year, at 10 percent for 35 years, results in a total present value of $6,905. Compared to the anticipated cost of the system of $11,000, this option, while not acceptable from a strictly economic stance, nevertheless, shows promise.

A sensitivity analysis indicates that this alternative would be viable economically when the cost of water is greater than $1.95 per 100 cubic feet. This was determined as follows:

$$9.6442 \times 584 \times X = \$11,000$$

$$X = \$1.95$$

This would be an increase of 160 percent over the 1985 cost of $1.226 per 100 cubic feet. With the rate of water cost increases, this option could be economically viable in a few years.

A second alternative would be to construct a catchment area toward the peak of the Presidio hill. This hill has an elevation of 775 feet and rainwater runoff flows into four drainage sub-basins. Capturing water at this elevation would provide more than adequate gravity-feed pressure for such uses as fire fighting and irrigation. Currently, water must be pumped to that hill and then there is only enough for local use on the post. If adequate storage could be provided and large enough catchment areas constructed, energy could be saved by not pumping water to the peak. Also, this large quantity of water would be available for use by the fire departments in surrounding districts. There would be an obvious good-will benefit from this arrangement as well as tangible benefits from the savings in not buying potable water for irrigation.

The cost question for this alternative revolves around the optimal size of the catchment area and storage facilities. Above, it was calculated that 40,000 square feet of catchment area yields about 431,600 gallons. In [Ref. 18: p. 3] it was stated that "the roof or collection area determines the amount or volume of water that the system can provide." Also, it was determined that the effective population of 4,100 used approximately 44.9 million gallons of water per year on external applications. Therefore, a 4,000,000 square foot catchment would provide approximately 42.2 million gallons per year, enough to cover most of the amount needed for the effective population of 4,100 people. A land area of 100 acres would result in 4,356,000 square feet of catchemnt area.

Since the top of the hill area at the Presidio is about 140 acres, almost 75 percent of it would need to be converted to a catchemnt, by covering the 100 acres with a nonporous material and channeling the water to storage areas in tanks or ponds. Between 10 and 20 million gallons of storage would probably provide an adequate amount, considering it would be used throughout the year [Ref. 8: p. 16]. This would also provide an adequate buffer for fire emergencies, since [Ref. 25: p. 3-26] has determined that the total storage required for the Presidio to meet demands for fire fighting plus 50 percent of the normal demand for the rest of the base is 1,100,000 gallons.

The cost savings of this approach would amount to the 30 gpcd for 4,100 people, the outdoor water use, that would not have to be provided by potable water. This would amount to $71,550 per year, at 1985 water prices. If this were also assumed to be a capital project that would have a useful life of 35 years and a discount factor of 10 percent, then the total current outlay that could economically be spent for this stream of future savings would be $690,000. That total amount comes from 9.6442 times $71,550.

Therefore, if the catchment and tank construction, piping, pumps, and other pieces of machinery could be acquired for approximately $700,000, this project would be cost beneficial. It would prove cheaper if lakes or ponds could be developed that would act as storage areas or if reservoirs, such as the David Avenue reservoir, which Cal-Am has declared nonpotable, could be used. As the price of water increases due to growing scarcity, this option becomes increasingly attractive.

2. Consumption Reduction

This section deals with ways to conserve water that are built-in at the time of construction, except for the last method, public education, that by its very nature would be targeted toward the whole post population. Since the other ways are not retrofits to the rest of the post housing and barracks areas, the savings will be generated only from the new construction and from the personnel who will occupy those barracks, the 1,232 added personnel.

The new barracks population of 1,232, consuming water at the three year average of 80 gpcd, would yield a total consumption of 98,560 gallons per day or 35.9 million gallons per year. That amounts to 48,070 units of 100 cubic feet each at $1.226 in 1985 costs, or $58,930 per year increased potable water costs due to the new construction.

The methods discussed in Chapter Two are considered in the next section for the approximate cost savings they would generate.

a. Applied Conservation Techniques

Four major approaches to reducing the flow of water through a house were considered. The strength of these methods lies in their passive nature. Whereas with the reuse and rainwater capture methods, there are specific

actions needed such as altered construction procedures and health authority approval, flow reduction methods are put in place during construction and can be forgotten. They go on saving water and are really not considered again once the decision is made to install them.

One of the largest users of water in the typical home is the toilet. However, there is no projected savings of water at the Presidio since military barracks already use one of the more water-efficient toilets, the flush valve, which uses 3 to 4 gallons per flush [Ref. 19: p. 73]. If current water usage were based on a tank toilet using 5 or 6 gallons per flush, then a savings could be considered, by adding a more water efficient toilet.

A second technique considered in Chapter Two was the reduction of flow from showers and faucets. Installation of flow reducers in showers and faucets has been shown to lower use by about 50 percent, especially if a cutoff valve is installed in the shower to shutoff the water without affecting the hot/cold mix. If this 50 percent reduction is applied against the shower and lavatory/sink usage of 16 gpcd and 3 gpcd, respectively, the result is 8 gpcd and 1.5 gpcd, respectively.

The appliance reduction section of Chapter Two does not apply to the particular construction under consideration at the Presidio of Monterey since barracks do not have as many appliances as individual dwellings would. Several washing machines might be installed in each building, but not enough to make a difference, although the post laundry or laundromat will continue to consume water. Also, most new clothes washers are water and energy efficient so no new savings would be available. Future construction of laundromats should evaluate the type of washer being installed.

Pressure reduction valves could also be used to lower water consumption. The actual amount of savings would be difficult to determine since both the pressure reduction valve and the flow reducers produce savings in the same way, by reducing the flow rate. Studies referred to in Chapter Two indicated a savings of 4 to 5 percent using a valve that would reduce pressure from 80 psi to 40 psi. If this figure were applied to the overall inside water usage of 50 gpcd, a savings of 2 to 2.5 gpcd would result.

Chapter Two considered the impact of metering the water usage. When metering is used and units are billed on the basis of the amount of water that they use, less water is usually consumed [Ref. 11: p. 89]. While metering of military housing would provide useful data, there would not be much incentive to conserve since the bill is not paid by the occupant. There would also be a problem in metering barracks, since two people share a room and the bath is shared by two to four rooms. Metering is not really possible in this situation.

Drought-resistant plants were also considered as a way of conserving water. The main reason for use of these plants is not so much during the time of normal nondrought water usage as at the times of drought when water can not be spared for plants. Landscape planning should take this into account. Indeed, in [Ref. 25: p. 3-22] Brown and Caldwell recommend this for the Presidio of Monterey: "it is proposed that drought-resistant plant materials be used for landscaping, and that minimal irrigation will be required following initial establishment of the plant materials." Current impact on lessening water use is considered to be negligible.

Lastly, public education was considered in Chapter Two. Raising the public awareness of the need for water conservation would require an extensive campaign, but

it could generate significant savings. Studies have shown a savings of 5 to 10 percent [Ref. 19: P. 31]. In the case of the Presidio of Monterey, the public education would be aimed at the whole post, but the specific impact on the new construction would be to lessen the per capita demand for potable water by anywhere from 2.5 gpcd to 5 gpcd.

b. Total Savings via Conservation Techniques

Application of the above analysis to the water usage amounts in Table IV results in Table VI, assuming that all of the above techniques are used.

TABLE VI

Applied Conservation Techniques

Water Use	Before (gpcd)	After (gpcd)
Toilet	17	17
Shower/faucet	16	8
Lavatory/sink	3	1.5
Laundry	8	8
Dishwashing	3	3
Cullinary	3	3
Total	50	40.5
Less: Pressure reducing valve		2.0
Public Education		4.0
Total: possible reduction to		34.5
Add: outside use	30	30
Total	80	64.5

Applying the total of 80 gpcd from Table VI to the population of 1,232 at $1.226 per 100 cubic feet, the before yearly potable water total is $58,930. Likewise, applying the total of 64.5 gpcd from Table VI to the population of 1,232 yields the after yearly potable water total is $38,755. The total yearly savings is $20,175.

The outlay to generate this savings is minimal. Shower heads and faucets must be purchased anyway and flow-reduction types are no more expensive than the high usage heads. Adding pressure reducing valves would cost between $30 and $50 per valve [Ref. 19: p. 74]. A public education campaign could be expensive, depending on how extensive the campaign would be.

Using the same discount factor of 10 percent for 35 years, the present value of the stream of savings of $20,175 per year amounts to $194,570. It is hardly likely that the pressure reducing valves and public education would cost more than that. This alternative, therefore, is highly favorable as it generates savings in excess of the outlays.

The preceeding analysis leads to the acceptance of Hypothesis Two, since the conservation techniques evaluated "result in significant cost savings for the United States government through decreased water consumption."

H. DOD-WIDE APPLICATIONS

The preceding analysis has dealt specifically with the effect on the Presidio of Monterey of six methods of water conservation. A further issue to be explored is the applicability of those findings to other military bases, not in terms of a check list but rather a general framework of questions and points to consider as a part of the planning mechanism for water system construction, either as new construction or as a renovation of currently functioning systems.

In each case, base officials need to be made aware that a potential problem exists. The question to be asked is: "What would cause a base commander to consider the need for water conservation?"

One way to answer that question is to record two relevant flows of information--water costs and water usage. As these are evaluated each month against both the historic usage at the base and in the surrounding civilian community, trends can be identified. The usage and cost would be compared to some pre-determined level. Recording the data, making the comparisons, and flagging trends that exceed the pre-determined level, could all be done by one person.

By having one person handle the total water information, the data dispursion that often takes place, where some data elements are buried in a file cabinet, some in a desk drawer, and still more is found only in one individual's memory, would be ameliorated.

If the usage and cost are within the established bounds, no further action is required. But, if they exceed limits, then the local commander or higher authority would be informed and presented with the options that could be persued in a logical order to bring use and cost back into line. This would be a system of exception reporting. Only when the use or cost appears to be getting out of control is the problem brought to the attention of the appropriate authority.

The problem, of course, is to determine what those bounds would be, since they would be different for each installation due to varying rainfall quantities, base-use areas, and consumption patterns of the assigned personnel. Setting those bounds might require the assistance of outside consultants from the local water management district, in conjunction with the regulations of that particular service as applied by the base engineers and the command.

Cost bounds could be developed that would relate the increased cost of water and sewage to the cost of implementing the various conservation methods. The amount of savings generated by each method should also be determined.

In this way, a cost analysis would be developed to monitor the marginal cost of water with boundaries set to reflect the cost benefits and trade-offs as the price of potable water increases.

In the same way, boundaries on usage could be developed which would identify when the usage on the base was getting out of line with the historical and local levels. There would not be as many variables in this formulation, but projections of population increases and use factors would be primary inputs necessary to set the boundaries.

A series of boundaries might be needed due to the long lead time necessary for several of the available options. The process that determines the bounds would have to consider this lead time and allow for it when measuring the trends and projecting them into the future.

If one of these projections approaches a limit some time in the future, the options to be considered should be tailored to the length of time available for implementation. For example, if it were determined that the wastewater reuse option would take two years to install and become operational, then the limit for that system would start at the two year mark. If the projection showed that a sudden increase would cause the limit to be reached in a year, then the wastewater reuse option would be less favorable, unless a crash project was decided upon. Use of network analysis such as Program Evaluation and Review Technique (PERT) and Critical Path Method (CPM) would facilitate the costing of crash projects as well as assisting in the setting up of the boundary system.

It can be seen that this type of control mechanism would have many interrelated parts that would require extensive planning and coordination. The participants in the design of the boundaries would need to factor in all of these parts to determine an appropriate projection for the future.

Statistical techniques such as regression analysis might be useful for this purpose.

The planning and control mechanism would also have a part, not just in evaluating and projecting the current and future usage, but also in assisting in the planning for new construction. Baseline amounts for per capita consumption could be developed that show the pattern of actual consumption in a specific geographic area. These usage amounts could be used to plan adequate water acquisition for new construction. The new construction plans would be a part of the usage projections that might trigger an alarm as a boundary is forecast to be reached. Therefore, the consideration of base population increases could initiate an evaluation of various water conservation projects.

Since worthy projects are always chasing scarce dollars, a way to differentiate just what, when, where, and how the water system should be adjusted would provide flexibility for planning. It would not be just a matter of doing everything possible immediately and hoping for a savings in cost or usage. It would be, rather, a systematic evaluation based on economic criteria as to when something, if anything, needs to be done. If no mechanism is available, then the need only becomes known, very often, when a crisis develops. For water projects to be able to claim their share of those scarce dollars, a mechanism, besides crisis management, needs to be in place.

When it has been determined that something can indeed be done to reduce water usage and after the historic costs have been plotted and the future trends have been projected, the analysis can shift to the individual techniques that would be applicable to the different boundaries.

The reuse option has several points to consider. First, from a cost perspective, the method used to bill the base for its sewage treatment is important. Several methods

exist from flat fee to metered usage to basing the sewage costs on the inflow of potable water to the fresh water system. The last two of these provide a cost reduction incentive to reuse. If the actual outflow is metered, then reducing that outflow by reusing the water lowers the cost. If reused water takes the place of potable water usually demanded from the system, then less potable water is used and costs are lowered. Of course, a flat fee, as at the Presidio of Monterey, provides no incentive for developing reuse facilities.

Reuse must also be carefully planned. The storage tanks need to be close to the point of use and be able to take advantage of gravity feed as much as possible so as to lower energy costs required for pumping. The costs of additional piping also need to be taken into account.

If this method of conservation is being considered then the attitudes of the command and the base population must be evaluated. In some areas [Ref. 14], the population has had to be convinced about the adequacy of non-potable water being used for applications that have formerly always used potable water. Indeed, this attitude problem is perhaps one of the most difficult hurdles for reuse, since in the United States, potable water has been used for everything; even toilet flushing water is of a drinkable quality.

As the above considerations are discussed and resolved, the Army three-tier model referred to in Chapter Two provides the next level to move to for a fuller evaluation of the potential for a workable water reuse technique.

Captured rainfall in cisterns or ponds offers another option that would require a relatively long lead time due to construction time. If this option is considered for any base, several factors should be evaluated. The major one is the rainfall amounts and patterns on the base. If rainfall occurs mostly in the fall and winter but water consumption

is highest in the dry months of summer, storage facilities adequate to supply the determined need would have to be constructed. A lesser amount of stored water would require smaller tanks and thus lower cost, but would possibly not provide all the water necessary to meet the demand. The trade-offs between cost and water availability would have to be evaluated.

A second major consideration would be the reliability of the public water supply. During times of water abundance, no problem would be anticipated. However, during droughts, the public supply would be reduced. Cistern water as a backup to the public water system would be a major factor if the base were in a drought-prone area or if there were critical needs for water to support the mission of the base, i.e., cooling water for nuclear energy production or fresh water for aircraft washdown facilities. These needs would argue strongly for the installation of a cistern system.

Flow reduction methods of water conservation provide a third option with less lead time and relatively lower cost. It is necessary to know the current water usage quantities in the quarters and barracks, since some people install their own shower heads or remove reduction devices. Also, appliances used in quarters cannot be controlled if they are owned by the occupants. If the number of housing units having water-saving shower heads is not known, then any projections based on the installation of new shower heads could be very inaccurate and not provide the amount of savings anticipated.

After these devices are installed, they will conserve water without any conscious act by the occupant. However, they can be overridden, as noted above, so this method would require frequent monitoring.

Metering of water use at individual units and work centers would cause personnel to be aware of the amount of water used and its cost in the civilian market. Its main advantage would be allowing recognition of those who conserve and guidance to those who use more than others. It would pinpoint areas of high usage indicating the possibility of leaks in the delivery pipes.

Drought-resistant vegetation is an option that would be middle-term, one to two years, since it takes some time for the plants to become established, during which time they require larger amounts of water than they will when fully rooted. It is important to keep in mind that indigenous plants are not necessarily the best. Often these plants have adapted themselves to the climate of the area, but also they may be able to be replaced with other, more hearty low-water-use plants. The major consideration with this option is to be aware of it and the potential savings. Many types of plants are available and an evaluation of what would be best suited for the base would provide data for the decision makers to use when considering the options in water conservation.

Public information and education is an option with a short lead time, but one that needs to be ongoing. A short, intense public education campaign may lower consumption for a while, but when the emphasis discontinues, consumption goes back up [Ref. 19: p. 35]. Public education must also be a coordinated approach aimed at producing a "conservation consciousness as a continuing means of demand reduction." [Ref. 22: p. 232] This might mean having a program ready to go, geared to different levels so that, as the boundaries are approached, the appropriate level of education may be initiated.

I. SUMMARY

This chapter has compared the per capita water consumption at the three major military installations on the Monterey Peninsula with the urban Monterey County per capita water consumption. As a result of the comparison, Hypothesis One had to be rejected.

The next sections considered six methods of water conservation from a cost/benefit perspective as an evaluation of Hypothesis Two. The most promising approaches for the least cost are flow reducers for shower and faucets, pressure reducting valves, and public education. These methods would result in an approximate 15.5 gallons per capita per day reduction in water usage or an almost 20 percent decrease. Hypothesis Two was, therefore, accepted.

Long-term potential exists for water reuse and rainwater capture. Currently, water provided by Cal-Am is cheaper, but if the cost of water continues to rise, a point will be reached in the future where these techniques would be economically feasible.

This chapter concluded with an exploration of an approach to water conservation analysis on other military bases. The main point suggested was that having a mechanism in place that would evaluate trends in water usage and cost would allow for an orderly consideration of the appropriate options for conservation. These options would be recognized and implemented to provide maximum conservation within the lead time projected.

IV. CONCLUSIONS

This chapter summarizes the findings of the analysis of water conservation techniques at the Presidio of Monterey. Conclusions reached concerning the two hypotheses presented in Chapter One is described and specific recommendations for implementation at the Presidio of Monterey is presented. The chapter ends with a listing of ideas for further research.

A. SUMMARY OF FINDINGS

Two basic approaches to water conservation were reviewed--supply improvement and consumption reduction. Wastewater reuse and rainwater capture were evaluated as ways to improve the available supply of water. Although both methods are currently being used successfully in locations as diverse as Tokyo and Orange County, California, analysis shows that neither one would be cost effective, at present, for the Monterey Peninsula.

Four methods of conservation were considered that could bring about a reduced consumption--flow reduction techniques, metering, drought-resistant vegetation, and public education. Each of these was considered for the Presidio of Monterey. Flow reduction techniques function by reducing the quantity of water used in household application, such as in toilets, or for showers or laundry. Pressure reducing valves that operate by lowering the water pressure of the inflowing water to the house were also considered as a flow reducing technique. Two flow reduction methods were found to be very beneficial by cost/benefit analysis--reducers for showers and faucets and pressure reducing valves.

Metering of water inflows and use of drought-resistant vegetation were considered as ways to conserve water, but the savings were not as significant by these methods as they were with flow reduction devices. The impact on water usage of a public education and information campaign was evaluated and determined to be cost effective.

B. CONCLUSIONS

Chapter One established two hypotheses that were to be evaluated by the analysis. Hypothesis One was that "water consumption on military installations is proportionally higher than consumption in civilian communities." This hypothesis was rejected when the data collected indicated that water consumption on the three military installations on the Monterey Peninsula used less water than was used in urban Monterey County.

Hypothesis Two was that "conservation techniques can be implemented which will result in significant cost savings for the United States government through decreased water consumption." This hypothesis was accepted on the basis of the analysis in Chapter Three that applied the techniques of water conservation to the Presidio of Monterey.

C. RECOMMENDATIONS

Two major recommendations are developed in this thesis. The first one concerns the specific conservation techniques that should be implemented at the Presidio of Monterey. The recommended techniques are the installation of both reducers for showers and faucets and pressure reducing valves, and the institution of a public education campaign. The estimated savings generated by these options, as presented in Chapter Three, was about 20 percent. If these same methods could be retrofit to existing barracks and housing units,

the quantity of water saved would result in substantial dollar savings to the government. The major advantage of the flow reduction devices is that, once installed, they will function to conserve water without requiring further action. The public education and information campaign would take more planning and require constant oversight for it to have maximum effectiveness.

The second reccmmendation is that a trend analysis program as outlined at the end of Chapter Three be instituted for the Presidio of Monterey. That would provide for a continuous monitoring of water usage, with prededermined boundaries in place. If those boundaries are reached, appropriate conservation approaches should be initiated.

D. RECOMMENDATIONS FOR FURTHER STUDY

There are many areas for further studies to explore. Sewage treatment costs and the impact of a flat fee system should be studied to determine actual costs to the consumer and the utility company for sewage treatment.

Very few studies have been done on water consumption in military barracks. A contribution to the literature and a helpful understanding of military water usage could be accomplished by such a study. Questions to explore should include: (1) Is water usage different among young singles who live in barracks, and, if so, why? (2) What would be the impact of timed shower controls or roof catchments for use in that building for toilet flushing?

In the Monterey Peninsula area, military installations were shown to consume less water per capita than the average consumption in the surrounding urban communities and less than the consumption reported in studies of other locations in the United States. Is this unique or is per capita consumption of water less in all military bases or only

certain types or only those in certain locations? A study of other installations in different types of locales would provide data to help in analyzing the real water consumption amounts on military installations and the potential savings from conservation.

Cisterns are the major water supply source in many areas of the world. They could prove cost-effective, but only when a comprehensive study of the trade-offs of size of tank versus cost is available for a specific area based on rainfall quantities, collection surface area, pollution controls, etc. Cisterns can, of course, be built in different sizes. In [Ref. 18], some the problems involved in determining cistern capacity are discussed. If rainwater capture is a viable alternative, then cistern size options would have to be evaluated.

A study should be developed around pricing theory as it relates to water, a scarce resource but one considered by many as a 'free' good. Our culture is conditioned to think of potable water as a never ending resource, falling freely on all from the sky. But, in fact, water, as a scarce resource, is not billed at its open market price, but rather at a low, subsidized rate. An economic analysis of this artificially low price for water and the impact that low price has on use and conservation would provide data for the continual evaluation of water pricing.

The overall needs for a fire protection system could be the basis of a study, specifically related to the Presidio. An analysis should be made concerning the cost and benefits of cistern-provided water to surrounding fire protection districts.

Also related to the Presidio, a study could be made of rainwater capture, specifically considering the significant non-quantative factors involved in having a large catchment area and storage facility available at the top of Presidio

hill. In addition to fire protection, the areas to consider would include drought protection, ecological considerations, flood control, and water independence. Having an independent source of water would provide protection in case of a drought as well as insurance for the continued functioning of the base if the water lines of Cal-Am were ruptured by an earthquake or other natural disaster. Capture of the rain that lands on the Presidio would alleviate some of the flooding that occurs during heavy rainfall. It would also provide an example of how to handle and use a scarce resource. It is not the use of water, but rather its misuse or mismanagement, that creates problems.

A good public education campaign aimed at military audiences would be a study with general applicability. Many resources are available that could be modified and tailored to the military base population. Aids for presentation to school audiences, such as movies, comic books, and handouts for teachers about water conservation, as well as water conservation kits and public information brochures are available from the California State Department of Water Resources.

APPENDIX A

TERMS DEFINED

Acre Foot: The amount of water necessary to cover one acre to a depth of one foot of water; total of 325,581 gallons.

Aquifer: A permeable formation that stores and transmits groundwater in sufficient quantity to supply wells.

Artesian well: A well whose shaft penetrates through an impervious layer into a water-bearing stratum from which the water rises under pressure.

Graywater: Recycled water that is lower in quality than potable. Basically the equivalent to non-potable and subpotable.

Groundwater: The mass of water beneath the surface of the ground consisting largely of surface water that has seeped down; the source of water in springs and wells.

Non-potable water: A water that at all times meets or exceeds the "body-contact" standards of the California Administrative Code, Title 22, but is not suitable for drinking. Also referred to as subpotable.

Potable water: Water that is agreeable to the taste and does not contain any health-harming agents.

Reclaimed water: A domestic waste water that has received secondary treatment, in California, by the activated sludge process, resulting in a nitrified effluent that meets the most stringent California standards for beneficial use of reclaimed water, spray irrigation of food

crops and non-restricted recreational impoundments (body-contact). However, it is not coagulated and filtered, so it is not in technical compliance with the standards for potable water.

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