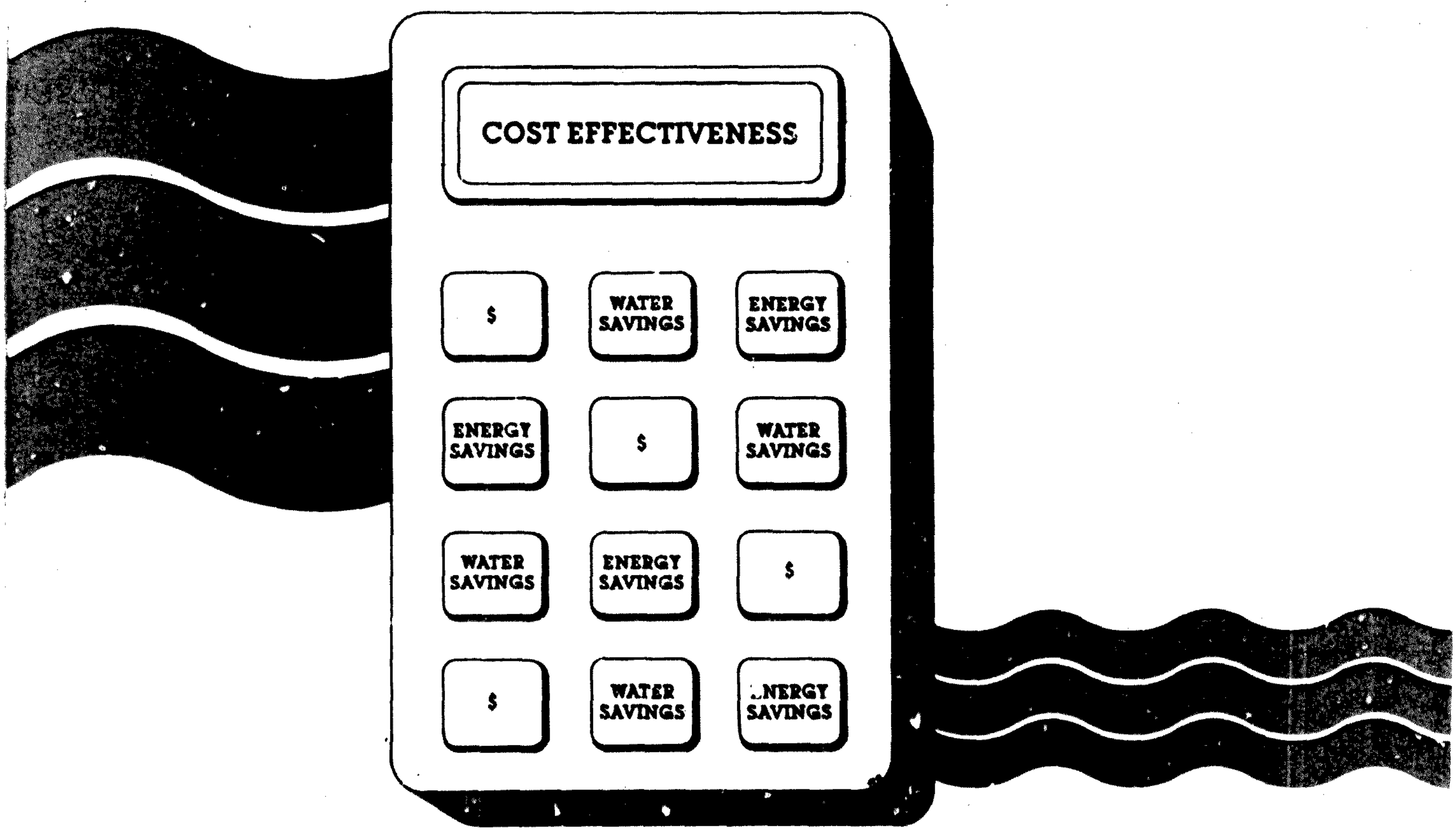
EPA

Flow Reduction

Methods, Analysis Procedures, Examples



TECHNICAL REPORT DATA

(Please read Instructions on the reverse before completing)

1 REPORT NO	2	3 RECIPIENT'S ACCESSION NO PB81-203713
4 TITLE AND SUBTITLE Flow Reduction - Methods, Analysis, Procedures, Examples		5 REPORT DATE March, 1981
		6 PERFORMING ORGANIZATION CODE
7 AUTHOR(S)		8 PERFORMING ORGANIZATION REPORT NO
9 PERFORMING ORGANIZATION NAME AND ADDRESS Office of Water Program Operations, Facility Requirement Division, Washington, DC 20460		10 PROGRAM ELEMENT NO
		11 CONTRACT/GRANT NO
12 SPONSORING AGENCY NAME AND ADDRESS Office of Water Program Operations, US Environmental Protection Agency, Washington, DC 20460		13 TYPE OF REPORT AND PERIOD COVERED Technical Report
		14 SPONSORING AGENCY CODE 700/02
15 SUPPLEMENTARY NOTES		

16 ABSTRACT

This report is a study of the effect of the Industrial Cost Exclusion (ICE) on the construction grants program. This study and the report were directed by the Congress in section 4 of a recent amendment to the Federal Water Pollution Control Act (Public Law 96-483). The report reflects the full range of opinions expressed to the Agency during the conduct of our study. Comments and data were provided by water pollution control agencies of the several States, communities and industries that will be affected by the industrial cost exclusion, interested public and private interest groups and other parties.

The impacts of ICE have been assessed from both the industrial and municipal perspectives in order to objectively analyze the potential consequences. Further, the report analyzes the impacts on rural communities and on industries in economically distressed areas and areas with high unemployment. Specific communities and projects are identified and each State is analyzed in terms of short-term and long-term effects of ICE.

This report contains a factual analysis of the effect of the ICE as well as a review of the impacts of a number of alternatives to the ICE requirements.

17 KEY WORDS AND DOCUMENT ANALYSIS

a DESCRIPTORS	b IDENTIFIERS/OPEN ENDED TERMS	c COSATI Field/Group
Water Conservation	Flow Reduction	

18 DISTRIBUTION STATEMENT	19 SECURITY CLASS (This Report) Unclassified	21 NO OF PAGES 96
	20 SECURITY CLASS (This page) Unclassified	22 PRICE

EPA Form 2220-1 (Rev. 4-77) PREVIOUS EDITION IS OBSOLETE

Flow Reduction

Methods, Analysis Procedures, Examples

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March 1981

Preface

Flow Reduction: Methods, Analysis Procedures, Examples, is the first volume of a three-volume series pertaining to wastewater flow reduction analysis and program planning. With increasing numbers of communities becoming interested in the potential benefits of flow reduction and with the introduction of flow reduction analysis requirements into the treatment facilities Planning (Step 1) phase of EPA's Construction Grants Program, a need was felt to provide guidance on flow reduction analysis procedures and in developing community programs. Each volume of this series thus works toward the ultimate objective of developing community flow reduction programs that are practical, cost effective and able to be implemented.

- **Part I** of this first volume provides background information on flow reduction, including its role in facilities planning, its relationship to other water and wastewater programs, and case examples of communities which have implemented programs. **Part II** provides a step-by-step methodology to serve as a guide in carrying out the flow reduction analysis. Descriptions of various flow reduction measures are included along with an assessment of their cost effectiveness.
- **Part III**, a separate volume, demonstrates the flow reduction methodology by applying it to two real world communities. These documented case studies not only clarify the procedure but highlight the nature of flow reduction's costs and benefits.
- **Part IV** is a package of flow reduction public information material designed to supplement a community's flow reduction program. This package consists of general guidance in developing a public information program, examples of specific techniques communities have used, and sample material which can be adapted for direct use in a community's program.

Through these three interrelated documents it is hoped that community leaders and planners will find the practical rationale and overall guidance needed to consider the potential of flow reduction in their particular settings.

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Acknowledgments

Flow Reduction: Methods, Analysis Procedures, Examples was prepared under the direction of Myron Tiemens, Deputy Director of EPA's Facility Requirements Division, and Barbara Yeaman, Public Education Consultant to EPA. Both provided comments and guidance which greatly benefited this document

Contractor on this project was INTASA, Inc. of Menlo Park, California. Nicolaos V Arvanitidis, President of INTASA, supervised preparation of this document and performed coordination with EPA Day-to-day project management was the responsibility of Bill Betchart, research and writing on the project was by Sandra Postel and Sally Davenport as well as Mr Betchart Graphic design and artwork preparation were the responsibility of John Bird Advertising & Design of Palo Alto, California The manuscript text was typeset at LARC Computing, Inc of Los Altos, California

Finally, the INTASA team wishes to acknowledge all those both inside and outside of EPA who took the time to review and comment on draft versions of this document

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Flow reduction can mean:	This document will show
[illegible]	How to calculate the monetary costs and benefits of the flow reduction program
Substantial savings to consumers in [illegible] costs as well as water supply and wastewater agencies	What household monetary savings can be achieved through different flow reduction measures
[illegible]	Examples of communities that have avoided economic losses by implementing common flow reduction measures
Achieving a well-planned program designed to meet a particular community's needs	How a community can put together a workable flow reduction package
[illegible] Federal funds [illegible]	How facilities planners can meet EPA's flow reduction analysis requirements

Table 1 Cornerstones Of Flow Reduction And This Document

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I AN OVERVIEW OF WASTEWATER FLOW REDUCTION AND USE OF THIS DOCUMENT

When the one-million-gallon-per-day (mgd) wastewater treatment plant serving Gettysburg, Pennsylvania became overloaded in 1973, a construction moratorium went into effect which threatened to cause substantial economic losses to the area As a direct result of a concerted effort to reduce wastewater flows, the ban was partially lifted in 1976, saving an estimated $29 million to the regional economy (Sharpe, 1978)

Increasing numbers of communities across the nation are turning to flow reduction programs to deal with municipal wastewater management problems While many of these programs have been undertaken in direct response to existing or imminent crisis situations, the potential to realize long-term benefits is also being recognized

Moreover, flow reduction must now be a direct concern of wastewater treatment facilities planners With the exception of those areas with (1) populations under 10,000, (2) average daily base flows less than 70 gallons per capita per day (gpcd), or (3) an approved flow reduction program, all municipalities or districts seeking Federal funds for construction of wastewater treatment plants are now required by the U S Environmental Protection Agency (EPA) to examine flow reduction alternatives in their facilities planning

Carrying out the flow reduction analysis required by EPA in no way interrupts the other aspects of facilities planning Much of the information and data needed for the analysis is also essential to the overall facilities plan. The planning process and flow reduction analysis can be carried out simultaneously, with the recommended flow reduction program being incorporated into the final facilities plan

This document highlights the nature and potential effects of a flow reduction program and informs local officials about benefits their communities can receive from implementing such a program In addition, Part II presents a procedure by which planners can evaluate and compare the effects of alternative flow reduction programs on the community's wastewater utility, water supply utility, and individual households Table 1 highlights potential benefits of flow reduction to the community, and the usefulness of methods, analysis procedures, and examples provided in this document in realizing that potential

A. What Is Flow Reduction?

As its name implies, generic flow reduction is oriented toward reducing (or at least slowing the growth of) the quantity of wastewater flowing into a municipality's wastewater treatment plant Within wastewater facilities planning under the Clean Water Act, "flow reduction analysis" has a more specific meaning

It is directed toward reducing wastewater flows by implementing broadly applicable water conservation techniques in residential, commercial, public and small-scale industrial settings Quantities of wastewater flowing into treatment works are significantly affected by these community-wide water uses Thus efforts to reduce water use often simultaneously serve to reduce wastewater flows, and flow reduction is closely tied to water conservation Although the two types of programs differ (for example, water conservation efforts to reduce water use for landscape irrigation will have little effect on the quantity of wastewater flow), water conservation or water saving measures are the core of any flow reduction program

Two other types of analytical efforts to reduce wastewater flows are separate from but supplementary to, the flow reduction analysis addressed in this document

- Infiltration/inflow analysis, which attempts to reduce the amounts of groundwater and rain water that find their way into the wastewater system
- Industrial wastewater flow analysis, which attempts to reduce wastewater flow from specific industrial users (i e, those with flows greater than 25,000 gallons per day (gpd)) by analyzing their process configurations to achieve more efficient water use and reduced waste loadings

Though not further emphasized herein, both infiltration/inflow and industrial flows can be major contributors to the total wastewater flow and thus of significance in sizing wastewater treatment works

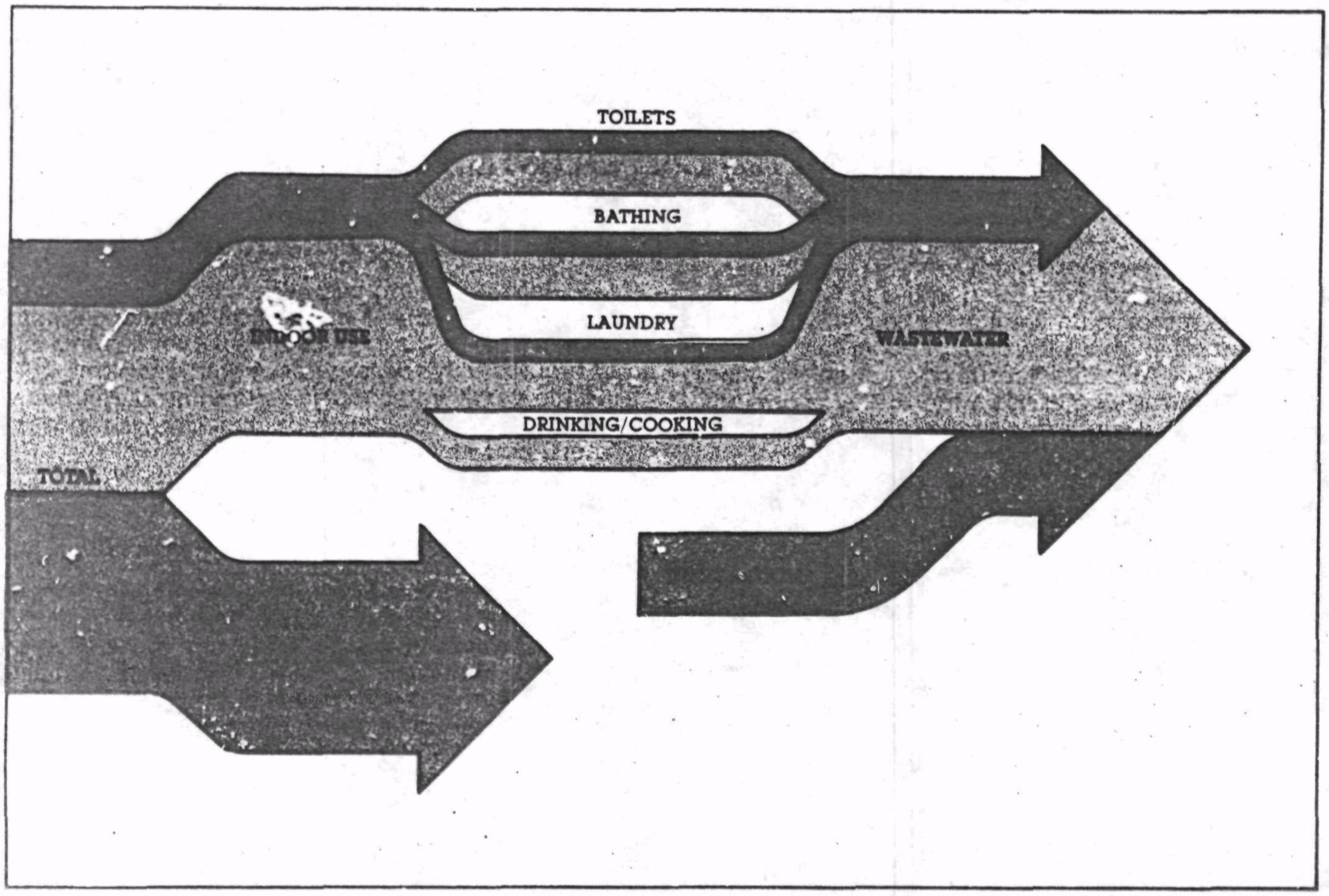


Figure 1 Potential Reductions In Water Use And Wastewater Flows From Indoor Water Conservation

B. What are the Potential Benefits of a Flow Reduction Program?

An effective flow reduction program can provide immediate and long-term benefits to both the community and the individual consumer. The immediate benefit of averting a pending water supply or wastewater treatment crisis is one frequently mentioned example. However, lasting program-induced reductions in water use and wastewater flows can produce significant long-term benefits. Where such long-term benefits can be identified, short-term crises need not be present to motivate and justify a flow reduction program.

Long-term monetary benefits to the community can result from being able to postpone, or eliminate, expansion of an existing treatment facility or construction of a new facility. Or, a flow reduction program may enable a community to plan for and construct a smaller treatment plant than would have been possible without flow reduction efforts. In these situations, there can be benefits in the form of reduced capital and interest expenditures as well as operation and maintenance costs. As discussed more fully in Part II, the realization and magnitude of these cost savings will depend upon the community's specific wastewater and treatment-facility characteristics.

Water conservation measures implemented as part of a flow reduction program will produce similar long-term water supply cost savings by reducing the scale or postponing the expansion of different aspects of the water supply operation. On the other hand, the short-term effect of reducing a community's water use may be to decrease revenues without substantially altering costs, since most of the utility's costs are fixed costs tied to available capacity. Although this revenue effect can be a major concern, the problem is by no means insurmountable. Revenues lost through conservation may be offset by a normal increase in the number of customers served, unused

Indoor Water Use	Total Indoor Use (percent)	Without Conservation[a] (gpcd)[c]	With Conservation[b] (gpcd)[c]	Reduction (percent)
Toilet flushing	40	25	17.5	30
Bathing	30	20	16	21
Lavatory sink	5	3	3	-
Laundry & dishes	20	13	9.5	27
Drinking & cooking	5	4	4	-
Total	100	65	50	23

a Based on data in U.S. EPA, 1979
b Assumes use of toilet dams, plastic shower head inserts and water conserving dishwashers and washing machines
c Gallons per capita per day

Table 2 Indoor Residential Water Use and Potential For Water Savings With Conservation

capacity thereby remaining unchanged. Lost revenues may also be recovered through a rate increase which will still be likely to result in a lower water bill to the average, conserving residential user. Or, a flow reduction program can be implemented gradually so that no immediate reduction in revenues occurs. The manner in which the problem is tackled will depend upon the particular community.

Individual water users within the community will also benefit directly from a flow reduction program's effects on capacity. The lower fixed costs associated with constructing and operating a smaller facility, or delaying facility expansion, will translate over the long term into lower (or smaller increases in) water and wastewater bills for the water user who ultimately must pay the cost of these services. In addition, a reduction in water use will mean a saving in costs for energy used to heat water.

Table 2 provides figures on an average household's indoor water use and potential water savings with selected conservation/flow reduction measures. Figure 1 pictorially displays the magnitude of these savings and Figure 2 portrays what these savings can mean to the community - both to the water and wastewater utilities and to individual water users.

An array of nonmonetary benefits may also accrue to the community as a result of flow reduction and associated water conservation efforts. Clearly, these benefits will vary greatly depending upon the particular circumstances of the community but may include:

- Enhanced fish and wildlife, recreation, and aesthetic benefits
- Increased number of services that can be supplied from existing facilities with the associated land-use and socioeconomic advantages
- Increased groundwater reserves
- Avoidance of an imminent water supply or wastewater treatment crisis
- Provision of the additional safety value of no longer operating at the margin of available water supply

C. What Have Other Communities Achieved?

- A drought-inspired conservation effort undertaken by the East Bay Municipal Utility District serving **Oakland and Berkeley, California** has resulted in long-term post drought reductions of about 15 percent in water use and 10 percent in dry weather wastewater flows. During the 1977 drought, wastewater flows were reduced by 28 percent (Vossbrink, 1980).
- **Springettsbury Township, Pennsylvania** succeeded in reducing average wastewater flows by 2.5 mgd, allowing for termination of a construction moratorium put into effect when its 8 mgd wastewater treatment plant became overloaded. As a result of infiltration/inflow and flow reduction programs, the cost of operating and maintaining the wastewater facility has decreased by $18,000 annually at the same time that new connections have led to increases in the utility's revenues (Sharpe, 1978).
- An overloaded wastewater treatment plant and predicted future water shortages led the

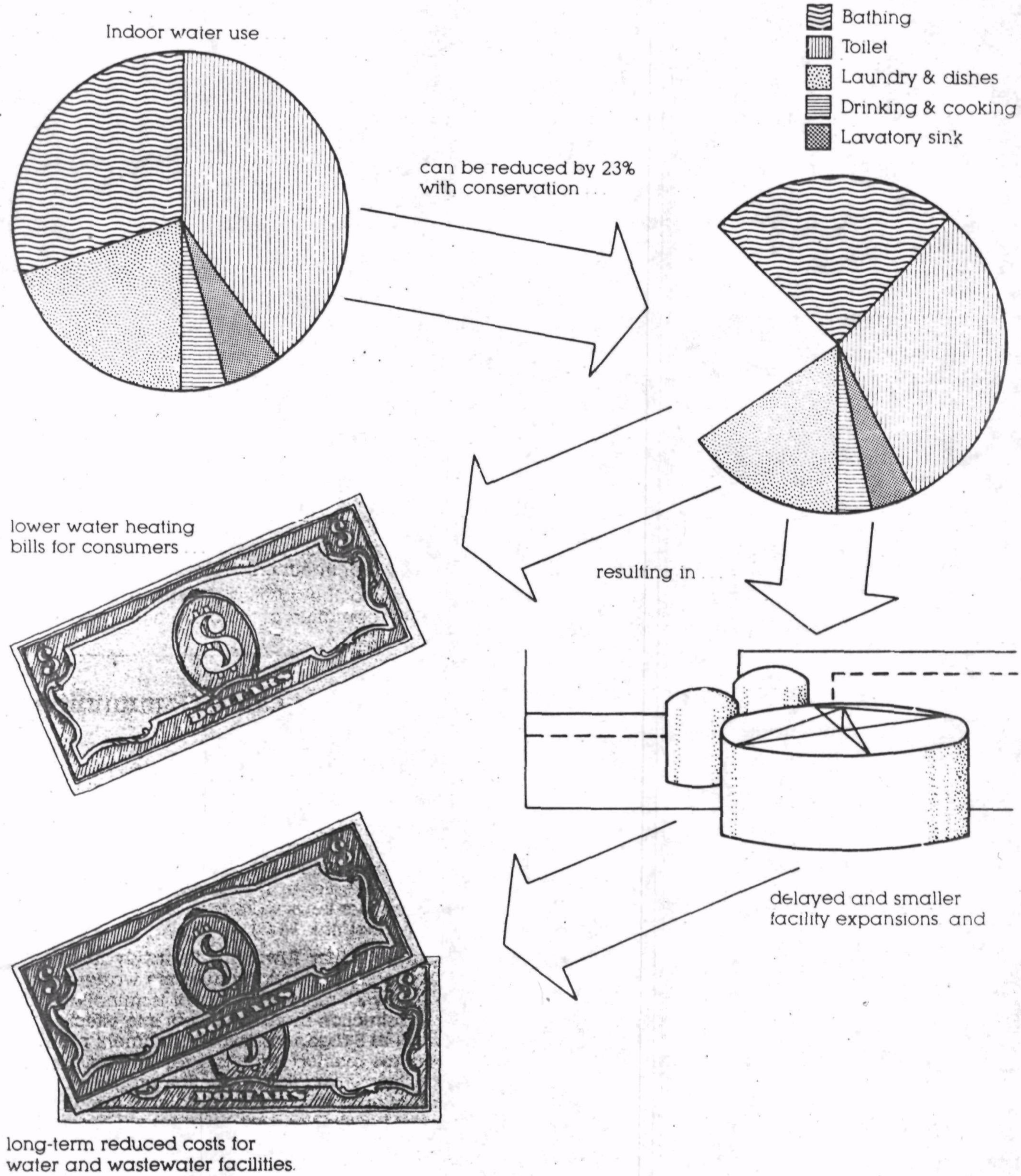


Figure 2 **Long-Term Monetary Benefits To The Community From Water Conservation/Flow Reduction**

community of **Elmhurst Illinois** to implement a water conservation program targeted at reducing wastewater flows by 8 to 10 percent As a result of the program Elmhurst was able to cancel construction of a $400,000 deep well and to remove other deep wells and storage facilities from use (Deline, 1978) A comparison of an average of the three years prior to the program with an average of the three years after the program indicates that water use in terms of average daily base flow has decreased by 9 percent while peak-day flows have decreased by 14 percent (Fulton, 1980)

- A mass retrofit program in **Oak Park, California** during the 1976-1977 drought helped reduce total water deliveries by as much as 48 percent and wastewater flows by as much as 31 percent (California Department of Water Resources (DWR), March 1978) An analysis of the long-term effects of the program indicates that dry weather wastewater flows have decreased by about 25 percent since the retrofit program compared to the 17 months prior to the program When data from the months with high infiltration are included, an 18 percent reduction in wastewater flows is indicated (California DWR, September, 1979) Figure 3 displays the magnitude of these reductions
- A "Pilot Water Conservation Program" comprising **six areas (including Oak Park) in California** produced annual energy and water savings estimated to be over $1.5 million. The annualized cost of the state and local program was approximately $317,594 Moreover, survey results from four of the areas indicated strong public acceptance (in the range of 85 to 90 percent) of the water saving devices installed (California DWR, October 1978)

It is important to recognize that while the ultimate goals of flow reduction programs are quite similar, the means of achieving these goals vary greatly. A flow reduction program can consist of a variety of very different flow reduction measures, packaged so as to meet a community's specific needs, budget, and opportunities, and to respond to its particular socioeconomic, political and environmental setting Thus throughout this document, an emphasis is placed on alternatives

D. Motivations for Flow Reduction

In addition to the potential monetary and nonmonetary community benefits already discussed, an important motivating factor for flow reduction is that it will enable a limited amount of Federal funds to go further in meeting water quality goals As of January 1978, EPA estimated that wastewater facilities needed for the year 2000 (excluding stormwater control) would require funds totaling $106 billion of which 75 percent, or $79.5 billion, would be Federal dollars (January 1978 dollars) With annual Federal appropriations of $4.2 billion in Fiscal Year 1979 toward this 75 percent Federal share - and without considering inflation - it would take 19 years to satisfy these needs Even if inflation were only 5.5 percent per year, the year 2000 needs would never be met, even by appropriating $4.2 billion per year forever (U S EPA, 1979)

Federal construction grants appropriations in Fiscal Year 1980 were $3.4 billion and the budget request for Fiscal Year 1981 was $3.7 billion Considering that these amounts are substantially less than earlier levels and that inflation has been much greater than 5.5 percent per year, it will be extremely difficult to catch up with our treatment facility needs Flow reduction is an important component of the fight to control our ever-expanding wastewater treatment needs and an opportunity for municipalities to demonstrate success in this struggle

E. The Legal Basis of Flow Reduction

EPA's requirement that flow reduction be considered in wastewater treatment facilities planning stems from several policy initiatives in both the executive and legislative branches of the federal government

- **President Carter**, in his June 6, 1978 Water Policy Message, resolved to make water conservation a national priority Along with requiring that water conservation be added to the Water Resources Council's "Principles and Standards," the President issued a specific directive to the EPA and Departments of Agriculture, Commerce, and Housing and Urban Development to make "appropriate community water conservation measures a condition of water supply and wastewater treatment grant and loan programs "
- **Congress**, with passage of the 1977 Clean Water Act, altered EPA's wastewater Construction Grants Program to require that the approvable amount of reserve capacity for

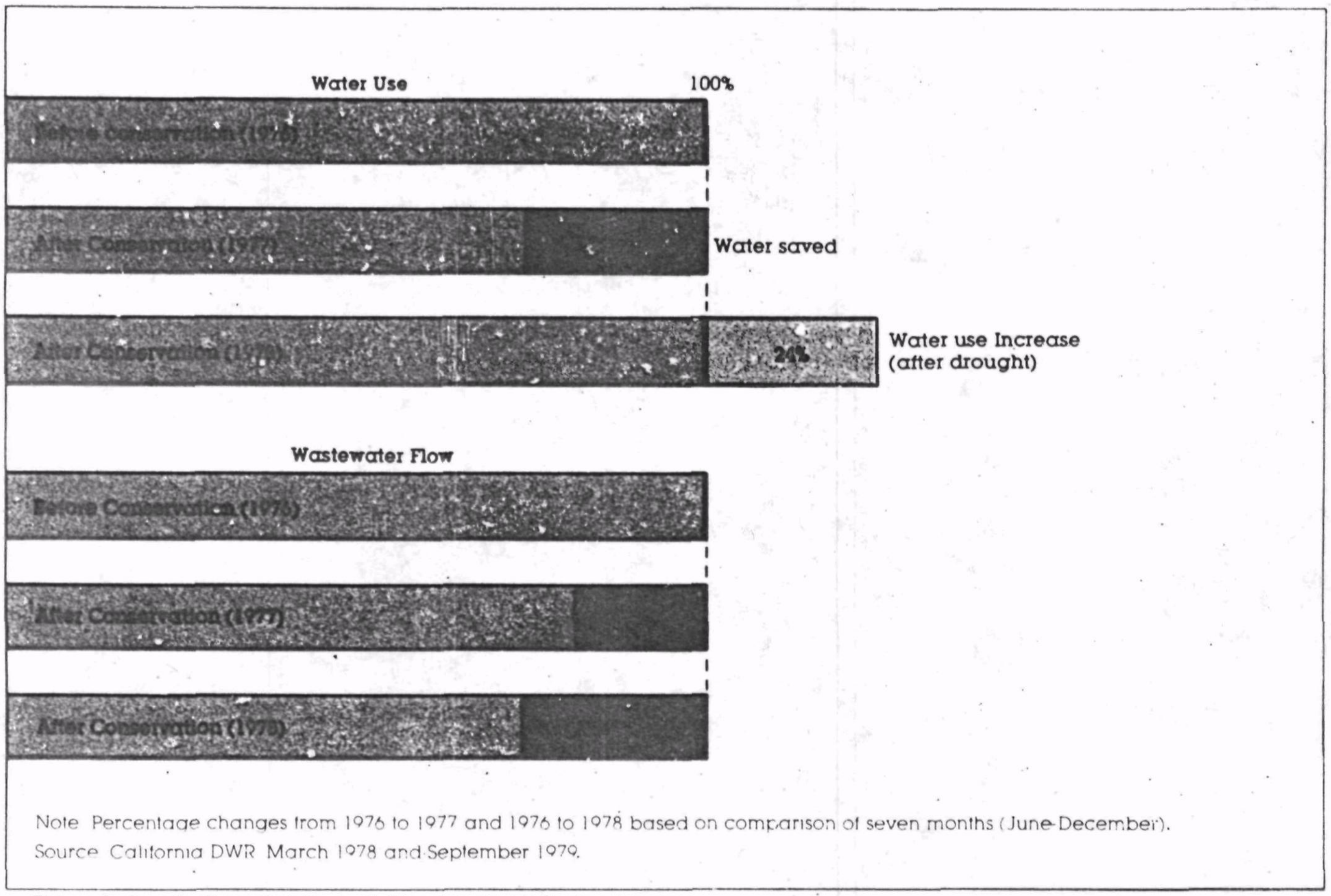


Figure 3. **Results From Oak Park, California's Water Saving Program**

treatment facilities take into account "efforts to reduce total flow of sewage and unnecessary water consumption."

- EPA, acting under this new authority, included in its cost-effectiveness guidelines for the Construction Grants Program the requirement that: "The cost-effectiveness analysis for each facility planning area shall include an evaluation of the costs, cost savings, and effects of flow reduction measures unless the existing ADBF (average daily base flow) from the area is less than 70 gpcd, or the current population of the applicant municipality is under 10,000, or the Regional Administrator exempts the area for having an effective, existing flow reduction program." Thus, all grant applicants not exempt under these conditions must consider flow reduction programs within their facilities planning and must include such a program if it is found to be cost-effective and implementable. (See Appendix A for full text of Section 8c of EPA's Cost-Effectiveness Guidelines.)

F. What Are the Determinants of Wastewater Flow?

Water use is one main determinant influencing wastewater flow. Knowledge about expected future water use and the patterns of such use is essential to predicting and planning for future wastewater flows. Specific factors influencing future water use and, secondarily, wastewater flows include:

- Population - including number, growth rate, distribution and density of water users.
- Per capita use in various sectors of the community - residential, commercial, industrial, public.
- Per capita use within categories of certain sectors - for example, indoor versus outdoor residential use and breakdown of indoor use into activities such as bathing, and toilet flushing.
- Specifically identified industrial flows (under Section 8d of Cost-Effectiveness Guidelines).

- Limitations on the quantity and quality of water supply available
- Relative energy and capital costs associated with storing, treating and distributing water supplies

In addition to these water use characteristics, the quantity of wastewater flow may be significantly affected by the amount of rain water or groundwater entering sewer pipes through leaks (infiltration) and by water entering sewers via roof downspouts and patio drains connected to the sewer lines (inflow)

G. How is "Flow Reduction" Related to Other Programs?

As implied before in this discussion, a variety of factors affect wastewater flows The following subsections provide more detail on the scope of flow reduction analysis in the context of facilities planning under the Clean Water Act and its relationship to other programs

1. Facilities Planning (Step 1) under the EPA Construction Grants Program

Flow reduction analysis is an integral part of facilities planning and is required in each Step 1 project unless the explicit conditions for exemption are met (see Appendix A) It focuses on that portion of facilities planning which estimates the expected magnitude of wastewater flow over time - these estimates will be used in determining the size and staging of a facility and thus the size of the immediate construction project It assumes that the facilities planners have already developed a "preliminary estimate" of expected wastewater flows (in accordance with most provisions of the Cost-Effectiveness Guidelines Sections 8a, b and d) This allows facilities planning to continue while three detailed tasks are performed (in accordance with the remaining provisions of Sections 8a, b, c and d) to refine these flow projections into "final estimates" The more detailed tasks are

- Flow reduction analysis
- Infiltration/inflow analysis
- Industrial wastewater flow analysis

These tasks are to determine whether there are cost advantages in spending money to reduce flows rather than to provide the larger facility capacities to transport and treat them Figure 4 shows how flow reduction analysis relates to the other tasks performed in facilities planning

2. Infiltration/Inflow Analysis

Step 1 facilities planning is required to demonstrate the nonexistence or possible existence of excessive infiltration/inflow (I/I) within the wastewater collection system Infiltration or inflow is deemed nonexcessive when it costs less to collect and treat the extra water than it would cost to eliminate it by rehabilitating the collection system More specific requirements and background regarding I/I analysis are provided in several program documents (see the bibliography in Appendix D)

Infiltration/inflow analysis is a separate facilities planning activity, parallel to flow reduction analysis and oriented toward developing final estimates of future wastewater flows Its interrelationship with flow reduction analysis is characterized by the following points

- Infiltration/inflow analysis may have a much larger effect on the final capacity of the treatment works than flow reduction analysis, depending on local circumstances Infiltration and inflow can increase the peak daily flow through a wastewater treatment plant by a factor of five or even ten over average dry-weather base flows (Holland, 1980) Cost-effective sewer system rehabilitation has reduced these extraneous flows by up to 30 percent (Conklin and Lewis, 1980 and Peil and Diehl, 1978) Thus in I/I analysis facilities planners are considering actions that may reduce peak daily flows by amounts equivalent to several hundred percent of the average dry-weather base flow It should be noted, however, that the costs involved in reducing I/I are generally much greater than costs associated with flow reduction Reducing I/I may, in many cases, not be cost effective
- The "nonexcessive I/I", remaining after cost-effective sewer system rehabilitation, can detract from accomplishments under a flow reduction program, especially if one considers only their relative effects on treatment works capacity For example, a flow reduction program might achieve a 10 percent reduction in dry-weather base flows through decreased and more efficient water use If the "nonexcessive I/I" were to point toward a treatment works hydraulic capacity equivalent to five times the unreduced average dry-weather base flow, the "10 percent flow reduction" from water conservation activities would result in only a 2 percent reduction in treatment works hydraulic capacity

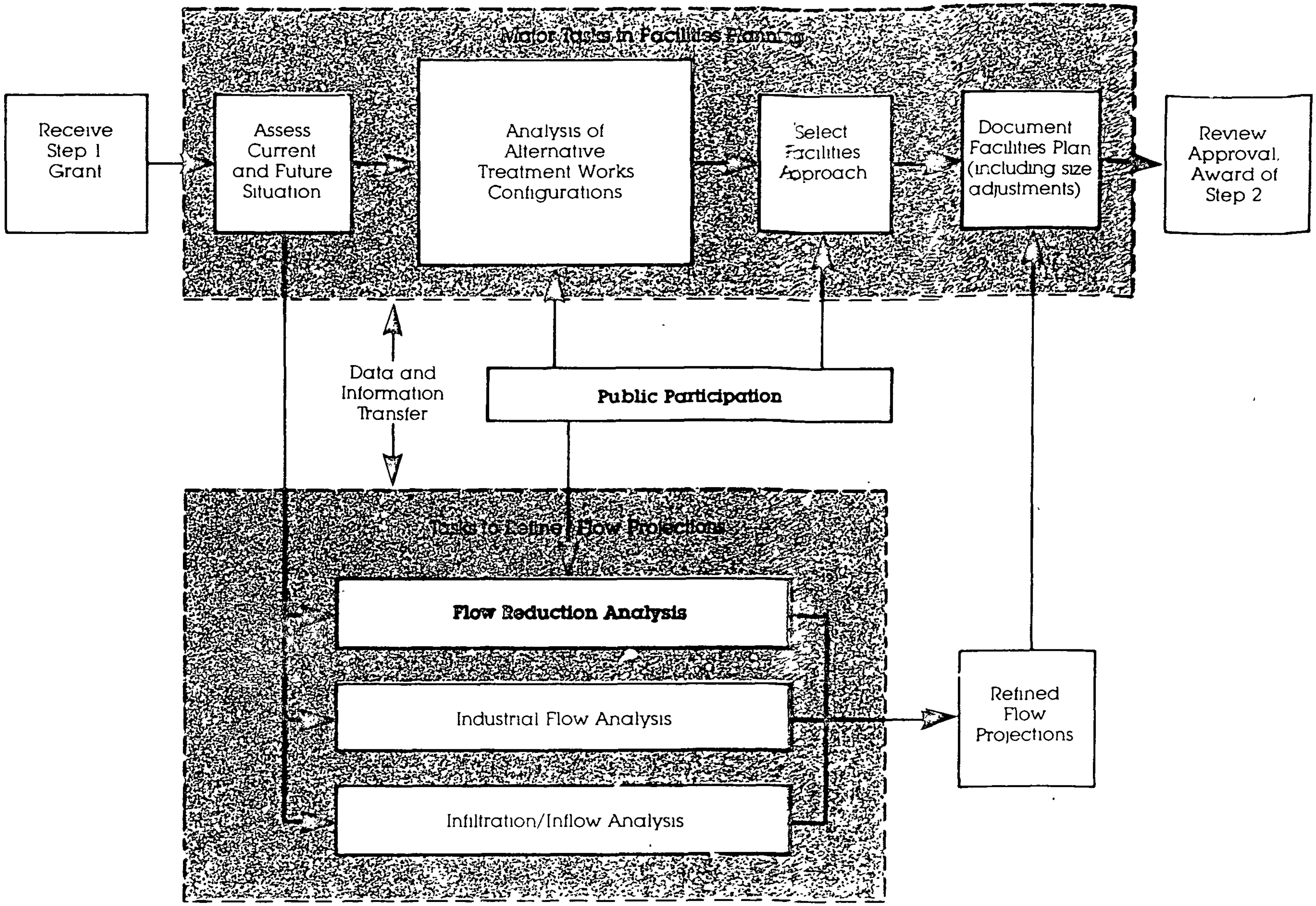


Figure 4 **Flow Reduction Analysis Within Facilities Planning**

3. Industrial Wastewater Flow Analysis

In developing wastewater flow estimates, planners may make specific allowances for present flows from industries now served, future additional flows from these or other specific industries, and additional unplanned flows from these or other unidentified industries (see Cost-Effectiveness Analysis Guidelines, Sections 8b and d). In the cases of present industrial flows and specifically identified future increases in flow, Section 8d requires that these flows "shall be carefully reviewed and means of reducing them shall be considered." This requirement is met by a special "Industrial Wastewater Flow Analysis," the third effort parallel to I/I analysis and flow reduction analysis and oriented toward final estimates of wastewater flows.

Industrial wastewater flow analysis focuses on refining estimates of specific future industrial needs for capacity in the municipal wastewater treatment works and on identifying and implementing specific opportunities for industrial users to decrease their process-related discharges to the wastewater system. This effort is closely related to several other industrial topics within the Construction Grants Program including pretreatment, user charges and industrial cost recovery.

4 Reuse

Relative to the Construction Grants Program, reuse means use of treated effluent from a wastewater facility for some purpose such as landscape or agricultural irrigation or industrial cooling or processing. This concern with use of treated wastewater does not affect the quantity of wastewater inflow into the facility. Thus reuse is viewed to be a separate topic, unrelated to flow reduction. EPA has recently published a separate document (Camp Dresser and McKee, 1980) which provides "Guidelines for Water Reuse."

5 Recycling

A water user such as an industry could choose to recycle some of the water it uses, thereby reducing the total quantity of water supply needed and wastewater discharged. If that industry's wastewater goes to the municipal treatment facility, such recycling will have a direct impact on the amount of wastewater inflow.

Recycling is particularly relevant to industries and thus it would be considered in "Industrial Wastewater Flow Analysis" under Section 8d. Since other users may also recycle, recycling is used in this handbook as an example of a specific, though somewhat exotic, flow reduction measure which could be analyzed in response to Section 8c.

6. Water Conservation

Flow reduction measures implemented in response to Section 8c are intended to reduce both water used and wastewater discharged to the sewers. Thus flow reduction measures constitute a subset of water conservation measures. The difference is one of scope. Flow reduction analysis focuses primarily on water conservation measures to reduce quantities of wastewater flowing into a treatment facility while water conservation analysis encompasses all measures to reduce water use. Thus measures to reduce water used for outside irrigation are not within the scope of flow reduction analysis; they would be a concern for water conservation planning. However, if a community so desires, it can do comprehensive water conservation analysis in conjunction with its flow reduction analysis - such an effort is considered grant eligible by EPA. In any case, the success of flow reduction efforts is dependent upon close coordination with water supply authorities and any ongoing water conservation program.

7. Energy Conservation

Wastewater flow reduction also promotes energy conservation. The principal mechanisms for energy savings with less water use are:

- Less energy needed to heat hot water if less hot water is used
- Less energy needed for water supply pumping and treatment
- Less energy needed for wastewater pumping and treatment

Because as much as half of the economic benefits of water conservation or flow reduction is due to energy savings, especially from less use of hot water, it is important to key in on energy benefits in flow reduction analysis. It is also important to coordinate flow reduction efforts with any on-going energy conservation efforts so that appropriate combinations of energy and water conservation are achieved.

H. Who is Involved in Flow Reduction Planning and Program Implementation and Why?

From the planning through implementation stages of a flow reduction program, various individuals, groups and entities assume important

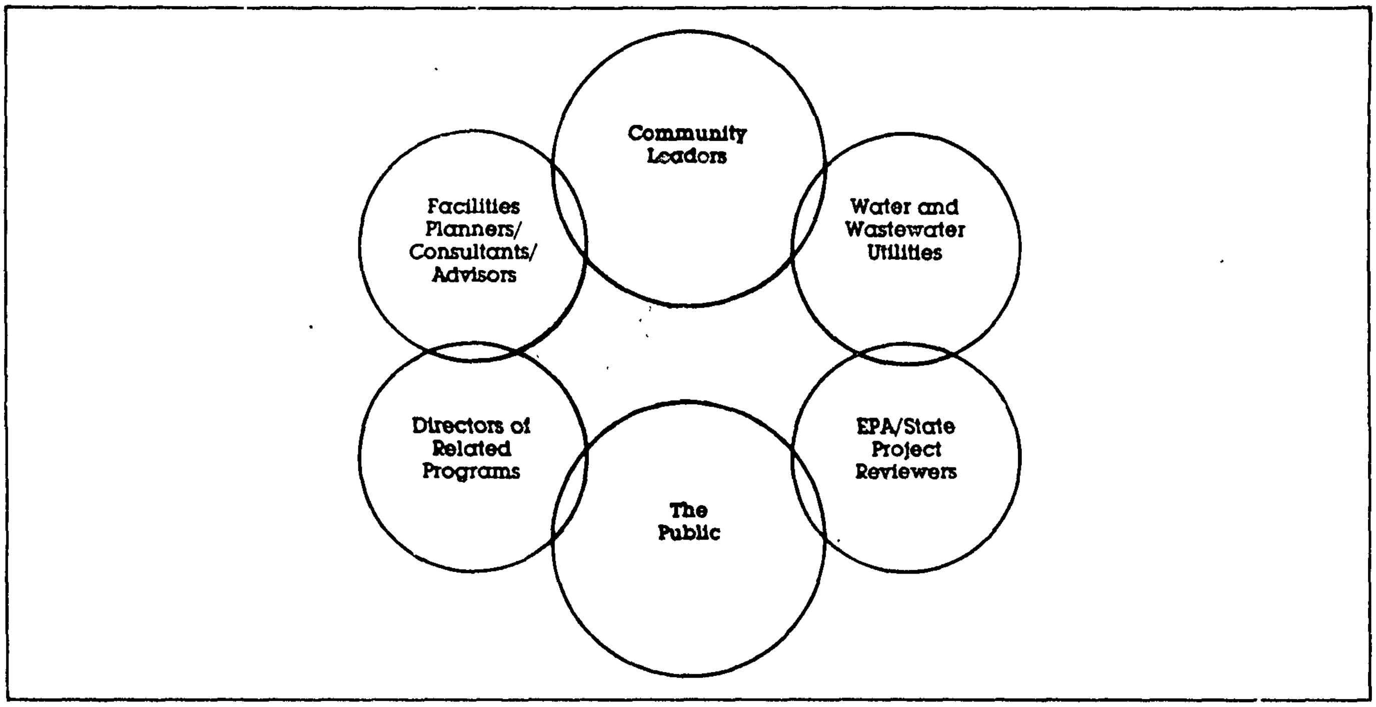


Figure 5 Who Participates In Flow Reduction Planning?

roles Vital to the success of any flow reduction program is that it be developed and implemented with full consideration of and full cooperation from all parties concerned The number of parties involved and the nature and extent of their involvement will vary with each particular community's circumstances but, as indicated in Figure 5, will most often include

- **Community leaders** They are the primary decision makers in selecting a program Their support for the program and the associated implementation and public information effort is vital to program success
- **The public** This group is comprised of individuals and groups in the affected planning area They can contribute to flow reduction planning by providing input and support during the planning process, and by being receptive to, or assisting in, the public information campaign They also assume primary roles in program implementation by supporting and using those measures comprising the program
- **Water and wastewater utilities.** They provide the data essential to the analysis and will be primary agents of program development and implementation Obtaining cooperation from the water supply utility early in the process is vital since the program will directly affect the utility and must be one which it can support
- **Directors of related programs** Those carrying out water conservation, energy conservation infiltration/inflow and other programs related to flow reduction can be useful sources of information Coordination with related programs can help avoid duplication of efforts and promote overall program efficiency
- **Facilities planners/consultants/advisors** They are responsible for developing the flow reduction program and incorporating its objectives into the facilities plan
- **EPA/state project reviewers** These professionals can provide input into programmatic aspects of the planning process They will also review the facilities plans which document results of the flow reduction analyses

I. How Can this Document Assist Municipalities in Responding to the Regulations?

In its cost-effectiveness guidelines, EPA outlines the key components of a flow reduction analysis and cites specific measures to be considered in developing a flow reduction program To help municipal planners both meet the requirements and develop a program of potential benefit to their communities, this document does the following

- Outlines a step-by-step process which municipal planners can follow in developing and evaluating alternative flow reduction programs
- Identifies and describes typical flow reduction measures and devices
- Provides information on the costs and cost savings to communities utilizing flow reduction measures
- Provides generic models and sample calculations which a planner can follow in performing the required cost and cost savings analyses of alternative programs
- Develops a framework to guide selection of a final flow reduction plan
- Provides references where more information about flow reduction measures and programs can be obtained

J. Four Examples of Programs Other Communities Have Implemented

1. Oak Park, California

A relatively simple, small community program was implemented in Oak Park during the 1976-1977 drought. A community consisting of 762 relatively new, single-family homes, Oak Park was one of six areas selected for a Pilot Water Conservation Program conducted by the California Department of Water Resources. Key aspects of the program include (California DWR March 1978)

- **Program Components** Free distribution and professional installation of water saving toilet and shower devices, a public information program
- **Program Costs**

Retrofit Devices	$ 2,500
Informational Material and Postage	200
Installation	7,200
Project Coordination and Preinstallation Preparation, Public Relations and Information	7,900
Total	$17,800

- **Significant Findings**
  - Annual net benefit per household = $16.83
  - Estimated annual savings in local system water and oil costs = $16,900
  - Equivalent annual direct program cost (amortized over 5 years at 6 percent interest rate) = $4,225
  - Of those persons contacted, 91.4 percent participated, 2.6 percent could not be contacted
  - Retrofit devices were installed in 88.6 percent of toilets and 75.9 percent of showers
  - Total monthly water deliveries decreased by as much as 31 percent as compared to the same month in 1976

2 Elmhurst, Illinois.

Located 15 miles west of Chicago, Elmhurst is primarily a residential community of approximately 45,000 which also supports a major hospital, a private college and an industrial development. Elmhurst, which owns and operates its own water supply and wastewater treatment systems, implemented a moderately complex, moderately costly program (Fulton, 1978)

- **Program Components** public information program, rate changes to encourage conservation, plumbing code amendments requiring water-efficient appliances, control of outdoor water use, free distribution of toilet tank dams, orifice reducers for shower heads, and dye tablets for leak detection
- **Program Cost** approximately $45,000 or $1 per capita
- **Significant Findings** preliminary results indicated a decrease in peak day water consumption of 30 percent in 1977 compared to 1976. The community was able to cancel construction of a $400,000 peaking well

3 Denver, Colorado

Serving a city resident population of 535,000 and a surrounding resident population of 375,000, the Denver Water Department undertook a water conservation program primarily consisting of public information and education. Key aspects include (Metcalf & Eddy, Inc., 1976)

- **Program Components** leaflets containing water conservation tips, radio jingles and spot announcements, animated color films, slide show, questionnaire to survey public attitudes, continued use of water news publication mailed with water bills
- **Program Cost**: estimated cost for 1973-1975 is $50,000 with an additional $35,000 for production of color film
- **Significant Findings** the public information program received a relatively high response rate on the questionnaire. Actual effects of the conservation effort are unclear. Total

water use in 1973 was 11 percent lower than in 1972, but 1974 use rose to 1972 levels The first 9 months of 1975 indicated a 9 percent reduction from 1974 use It was reported that 1974 was a warmer than average year, possibly accounting for the increase Achieving a definitive assessment of results in Denver is further complicated by the fact that older areas of the city are unmetered

4. Washington Suburban Sanitary Commission.

The Washington Suburban Sanitary Commission (WSSC) is an independent bi-county agency providing water and sewer services to approximately 1.2 million Maryland residents It initiated its relatively large-scale, and sophisticated Water Conservation/Wastewater Reduction/Customer Education Program to deal with a shortage of sewer capacity, and potential shortage of water supplies, to help offset increasing capital and operating expenses and to respond to an apparent public desire for such a program The program has served as a model for others

- **Program Components** public information including distribution of a water conservation handbook, holding workshops, and creating a 20-minute film, distribution of 300,000 toilet displacement "bottle kits" and leak detection pills, free shower flow control devices plumbing code changes requiring water saving toilets and shower heads, and pressure reducing valves in certain areas, a water conservation device test project covering 2,400 homes, and, most recently, institution of a conservation-oriented rate structure
- **Program Cost** over $500,000 was spent on the program between late 1971 and July 1975, equivalent to slightly over $2.00 per customer account (Grear, 1975)
- **Significant Findings**

  - A net minimum savings of 5.4 mgd was achieved in 1974 (as compared with 1972) amounting to a 4.42 percent reduction in overall flows Since this is a conservative estimate, it is quite possible that WSSC achieved its goal of a 5 percent reduction of indoor water use and resulting wastewater flows (WSSC, 1974)

  - Results from the test project (involving retrofit of toilets, shower heads and pressure reducing valves) indicated an 18 to 20 percent reduction in water consumption over a one year period in single family residences and a 12 percent reduction in apartment units (Bishop, 1975)

  - Preliminary indications, based on a limited time period, are that implementing the increasing rate structure has had an impact on residential customers but has not caused significant changes in commercial and government water use (McGarry 1978)

K. Key Steps in the Flow Reduction Analysis

Part II of this document is a guide to carrying out a flow reduction analysis The methodology developed in the guide consists of a sequence of steps which incorporates sufficient flexibility to accomodate differing community circumstances The steps of the flow reduction analysis are portrayed in Figure 6 and briefly described in Table 3

A	**Is Flow Reduction Analysis Required?** Examine exemption criteria and determine whether flow reduction analysis is required
B	**Without-Flow-Reduction Condition** Determine present and projected water use and wastewater flow characteristics without flow reduction to establish a base condition
C-1	**First-Cut Program.** Evaluate available flow reduction measures and develop a first-cut community program
D	**Costs and Benefits** Determine the full range of monetary and nonmonetary costs and benefits of the program alternative A with program/without program comparison is used in calculating monetary cost-savings
E	**Have All Reasonable Alternatives Been Considered?** Consider whether a better program may result from modifying the first-cut program or developing an entirely new program
C 2	**Modify Program or Develop Alternatives** If the response to Step E is no loop back to Step C-2 and then proceed through Step D to evaluate this new alternative When all alternatives have been evaluated proceed to Step F
F	**Public Participation Meeting** Present the analysis findings at a facilities planning public meeting or hearing Obtain public input and make appropriate changes in alternative programs and their evaluations
G	**Select a Flow Reduction Program** Evaluate the alternatives according to established selection criteria and select a recommended program
H	**Incorporate Into Facilities Plan** Make appropriate adjustments in the facilities plan documenting the recommended flow reduction program and its impact on wastewater flows

Table 3 Steps In Flow Reduction Analysis

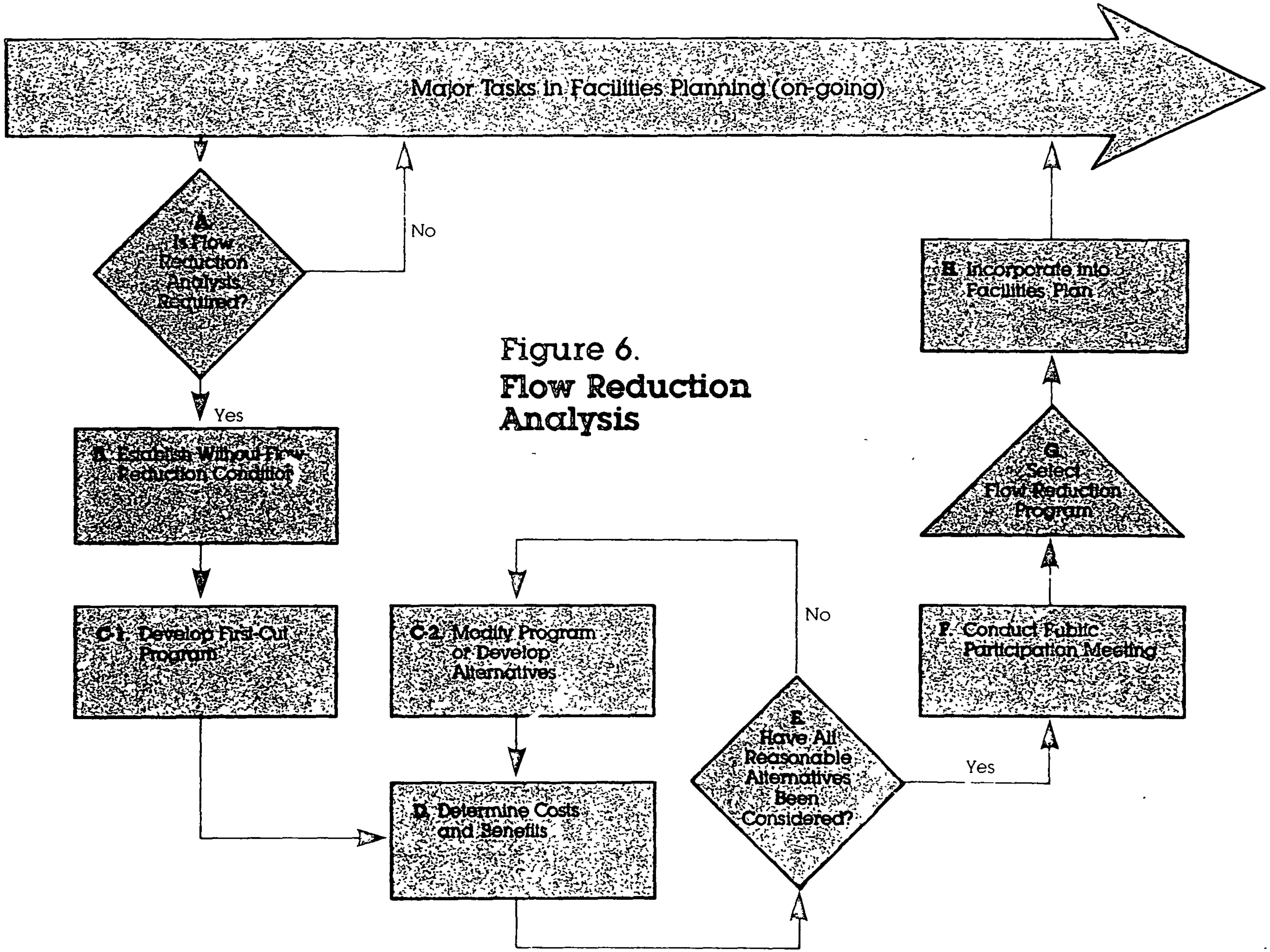


Figure 6.
Flow Reduction Analysis

II A GUIDE FOR FLOW REDUCTION ANALYSIS

The flow reduction analysis approach presented here is meant to serve as a guide for facilities planners charged with responsibility for performing a flow reduction analysis during the facilities planning (Step 1) phase of the Construction Grants process It represents one framework that can be used to structure thinking about the flow reduction measures a particular community might choose to adopt It is designed to be adaptable to individual community characteristics (it is not to be taken as a rigid set of directions for flow reduction planning) and to be nondisruptive to other elements of the facilities planning process The parallel relationship and interconnections between the flow reduction analysis and other tasks of facilities planning are evident from Figure 4 (page 10)

The methodology for flow reduction analysis developed herein consists of a sequence of steps that can be followed both to meet the requirements of Section 8c of EPA's Cost-Effectiveness Guidelines for Step 1 facilities planning, and to establish the foundation for a cost-effective and implementable community-wide water saving/flow reduction program As such it is the first phase of an effort that will continue throughout Step 2 (design) and Step 3 (construction) of the Construction Grants process should the results of the analysis point toward the desirability of instituting a flow reduction program in a particular community Thus the "bottom line" of flow reduction analysis is a **Flow Reduction Program** consisting of three vital components As illustrated in Figure 7, these components are

- A package of structural and nonstructural flow reduction measures for reducing water use and thus achieving reduction of wastewater flows
- A plan for informing the public about these water saving/flow reduction measures and the benefits to the community and consumers of adopting them
- A plan for implementing both the water saving/flow reduction measures and the public information effort, including interagency coordination agreements, budget and manpower requirements, schedule, and the like

These program components are mutually supporting and essential for achieving immediate and long-term water savings and the resultant wastewater flow reductions in the context of a community's wastewater management program

The remainder of Part II presents information to assist in performing each step of the flow reduction analysis approach depicted in Figure 6 (page 15) For each step several types of information are provided, depending on the complexity of the analysis involved, including (1) purpose of the step, (2) data and information needs for executing the step, (3) suggestions about a procedure to follow, (4) examples of possible methods of calculation or analytical procedures, and (5) observations on important factors to consider in carrying out the analysis Although the presentation is linear in that steps are described in sequence, the approach illustrated in Figure 6 (page 15) is intended to be nonrestrictive as exhibited by the following features of the guidance·

- **An emphasis on alternatives** As exemplified by the loop in Figure 6, the flow reduction analysis approach is intended to result in an array of potentially workable programs each of which is then analyzed and refined A "first cut program" is identified quickly to provide a tangible benchmark for evaluation and to obtain insight into information needs for public involvement and for program implementation The methodology then shifts emphasis toward identifying and evaluating alternatives which may be either modifications of the first-cut program or entirely new approaches
- **Practicality** Although there are exotic methods of achieving flow reduction that may be appropriate in certain situations, the methodology developed here stresses practical measures which will usually apply to an average community's circumstances
- **Consideration of both monetary and nonmonetary costs and benefits** The approach recognizes that monetary savings are not the only consideration in effective program planning - a myriad of social, political, economic and environmental effects may also be associated with each alternative and warrant equal consideration Thus, maximizing total community welfare through a water saving/flow reduction program is emphasized

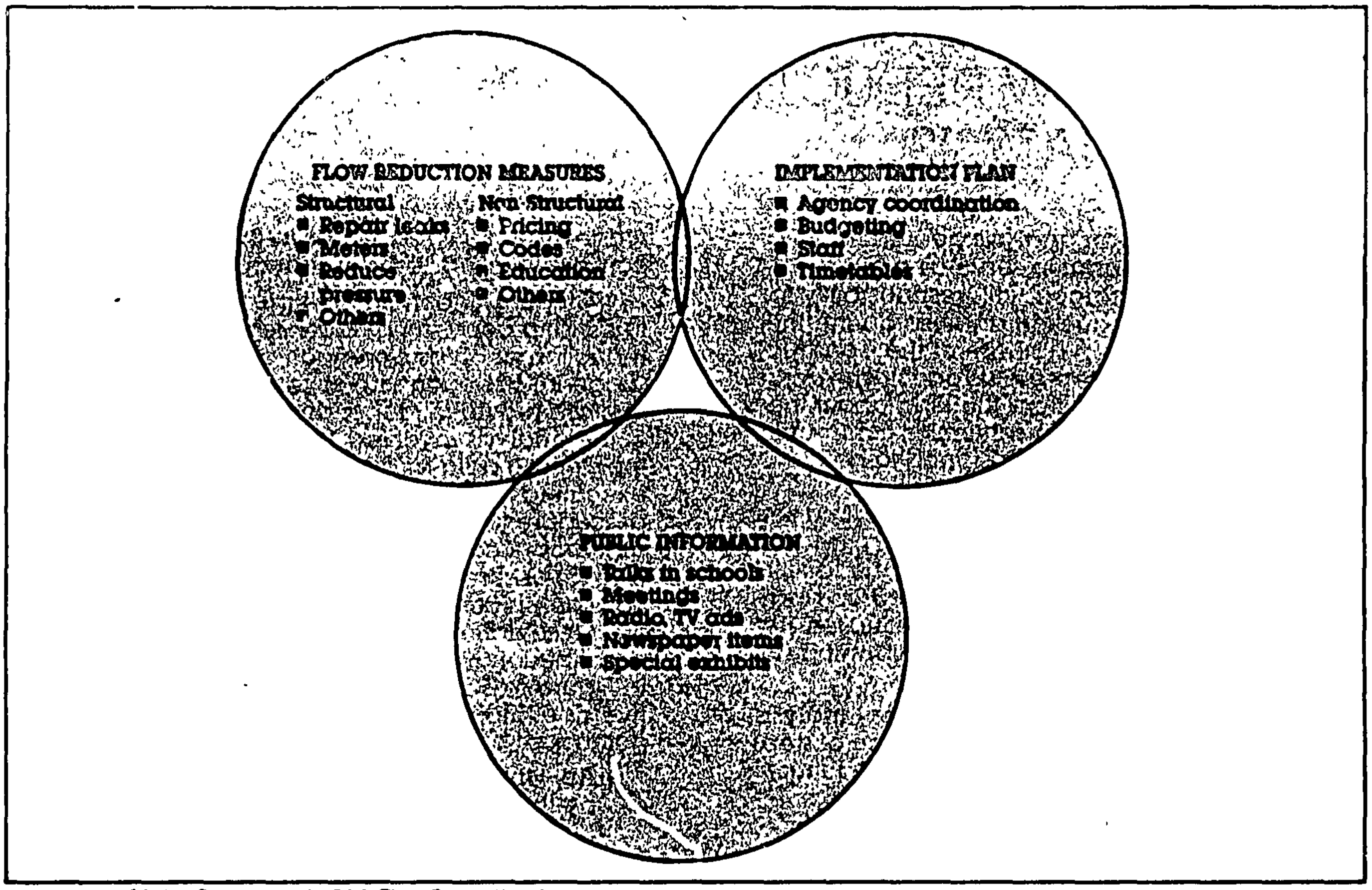


Figure 7 **Major Components Of A Flow Reduction Program**

- **An emphasis on public participation.** The approach recognizes that successful development and implementation of a flow reduction program requires understanding and support from community officials and the public. An effective public information effort is crucial to developing this needed support and to fostering informed public input. Input from a range of "publics" is essential throughout program planning to determine the acceptability of various options, to obtain insights about potential effects previously overlooked, and to encourage interest in the program's objectives. Thus, active coordination with, and support from, water supply and energy utilities as well as from businesses, industries and public agencies is a hallmark of the approach.

  It is also recognized that participation by the general public in developing the flow reduction program through workshops or public information meetings, can and should be coordinated with public participation for facilities planning, both for efficiency and for clarifying the relationship between the two processes

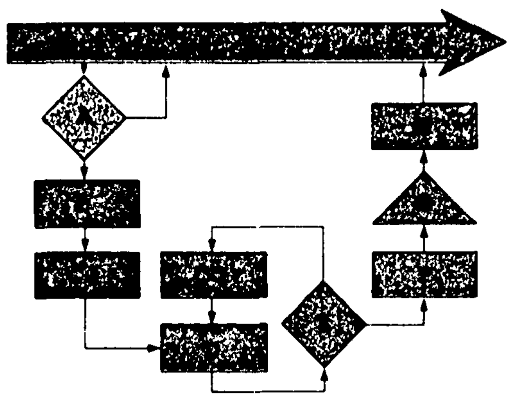
- **An iterative process.** Although the approach is portrayed as a sequence of steps, the methodology is in fact open ended at every phase. Program components are added, subtracted or modified as more information is obtained about costs and benefits. Public input may in turn provide more information about costs and benefits necessitating further redesign of program alternatives, and so forth

- **Examples** provided with the various steps are intended to show how needed calculations can be performed and how the cost-benefit analysis of program alternatives can be carried out. Thus they are illustrations of how one can go about the analysis, rather than cookbook recipes to be followed to the letter, and modifications may be necessary to suit each particular case.

Emphasis on flow reduction measures. In this document emphasis is placed only on those measures that would result in reducing flows into the wastewater facility. Within this context, flow reduction measures are considered to be a subset of all water conservation or water saving measures Thus throughout this document the terms "flow reduction", "water conservation", and "water saving" are used interchangably, even though water conservation measures unrelated to flow reduction (e.g., techniques for saving water used in outside lawn irrigation) are not considered herein.

- **More detailed information** on individual flow reduction measures is provided in Appendix B to assist in evaluating the various components of a first-cut program; additional detail on cost-effectiveness calculations is provided in Appendix C; and, additional sources where more information can be found are cited in Appendix D

The following material is organized by steps (see Figure 6, page 15) with a general outline of each step preceding discussion of it



Step A.
Is Flow Reduction Analysis Required?

Conditions for exemption:

- ADBF is <70 gpcd, or
- Current population of applicant municipality is <10,000, or
- Regional Administrator has exempted area for having in existence an effective flow reduction program.

A. Is Flow Reduction Analysis Required?

1. Statement of Purpose

The purpose of this step is to determine formally, according to the criteria set forth in EPA's Cost-Effectiveness Guidelines, whether or not a flow reduction analysis is required.

2. Data and Information Needs

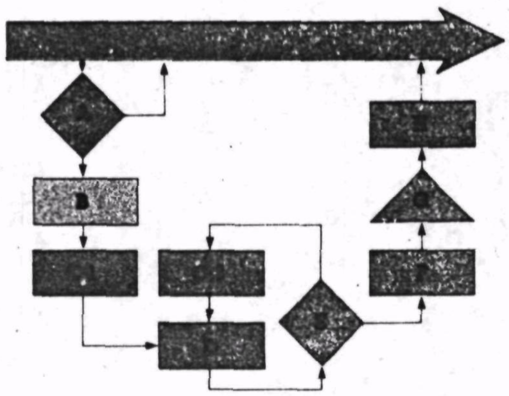
The data required to respond to this initial step should be readily available from the facilities planning effort and include:

- Existing average daily base flow (ADBF) from the area. ADBF includes flows from residential, commercial and institutional sources, as well as industries with flows of less than 25,000 gallons per day (gpd). (See Cost-Effectiveness Guidelines, Section 8b, in Appendix A.)
- Current population of the applicant municipality. Note that the definition of "municipality" in the Construction Grants Regulations applies to special districts such as water, sewer, or sanitary districts that provide wastewater services to the surrounding community. Excluded are those special districts (e.g., an airport) which do not serve the surrounding community. If there are multiple municipalities within the planning area, one or more may be exempt if the exemption conditions are satisfied, even though the analysis is required for other communities in the area.
- Knowledge of whether exemption from flow reduction analysis has already been granted.

3. What To Do

- Determine whether the existing ADBF lies below 70 gallons per capita per day (gpcd). Existing ADBF may be determined by subtracting from the historical dry-weather flow both dry-weather infiltration and specific industrial flows which exceed 25,000 gpd, and then dividing by the existing sewered resident population.
- Determine whether the current population of the applicant "municipality" is under 10,000.
- Determine whether or not the Regional Administrator has exempted the area for already having an effective flow reduction program in existence.

If one or more of these conditions is met, the applicant is exempt from the flow reduction analysis requirements. The applicant may nevertheless choose to undertake a flow reduction analysis to obtain the cost savings and nonmonetary benefits which a program can bring to a community. Even when not required, such an analysis is a grant-eligible part of the wastewater facilities planning costs.



Step B. Establish Without-Flow-Reduction Condition

- Assemble data from facilities planning:
  - preliminary estimates of total wastewater flow, both existing and future.
- Additional data needs:
  - breakdown of water use by sectors.
  - relationship between average and peak water use.
  - projections of future water use.
- Evaluate data and formulate goals for flow reduction program.

B. Establish Without-Flow-Reduction Condition

1. Statement of Purpose

The objective of this step is to determine and document the water supply, wastewater flow and related conditions as they exist and are projected without flow reduction. This establishes a base condition for use in later analysis steps.

2. Data and Information Needs

Much of the information needed for this step should be available from the facilities planning process Data such as population, water use and wastewater flow characteristics are organized to portray the "without-flow-reduction" condition, so as to establish a benchmark case against which the "with-flow-reduction" condition can be compared. Specific data needs and sources of information are:

- **Information on the breakdown of water use by sectors** within the municipality, even if only approximate. To the extent possible, this breakdown should include water use in the residential, commercial, industrial and public sectors and differentiation of seasonal from nonseasonal use where appropriate. Water billing records are the major source of information on water use Where disaggregated billing data do not exist, any significant industrial users (i.e., those using more than 25,000 gpd) can be manually separated and the remaining water use divided between residential and nonresidential use according to meter size. Water production records can be used along with billing data to estimate the amount of water lost or unaccounted for (Baumann et al., 1980) If water use is not metered, estimates of residential and nonresidential use can be made based on total water production and knowledge of residential and nonresidential land use patterns.
- **A breakdown of indoor versus outdoor residential use and categories of indoor use.** Indoor use may be approximated by winter season residential water use in most cases. For an average community, the breakdown of indoor water use provided in Table 2 (page 5) should be fairly accurate.
- **Projections on water use by sector** over the planning period In most cases, forecasts of water use made by local agencies will not be disaggregated by category of use. If time allows and the task is not too formidable, an attempt can be made to develop disaggregated forecasts based on disaggregated billing data (where available), local agency water use projections, population trends and forecasts, and other available information (Baumann et al., 1980). Where the time, resources or data required to make disaggregated forecasts do not exist, lumped forecasts already available can be used, basing future percent allocations for each sector on reasonable assumptions about expected changes in these percentages over time Unless there is reason to expect otherwise, (e.g., it is known that several large water using industries will be moving into the community in the near future), the proportion of water used by each sector can be assumed to remain constant.
- **Estimates of existing and future average wastewater flow conditions** without consideration of flow reduction. These estimates should already have been made on a preliminary basis as part of the facilities planning process. Four major components must be considered in these flow estimates:

  - Average daily base flow (see previous discussion of Step 1, and Section 8b of the Cost-Effectiveness Guidelines provided in Appendix A for methods of estimating existing and future ADBF) Note that allowances for future increases of per capita flow over time are not permitted.
  - Present and expected future flows from specific industries which exceed 25,000 gpd.
  - General allowance for future industrial flows
  - Nonexcessive infiltration and inflow.

- **Estimates of peak water use and wastewater flows.** In many instances (particularly where there are significant outdoor residential or seasonal industrial water uses bearing on the water supply system or where there is large infiltration/inflow to the wastewater facility) peak hourly or daily water demand and peak daily wastewater flows may be overriding factors in determining the necessary capacity for water supply and wastewater treatment facilities. In making these estimates, consideration should be given to efforts planned or in operation to reduce peak water demand or wastewater flows, such as I/I analysis or flow equalization.

The accompanying data sheets (Tables 4 and 5) are intended to be guides for data collection. Figures need not be entered in every space, particularly under the peak columns. Certain categories, however, will significantly affect peak

Water Use Category	Average Daily Water Use Present	Projected 10 yrs	Projected 20 yrs	Peak-Day or -Hour Water Use Present	Projected 10 yrs	Projected 20 yrs
Residential						
▪ Nonseasonal (= indoor)						
▪ Seasonal						
Commercial						
Public						
Industrial						
▪ <25,000 gpd						
▪ >25,000 gpd						
Allowance for Industrial Growth						
Unaccounted-for Water						
Total						

Table 4. **Sample Data Sheet For Water Use Projections**

daily or peak hourly estimates; e.g., outdoor residential use on the water supply side (from extensive sprinkling during dry periods) and seasonal industrial flows on the water supply or wastewater side (such as from fruit canning industries).

3. What To Do

The data acquired are used to determine the system capacities needed to meet estimated water supply and wastewater treatment needs over the planning period. Both average and peak conditions should be considered in making these estimates of total water supply over time and total wastewater flow over time. The data are then analyzed to determine the necessary staging periods for facilities construction and expansion; this determination of the without-flow-reduction condition can be used in later comparisons of staging requirements for the with-flow-reduction condition. A diagram similar to that shown in Figure 8 may be useful for organizing results and displaying them in a meaningful way to the public.

This without-flow-reduction condition is then evaluated to determine appropriate goals for the flow reduction program in light of specific characteristics of the community. These goals may be in the form of specific targets that a flow reduction program is designed to meet (e.g., reducing ADBF by x amount by year n), or they may remain general (e.g., attempting to maximize total community net benefits). Specific consideration should be given to (1) selecting target sectors for flow reduction, and (2) deciding whether to focus on peak flows or average flows. For purposes of carrying out the next step (i.e., developing a first-cut program) explicit attention should be given to whether the goal(s) established are immediate or long-term, and why.

4. Example

A community may find it particularly useful to set a target for the program if the municipal wastewater treatment plant is nearing capacity and the possibility of an overload looms ahead. Such a community may want to set a target to reduce average daily base flow or peak flow by some percentage (say, 5 percent) over a relatively short time period. An appropriate longer-term goal might be to sustain the initial success through continuing public information.

5. Major Observations

- The more disaggregated the data on water use and wastewater flows, the better the opportunity will be to focus on those sectors and activities for which the flow reduction potential is greatest.
- The availability of data to a large extent determines how this step will be carried out. At the very minimum, residential use, nonresidential use and public/unaccounted-for water should be distinguished, as well as seasonal from nonseasonal residential uses. This latter distinction is important since a large portion of seasonal residential water use is not discharged to sewers (Baumann, et al., 1980).

Wastewater Flow Category		Average Daily Wastewater Flow			Peak-Day Wastewater Flow		
		Present	Projected		Present	Projected	
			10 yrs	20 yrs		10 yrs	20 yrs
Comprise ADBF	**Residential (Indoor)**						
	Commercial						
	Public						
	Industrial (<25,000 gpd)						
	Industrial (>25,000 gpd)						
	Allowance for Industrial Growth						
	Infiltration/Inflow						
	▪ Excessive						
	▪ Nonexcessive						
Total							

Table 5 **Sample Data Sheet For Wastewater Flow Projections**

- Careful consideration should be given to the classification of apartment water use Frequently, this use is classified as commercial, yet for the purposes of a flow reduction program, apartment use will be responsive to measures geared toward the residential sector
- Clearly, these data needs require the cooperation of, and perhaps assistance from, the water supply utility Explicit consideration should be given to what formal or informal agreements may be appropriate to secure these arrangements. Establishing good working contacts with the water supply utility early in the process will also prove helpful (perhaps essential) to activities carried out later in the analysis. Thus, involving this segment of "the public" early in the planning effort is one aspect of public involvement, aimed toward the eventual task of implementing a flow reduction program.

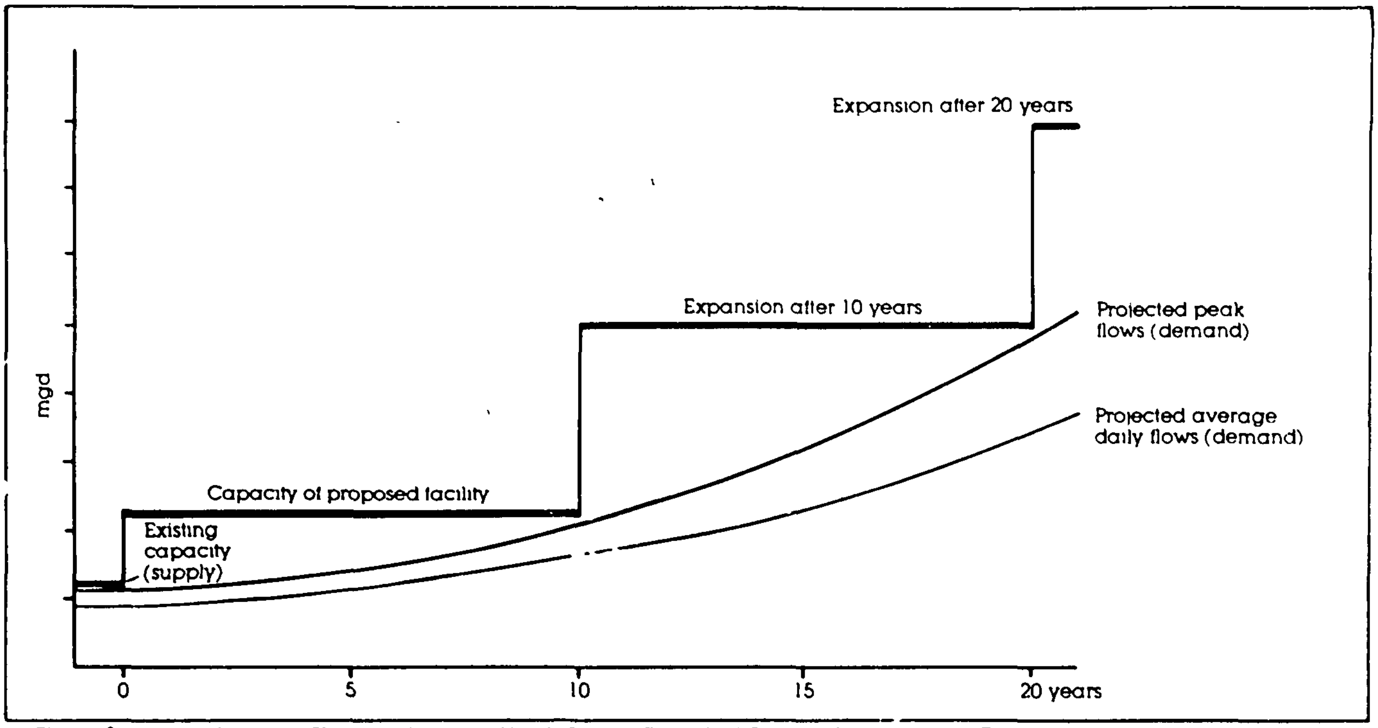
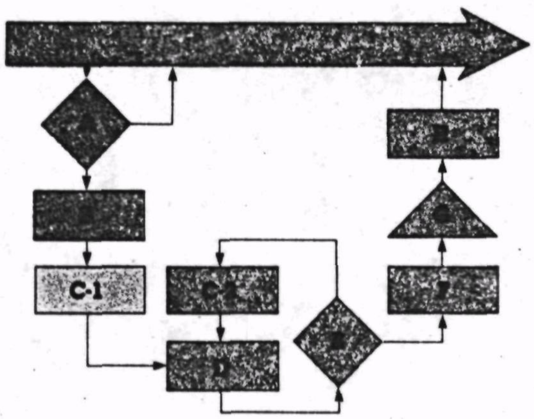


Figure 8 **Sample Diagram Showing Capacity Needs Versus Time And Staging Requirements For The Without-Flow- Reduction Condition**



Step C-1. Develop First-Cut Program

- Select individual flow reduction measures and synthesize a flow reduction package including:
  - structural measures
  - economic measures
  - legal/institutional measures
  - educational measures.
- Define a supporting public information program.
- Address implementation issues and develop an implementation plan.

C-1. Develop First-Cut Flow Reduction Program

1. Statement of Purpose

The purpose of developing a first-cut flow reduction program is to provide the planner with a tangible starting point for the program analysis. As implied by Figure 7 (page 18), this first-cut program should consist of the three basic components:

- A first-cut package of flow reduction measures.
- A first-cut plan for informing and involving the public.
- A first-cut implementation plan.

Through the evaluation of this first-cut program, the planner will get a better sense of the range of attractive alternatives available; the various "publics" (e.g., utilities, community officials) who should be involved, and why; and possible implementation issues. This step should be viewed as a learning experience, the final product of which is a first guess as to what might constitute a practical flow reduction program.

2. Data and Information Needs

In order to develop a first-cut flow reduction program, it is necessary to know the flow reduction measures available for inclusion in such a program and to have enough information on each particular measure to be able to assess its probable effectiveness and applicability given the circumstances at hand. To help meet these information needs, this document does the following:

- Describes, in this subsection, the categories or types of measures available; for specific measures, basic information about effectiveness, limitations to use, and potential for savings are provided where appropriate. This information can be used to make a preliminary selection of measures to be included in the first-cut program.
- Discusses, in Subsection 3b, basic considerations in formulating a public information/involvement effort.
- Discusses, in Subsection 3c, possible implementation issues and key elements of an implementation plan.
- Provides more detailed descriptions of specific flow reduction measures in Appendix B (i.e., devices, pricing mechanisms, and building codes).
- Assesses the relative economic benefits of common water saving devices in Appendix C.
- Provides examples of how to calculate the annual net monetary benefits of common water saving devices in Appendix C.

a. Categories of Flow Reduction Measures

Flow reduction measures can be grouped into four basic categories which stress the thrust of the implementation mechanism used for each: structural, economic, legal/institutional and educational. Common flow reduction measures in each of these categories, and the basic characteristics thereof, are listed in Table 6 and discussed in the following paragraphs.

1) Structural Methods. Structural methods of saving water, and thereby reducing wastewater flow, concentrate on improving efficiencies in the physical aspects of water using systems. Generic types of structural methods include: leak detection and repair on the user's premises, metering, flow control and water saving devices, recycling systems, and hot water line insulation. The following discussions are intended to provide a glimpse of the range of options available; further detail on individual devices is given in Appendix B.

a) Repairing leaks in water using fixtures in homes and businesses can reduce wastewater flow significantly. On premise leaks most commonly occur in faucets and toilets. Faucet leaks usually are caused by worn washers. Replacing the washer – an inexpensive task requiring little time – is frequently all that is necessary. Toilet tank leaks may result from a worn supply valve, a tank ball improperly seated or a leaking tank float. Many toilet leaks, though easy to repair, are virtually invisible and thus may go undetected. A colored dye placed in the toilet tank can be used to detect leaks quickly and inexpensively. Even so, the relatively high cost of plumbing service and low cost of water may cause many water users simply to ignore leaks until they become severe (California DWR, 1976). A public campaign emphasizing the minimal amount of effort involved in some leak repairs and their beneficial effects could produce positive results.

b) Installation of water meters is designed to sensitize customers to water use and water price. Metering is essential if pricing mechanisms are to be used as conservation incentives. In principle, the idea is to reduce water use by raising the marginal cost of water to the user from zero to some positive amount. Meter purchase, installation, maintenance, reading and billing require significant expenditures for both new connections and in existing unmetered connections. In areas of the country where there

Table 6. Characteristics of Common Flow Reduction Measures

Measure	Description	Applicability	Effectiveness	Limitations
Structural Measures				
Leak Detection and Repair	Encouraging residences and businesses to actively detect and repair any leaks in fixtures such as faucets and toilets.	General The potential for leaks to develop and contribute to wastewater flow exists in all homes and businesses	Variable In areas with large numbers of substantial leaks, an active public effort to detect and repair them could be very effective	For hard-to-fix leaks, the homeowner may not be willing to pay the cost of a plumber for repairs
Installation of Water Meters	Meters installed to measure water use, thereby creating incentive to conserve and permitting price systems that encourage conservation	New or existing construction	Essential for utilization of pricing. Effective consciousness-raising measure which will enhance effectiveness of other flow reduction measures Much of direct water saved will likely be from outdoor irrigation uses.	Expensive, especially in existing unmetered connections.
Installing Water Saving Devices				
A Showers and Faucets				
1. Flow controls	Reduces water flow rate	■ Retrofit (plastic inserts available). ■ New construction.	Reduces flow rates to about 2 gpm.	Some public dissatisfaction with low flow, but this should not be prohibitive.
2. Low flow shower heads	Shower heads with lower flow rates than conventional	■ New construction. ■ Retrofit.	Reduce flow rates to between 1.5 and 3 gpm (Conventional range is 3 to 8 gpm.)	No major limitations.
3 Aerators and spray taps (for faucets)	Reduces water flow rate by delivering water in a spray.	■ Retrofit. ■ New construction	Reduce flow rates to between .75 to 2 gpm.	No major limitations
B Toilets				
1. Flush valve	Forceful flushing action made possible by oversize feed line and quick release valve.	Most common in commercial establishments (restaurants, service stations, etc)	Estimated water savings of 1 to 2 gallons per flush over conventional type New types very water efficient.	None for commercial use Installation costs may be drawback to residential use
2. Shallow trap	Smaller tank than conventional; less water retained in bowl.	■ New residences. ■ New businesses unable to install flush valve.	Estimated water savings of 1.5 gallons per flush over conventional	Occasional need for double flushing Usually not a problem with proper design.
3. Dual cycle	Uses less water for flushing liquid wastes than solid wastes.	New construction	Estimated water savings of 3.75 and 2 5 gallons per flush for liquid and solid waste flushing, respectively. Experimental stages	Few manufactured in USA. Slightly more complex to operate.
4. Toilet dams and plastic bottles or bags	Through displacement, removes water from the active flush mode.	Retrofitting existing fixtures.	Estimated water savings of .7 to 1.5 gallons per flush over conventional.	No major limitations
5. Exotic waterless toilets	Use means other than water for eliminating waste (oil, biological decomposition, incineration, etc.).	■ New construction. ■ Depending on type, some useful only for particular housing densities or where central sewer is lacking.	Effectively reduces wastewater flow since no water is used.	Generally expensive Most have low public acceptance. Some have high energy demand.
C. Water Saving Clothes Washer	May have either a suds-saver for reuse of wash water or a variable water level and temperature control.	Must be built into original equipment.	Water saved depends on user. May reduce water used for normal cycle by 10 to 15 gallons over conventional model.	Suds-saver requires fairly large service sink
D. Water Saving Dishwasher	May feature cycle adjustment controls.	Must be built into original equipment.	May reduce water used for normal cycle by 3 to 4 gallons over conventional model.	No major limitations.

Measure	Description	Applicability	Effectiveness	Limitations
E. Pressure Reduction	Regulate the flow of water for individual services or distributional zones by installing valve to reduce pressure in service lines.	■ New construction. ■ Retrofit	Estimated potential water savings of 20 percent of total use.	■ May cause problem with outside irrigation systems designed for previous pressures. ■ Retrofit requires professional installation but likely still cost-effective.
Residential Water Recycling	Systems allowing the same water to be used for a sequence of functions, each requiring water of somewhat lower quality.	Appears more effective for multiple developments rather than single-family dwellings.	Amount of water saved is variable but significant. Possible net savings of 23 percent of primary water used.	Expense. Public acceptance may be low.
Insulation of Hot Water Lines	Insulating pipes to reduce time it takes for water to become hot.	Most easily done in new construction.	Estimated water savings of 3 percent of indoor use; substantial energy savings possible	Difficult and expensive in retrofitting.
Economic Measures Pricing Changes	Altering the water pricing schedule to encourage conservation. Trend toward increasing block rate structure; peak demand pricing.	■ Can be useful in any sector. ■ Requires metering.	Variable. Depends on water and sewer prices, demand elasticity, percentage of water used in various water-use categories, and other factors.	Public acceptability may be low. May be economically regressive
Demand Metering	Measure both volume of water used and time of use — price is higher during times of peak demand.	Potential alternative in areas replacing meters or previously without meters.	Uncertain. Still in developmental stage.	Still in experimental stage. Complications in meter design.
Legal/Institutional Measures Changing Building and Plumbing Codes	Legally mandate installation of water saving devices or fixtures	■ New construction. ■ Replacement for old fixtures.	Some areas have estimated that substantial savings would result in long run. Changes affect indoor use and would thus directly reduce wastewater flows.	May take several years to see significant results. Mandated retrofitting would likely meet social and political resistance.
Educational Measures Public Education/ Communication Program	Program to educate public about flow reduction and to obtain public support and help in program implementation. Achieve habit changes.	Applicable and necessary for the success of any flow reduction program.	Estimated water savings of 5 to 10 percent, although hard to differentiate effects of education measures from other measures.	No major limitations.

Information synthesized from: Feldman (1977),
Flack et al. (1977),
Hopp (1979),
Metcalf & Eddy, Inc. (1976),
Milne (1976),
and Nelson (1977).

is considerable outdoor water use (e.g., lawn sprinkling in the western states), much of the reduction in water use brought about directly by meter installation will likely be due to decreased outdoor use of water; that portion of reduced use will have little or no effect on wastewater flows. However, metering is an effective consciousness-raising measure which will enhance the effectiveness of other measures and help generate public acceptance of the flow reduction program.

c) Installing flow control/water saving devices and appliances in residences (and the commercial and public sectors) has proven an effective means of achieving water use reductions. This measure can be applied both as a retrofit plan for existing structures and as part of a conservation plan in new construction. Many communities have carried out retrofit programs with simple flow controlling devices, resulting in reduced water use and reduced household water and energy (to heat water) costs. Table 6 provides examples of some common devices suitable for both retrofit and new construction.

d) In-house recycling is an effective way to reduce water use and wastewater flow - approximately 30 percent of the water used in residences is recyclable and would yield a net saving of 23 percent of the primary water that would be used without a recycling system (McLaughlin, 1975). It usually involves reusing the "grey" water resulting from certain household activities (e.g., bathing or clothes washing) for other uses which do not require clean, pure water (e.g., toilet flushing).

As estimated in 1975, household storage and reuse of water appeared to be cost-effective when the combined water supply-wastewater costs were at least $1.50/1000 gallons (Schaefer, 1975). In the past, relatively low water and sewer rates have limited the situations in which recycling systems appear cost-effective. These rates have been rapidly increasing in some areas, however, and recycling systems may become increasingly economical. Moreover, they may be useful options in areas where water is in critical supply or where waste disposal and treatment systems are severely loaded.

Although an effective flow reducing measure, the installation of recycling systems will remain a consumer's choice. Aside from informing the public about grey-water reuse in public information activities of the flow reduction program, it is unlikely that in-house recycling will play an important role in an average community's broad-based program.

e) Insulation of hot water lines reduces the amount of time needed for water to become hot once turned on. Less water is thus wasted waiting for the hot water to arrive. Although insulation is most easily installed at the time of construction, it can also be installed on portions of piping in existing units exposed in the foundation area (Nelson, 1977). While this measure is more effective as an energy saver, it has been estimated that water savings of 3 percent of indoor use may result (Feldman, 1977).

2) Economic Methods. Encouraging flow reduction through water conservation by economic methods can be accomplished through action by the water or wastewater utilities. While pricing is the primary economic measure for achieving water use and wastewater flow reductions, "peak demand" metering and other incentives or penalties hold the potential for producing positive results. More detail on pricing mechanisms is provided in Appendix B.

a) Pricing structures are being changed by an increasing number of utilities from the traditional declining block rate to either a uniform unit rate or increasing block rate. An increasing block rate provides the greatest price incentive for conservation by raising the price of each additional quantity of water used.

In designing an appropriate rate structure, it is important to consider the elasticity of demand for water use in each sector. Knowledge about this demand elasticity (the ratio of the percentage change in quantity demanded to percentage change in price) helps to assess what reduction in water use may occur in each sector due to a given price increase. For example, while a laundry operation has little flexibility in its water use and would not respond significantly to price changes, certain industries and commercial operations (e.g., car wash) may be led by price increases to change their production processes or to institute recycling schemes to conserve water (Call, 1978).

Basing wastewater charges on nonseasonal (i.e., winter) water use using an increasing block scale provides increased incentive to reduce indoor water use. Of course, the use of price changes to promote conservation requires metering.

b) Demand metering is essentially a structural means of implementing daily peak demand pricing. It involves measuring incremental volumes of water used and the time of use and then designing a pricing structure which charges more for quantities of water used during peak hours.

c) Other economic incentives for reducing water use include rebates and tax breaks for

Fixture/Activity	Additional Cost/Fixture Above Conventional Cost ($'s): New, Remodel or Routine Replacement	Retrofit Material (+ labor)	Water Saved: Percent of Conventional Use	gpcd	Energy Savings From Hot Water Heating[f] (10^3 BTU's/capita/day)
Toilets	0 - 6	1 - 5 (+0-5)	30 - 55	8 - 11	0
Showers	0 - 5	1 - 5 (+0-4)	25 - 50	2.5 - 5[b]	1.1 - 2.2
Kitchen and Lavatory Faucets	0 - 2	0 - 2 (+ 2)	10 - 30	.5 - 1	0.2 - 0.4
Pressure Reducing Valve	30	30 (+20)	15 - 25 (of in-house use)	3 - 6[c]	1.1 - 2.2
Hot Water Pipes	0 - 20[a]	50 (+80)	4 - 12 (of hot water)	1 - 2	0.8 - 1.5
Clothes Washer	20 - 30	300 (+20)	35 - 65	3 - 6	1.5 - 3.0
Dishwasher	0 - 10	300 (+ 10)	0 - 50	.5[d]	0.4
Education	$2/Residence/Year		10 - 25 (of faucet use)	.5 - 1.5[c]	0.2 - 0.6
Total				17 - 29[e]	4.5 - 8.9[e,d]

a. Insulation at 50¢/foot; counterbalanced by less pipe.
b. Low estimate to allow for 50% baths.
c. Low estimate to lessen double counting.
d. Low estimate to allow for households without dishwashers.
e. Assumes pressure reducers applicable to 30% of residences.
f. Assumes 100% energy efficiency; this is a conservative estimate of energy savings.
Source: U.S. EPA (1979).

Table 7. Ranges of Costs and Water/Energy Savings From Indoor Residential Conservation (Conservative Estimates)

water conserving measures. Penalties or fines for the wasteful use of water may be counter-productive and should be reserved for severe crisis situations.

3) Legal/Institutional Methods.

a) Changes in building and plumbing codes are means of legally requiring the use of water saving fixtures in new construction or remodeling. Particularly in areas experiencing growth, such changes can result in significant reductions in water use. Code modifications are probably the most effective means of ensuring long-term implementation of conservation measures (U.S. EPA, 1979) and hence should be carefully considered in developing a first-cut flow reduction program. It has been estimated that for the Washington, D.C. area, a revision of plumbing codes to incorporate water saving/flow reduction devices would, within fifteen years, save as much as 25 million gallons of water per day in residential use alone (Schaefer, 1975). Appendix B provides additional information on building codes.

b) Placing legal restrictions on new fixtures offered for sale is a way of ensuring that new fixtures purchased within the state, county, or political entity to which the restrictions apply will be of the water saving variety. Some states, including New York and California, have already passed laws of this type.

c) Requiring water and energy labeling of new fixtures and appliances provides a way for consumers to compare the water and energy efficiency of various appliances prior to purchase and informs consumers as to the overall quantities of water and energy used by these appliances. Some manufacturers are already providing this information on a voluntary basis.

4) Educational Methods. Significant water savings can be achieved by educating the public about changes in water-using habits. Turning faucets off while shaving or brushing teeth and taking shorter showers are examples of minor habit changes which can produce positive results. Increasing public awareness about these possibilities for water savings can be accomplished as part of an overall public information program. (Public information program planning is further discussed as a separate task in this step.)

b. Costs and Water/Energy Saving Consequences of Individual Measures

Knowledge about the costs and the water and energy savings possible from individual flow reduction measures is essential in developing a practical first-cut program. Table 7 provides an overview of the range of these costs and savings pertaining to indoor residential conservation measures. Appendix C assesses the relative economic benefits of common water saving devices and provides examples of how to calculate the annual net monetary benefits associated with these devices. The information in Table 6 (page 30) along with that provided in Table 7 is sufficient to allow selection of a reasonable set of flow reduction measures to include in a first-cut program.

3. What To Do

a. Synthesize a First-Cut Program

Developing a first-cut flow reduction program is a subjective exercise which involves synthesizing and evaluating the data and information obtained thus far. Thus, based on common sense and practicality, one makes an initial selection of those flow reduction measures which, when implemented together as a package, seem to satisfactorily respond to the community's water/wastewater characteristics, goals, budget, and potential for savings.

No first-cut program can be suggested here as the "best" or the "right" one. The key to putting together a program with strong likelihood of success is to select flow reduction measures which will be effective and appropriate for the specific community where they will be implemented. Additional insight into the guiding rationale and methods used in developing a first-cut program is provided in another document of this flow reduction series, where two case studies are described. The following questions are designed to stimulate thought and provide direction in developing a first-cut program:

- Given the present and projected water use/wastewater characteristics, should the program be geared toward meeting only long-range goals or immediate goals as well?
- Are there specific program/implementation/timing features which should be included in order to create a broad consensus of support? (For example, should gradual implementation be planned so that per capita decreases in water use are counterbalanced by increased numbers of customers, thereby avoiding a reduction in water utility revenues?)
- Which measures can be eliminated for having effects which are too short or long ranged to meet goals?
- Are there barriers to implementation (e.g., cost, social acceptability) of any of these measures which foreclose their consideration in a practical program?
- Is the price charged for water and wastewater services sufficiently high to make economic measures (e.g., pricing) viable options? Or is the price so low that people simply won't notice a change toward "conservation" pricing?
- What community service groups are available to help carry out continuing public information and public education programs and perhaps to voluntarily distribute retrofit devices to residences?
- What are the key implementation issues which must be addressed in the implementation plan?

The above questions point toward consideration of the cost, effectiveness, timing of effects and social acceptability of individual measures in flow reduction program planning. It is also important to consider the combined effects of measures to be jointly implemented as part of an overall flow reduction program. For example, pricing is sometimes cited as an economic measure for which public acceptability is low; yet substantial public support for conservation-oriented price schedules has been obtained when accompanied by an effective public information campaign.

Perhaps more importantly, it is essential to realize in designing a first-cut program (particularly when specific targets are to be met) that combinations of several flow reduction measures do not usually result in strictly additive water savings. Frequently, adding the expected water savings from two or more individual measures, and taking the sum as the expected total water savings from implementing them together as a package, will result in a significant degree of double counting. For example, since both water saving shower heads and pressure reducing valves affect water use in the same manner, (i.e., by reducing the flow rate), the total amount of water saved is some amount less than the sum of the water saved by each individual measure. Certain measures, such as public education to accomplish changes in water use habits, produce savings that may be fully additive to the savings achieved by other measures. Combinations of more than two flow reduction measures create more complex interrelationships, and the resulting water savings will be dependent upon characteristics of the particular community (Flack, et al., 1977). Although attempts might be made to calculate or measure the combined effects of such measures, the informed judgment of planners or engineers familiar with local water use patterns may be adequate for planning purposes. Double counting is discussed more fully in Appendix C.

b. Define a Supporting Public Information Program

An effective public information program which generates discussion of and support for the flow reduction measures being considered and supplements the implementation plan (discussed in the next section) is vital to a flow reduction program's eventual success. Beginning to think about the elements of such a program, and getting them down on paper, is an important part of the first-cut program development effort. Public information programs can be designed to suit a wide variety of community goals and budgets and should be tailored to fit community needs accordingly. Four categories of elements comprising such a program can be identified (after Lattie, 1977):

- **Direct mail** (e.g., water bill inserts, newsletters).
- **News media** (e.g., news stories, radio and T.V. public service announcements).
- **Personal contact** (e.g., telephone calls, public meetings or hearings, speaking at schools and service clubs).
- **Special events/exhibits** (e.g., displays in shopping centers, county fairs, schools).

Several different mechanisms of information dispersal should be considered for inclusion in the program to ensure that most of the public is reached. For example, giving talks in local schools and at service organization meetings, sending flyers with water bills, and writing articles for community newsletters would likely bring the program's needs and goals to the attention of most of the community. Repeated messages over a period of time, as opposed to a one-shot effort, is also essential.

The cost of carrying out an immediate crisis-oriented public information program or of getting a long-term program underway can vary greatly. For example, it has been estimated that total annual program costs for a residential community of 25,000 could range from $2,000 to $15,000 depending upon such factors as availability of water/wastewater agency staff as opposed to hiring outside personnel, and local design and production costs for things such as informational brochures and films. Substantial savings and increased public support can often be realized by seeking the voluntary help of local youth groups or service organizations (Lattie, 1977). An effective public information program can be designed to fit the budget limitations of almost any community. As with the set of selected flow reduction measures, the type of program that is appropriate will depend upon the particular community's circumstances.

c. Address Implementation Issues and Develop an Implementation Plan

The ability to implement each individual flow reduction measure should be a criterion for judging whether or not to include it in the first-cut flow reduction program. Thus, a preliminary implementation plan should be developed for the program as a whole since it is futile to proceed with further evaluation and modification of a program which stands little chance of being effectively implemented. In developing the preliminary implementation plan, important questions to consider include:

- Does the agency or entity designing the program have the authority to implement all phases of the program, or is it necessary to acquire authority or secure cooperation from another source? (Note that this is not a trivial matter since EPA's Cost-Effectiveness Guidelines contain specific language regarding adoption of measures that lie "within the implementation authority of the grantee or another entity willing to cooperate with the grantee.")
- Even if implementation authority exists, does the ability to effectively implement the program hinge upon obtaining the support of key agencies, entities, individuals, or the general public?
- Can implementation of the program be accomplished more efficiently and expeditiously if an attempt is made to coordinate activities with other programs? Related programs may be those involving water conservation, energy conservation or infiltration/inflow.
- Will the budgetary costs of the program exceed available funds? Are other funding sources available?

Because an effective implementation plan is a crucial component of the flow reduction program, it should at a minimum contain the following elements:

- Milestones or timetables designating when certain phases or components of the program will take effect and when related implementation actions or products will be completed.
- Sources of funding for the various program components.
- Identification of who or what entity is responsible for implementing each aspect of the program. Commitments (written where necessary) will eventually need to be obtained from those being relied upon for some aspect of implementation when a final flow reduction program is selected.

Package of Flow Reduction Measures

- A mass retrofit program involving free distribution and installation of toilet dams and plastic shower heads, as well as free distribution of dye tablets and common washers for detecting and repairing residential leaks.
- A public education effort, as part of the broader public information program, oriented toward changing the public's water use habits.
- Change to increasing block rate structure provided system is metered.

A Public Information Plan

- Send flyers out with water bills explaining the need for and encouraging support of water saving/flow reduction measures.
- Publicizing the program through radio/TV public service announcements, talks in schools and to organizations, special exhibits at central locations.
- Establishing a telephone hot line where the public can obtain answers to questions about the program.

An Implementation Plan

- Organizing a voluntary assistance effort by local service organizations in distributing and installing devices, manning the telephone hot line as well as special exhibits (with needed training provided by utility staff).
- Soliciting contributions of free radio/TV time by local stations for brief advertisements, talk shows, and the like.
- Securing agreement from water supply utility to support program by sending flyers with water bills, training volunteers, sending staff persons to speak in schools, and the like.

Table 8. Sample Flow Reduction Program For Hypothetical Community With Relatively Immediate Flow Reduction Goals

- Number of man-years needed for implementation of the various program components. Building code changes, for example, will require time to write the regulations, get them approved.

Neglecting to contact key persons/groups/entities in the development of an implementation plan may result in the selection of implementation mechanisms much more costly or difficult to carry out than is necessary, may render particular program components ineffective, or may cause the entire program to fail. In short, the success of the program ultimately hinges upon this phase of program development.

Providing a mechanism for public input at some point in the development of the first-cut flow reduction program may prove invaluable. Much time, energy and resources can be saved if measures unacceptable to the public are flagged early in the process and either modified, eliminated or more clearly explained in the public information program to obtain public support. In addition, the efforts of people or groups willing to voluntarily assist in program development or implementation can be utilized, but a means of identifying these persons or groups early in the process must be provided. Thus the public information and involvement efforts are closely related to the implementation effort and vice versa.

For those communities without an active, full-scale public participation effort for Step 1 facilities planning, a special meeting or workshop may be scheduled to obtain public input on flow reduction at this stage. Note that such a meeting is grant eligible under Step 1. It may be best not to present an entire first-cut program to the public at this time since (1) this could give the impression that decisions have already been made when they really have not, and (2) the benefits and costs of a program have not yet been calculated (see Step D). At this stage, public input should be sought on measure-specific effects and specific implementation features rather than on a program as a whole. The initial strategy is to create an atmosphere of openness and practicality which avoids strong public reaction to or fear of preliminary ideas but which introduces enough ideas to test public preferences. Because of the importance of public input and involvement, a separate step (Step F) is entirely devoted to a discussion of this aspect of program development. It is also important, however, to begin public involvement early and to continue it throughout the flow reduction analysis process.

4. Examples

a. Sample Programs

The following sample programs are not meant to be directly applicable to any particular community but are examples of the types of programs communities in particular situations might consider.

First, a community faced with the prospect of a wastewater or water supply facility rapidly nearing capacity might consider developing a program which will produce relatively immediate reductions in water use or wastewater flows. Specific elements of the three main flow reduction program components which might be included are outlined in Table 8.

On the other hand, a community is in a markedly different position if it has sufficient reserve capacity in its water supply and wastewater treatment facilities to fulfill its immediate needs. It can afford to look a few years into the future and it may be attracted by the potential long-term benefits of flow reduction. As a result it might adopt a relatively aggressive, long-term program such as the one outlined in Table 9.

ackage of Flow Reduction Measures Building code changes to require: – installation of meters with all new connections; – installation of pressure reducing valves in new construction and major remodeling wherever service line pressures exceed 60 psig — pressure is reduced to a maximum of 50 psig for residences; and – installation of water saving fixtures and appliances in all new construction and major remodeling. Water and energy-use labeling of all plumbing fixtures and water using appliances. Includes setting standards for water and energy use which allow certain models to be labeled "water and energy efficient". Gradual (i.e., over a period of years) installation of water meters in all existing water connections. (The equity and consciousness-raising aspects of this measure are judged to outweigh the economic aspects.) Institution of an increasing block rate structure. Provision of a free water audit service oriented toward helping water users in existing buildings find and repair leaks and develop their own in-residence retrofit program. The service could also provide a list of qualified contractors to do retrofitting and a catalog of locally-available practical water saving/flow reduction measures. Public education to change water using habits such as turning faucets off while shaving and brushing teeth, and taking shorter showers.	**A Public Information Plan** ■ Elements similar to those displayed in Table 8 for a community program having immediate goals but carried out less intensively after the beginning program initiation activities. ■ Establishment of media contacts so that news items will be covered on local radio/TV newscasts, persons familiar with the program will be interviewed on talk shows, and the like. ■ Establishment of contacts with community groups staging special events (e.g., country fairs) periodically so that flow reduction exhibits can be displayed. **An Implementation Plan** ■ Obtaining support/assistance from water supply utility(ies) for installation of meters and pressure reducing valves, institution of increasing block rate structure, promotion of flow reduction through inclusion of flyers with water bills, and other actions as appropriate. ■ Obtaining voluntary help from local service groups and individuals for overall program promotion. ■ Obtaining advice/support from plumbers and building inspectors in instituting the building code changes. ■ Obtaining support from manufacturers/retailers in water and energy-use labeling.

Table 9. **Sample Flow Reduction Program For Hypothetical Community With Relatively Long-Term, Aggressive Goals**

b. Calculating Expected Reduction in Indoor Residential Water Use From Implementation of a Flow Reduction Program – Hypothetical Case

For purposes of illustration it is assumed that a hypothetical community has the following characteristics relative to the analysis: (1) a 1980 population of 18,500; (2) a population growth rate of 3 percent per year; (3) an average indoor residential water use of 65 gpcd. It is also assumed that in 1980, implementation of a flow reduction program begins consisting of the following measures:

- **A retrofit program** which includes free distribution of toilet dams, plastic shower head inserts, faucet washers, and dye tablets for leak detection, as well as information on how to install the devices, use the tablets, and fix simple leaks in toilets and faucets. (Other distribution methods and an assessment of their relative effectiveness are provided in Appendix B.)
- **Building code changes** which will require all new residences to be equipped with shallow trap toilets, low flow showerheads, water meters, and (where line pressures exceed 60 pounds per square inch gage (psig)) pressure reducers which reduce pressure to 50 psig.
- **A public information and education program** designed to support the retrofit and building code components of the program by distributing flyers in the water bills, talking in schools and at organizational meetings, and arranging various special exhibits. Along with supporting other aspects of the program, the public education effort is expected to raise public consciousness and concern about water saving/flow reduction and bring about additional savings of 1 gpcd due to increased awareness of water value and water wasting. Changes in habits, such as turning faucets off while brushing teeth or shaving, taking shorter showers, and the like, can be expected, resulting in at least minor reductions in water use.
- **An implementation plan** similar to that outlined in the sample program, Table 9.

Calculating the expected total indoor residential water savings from the program involves:

- Determining how each program element will affect per capita water use in an average residence where it is implemented.
- Adjusting water use reduction estimates wherever necessary to avoid double counting (see Appendix C).
- Determining how many residences (or what portion of the population) will be implementing each program element each year in the time period. This will be estimated based on the rate of population growth, the percentage

Program Element	Water Savings (gpcd)	Timing of Effect and Percent Implementing Measure
Retrofit		
Toilet dams	7.5	Becomes effective in 1981; 30% install devices and check for leaks; population using devices each year is 30% of 1981 population.
Shower head inserts	4.0	
Toilet/faucet leak repair	1 0	
Total	12 5	
Building Code Changes		
Shallow trap toilets	7 5	Becomes effective in 1984; effective in 100% of new residences.
Low flow shower heads	4 0	
Pressure reducing valve[a]	2 0	
Meters[b]	1 0	
Total	14 5	
Public Education	1 0	Becomes effective in 1981; remains constant each year.

a. Low estimate to allow for double counting and expectation that pressure reduction is required in 40 percent of new residences

b. Expected savings result from increased public consciousness about water use.

Table 10. Effects of Program Elements On Residential Indoor Per Capita Water Use For Hypothetical Community (gpcd)

of residences expected to actually implement the measure, and the time when the program elements become effective.

The hypothetical effect of each program element on indoor, per capita water use is shown in Table 10.

After the projected population for each year is tabulated, the information in Table 10 is applied to determine the total savings in indoor water use for each year from each element of the program, as is shown in Table 11. In that table, the horizontal sum of the expected water savings from each program element is the total expected indoor water savings for that year.

Finally, Table 12 compares residential indoor water use with and without the flow reduction program and shows the percent of indoor water use saved as a result of the program. Notice that the percentage of indoor water use saved decreases until the building code changes take effect in 1984, after which residential indoor water savings from the flow reduction program continually increase.

Complete consideration of the potential for community water savings will include similar programs and calculations for the commercial, public and nonspecific industrial (i.e. those discharging less than 25,000 gpd of wastewater) sectors. The sum of these estimated water savings from all sectors will constitute the total expected community-wide water savings. The extent to which these estimated water savings will allow for an alteration of the design capacity of the planned wastewater treatment plant will depend upon the relationship between peak flows and average daily base flows and the relative amount of infiltration/inflow entering the treatment facility. Similarly, resulting changes in operating and maintenance costs will depend upon the particular treatment plant and community wastewater flow characteristics.

5. Major Observations

- Before the first-cut program is well defined, it may be helpful to at least outline the main components of a complete program so that a tangible focus for discussion is available during early contacts with the water supply utility, other related agencies and representatives of the public. Consider in this "straw man" program:

  - All sectors of water use (i.e., residential, commercial, public and non-specific industries).

  - All major components of the flow reduction program (i.e., a set of flow reduction measures, a public information program, and an implementation plan).

  - An estimate of first-order effects (i.e., program costs, and effects on water use and waste-

Year	Population	Savings from Retrofit[a]	Savings from Building Code[b]	Savings from Education Program[c]	Total Savings
1980	18,500	-	-	-	-
1981	19,055	.071	-	.019	.090
1982	19,627	071	-	.020	.091
1983	20,216	.071	-	.020	.091
1984	20,823	.071	.009	.021	.101
1985	21,448	.071	.018	.021	.110
1990	24,864	.071	.067	.025	.163
1995	28,823	.071	.125	.029	.225
2000	33,414	.071	.191	.033	.295

a. Determined by multiplying the per capita per day savings from the retrofit program (12.5 gpcd) by the 1981 population (19,055) by the percent installing the devices (.30).

b. Determined by multiplying the expected savings from the building code changes (14.5 gpcd) by the increase in population over the previous year, and adding to this amount the total savings from building code changes in the previous year.

c. Determined by multiplying the 1 gpcd savings by that year's population.

Table 11. **Expected Residential Water Savings From Flow Reduction Program Elements For Hypothetical Community (mgd)**

water flows over time).

- Significant institutional constraints related to separate administration of the water supply and wastewater treatment systems may limit program implementation and effectiveness. For example, the presence of high fixed costs on the water supply side may lead to the encouragement of maximum system use to help "pay off" the system. If not dealt with explicitly in program design and implementation, this may frustrate efforts to achieve flow reduction (Schaefer, July 1975).
- Flow reduction devices often become cost-effective from the community point of view only when water supply, wastewater treatment and hot water energy costs are integrated. This integration of functions may not occur due to the utilities' institutional separation and their differing economic viewpoints (Schaefer, July 1975). As energy costs escalate, however, flow reduction devices will become increasingly cost-effective.
- Many flow reduction measures - even ones which have major cost saving advantages - will only be adopted if they have public support and if the wastewater utility has authority to implement them or can obtain the cooperation of another entity having the needed authority. When the wastewater utility is an independent authority, not responsible to the community in any way outside the provision of wastewater services, this vital implementation link may be difficult to obtain (U.S. EPA, January 1979) unless a cooperative relationship with the water agency is developed from the outset of the flow reduction analysis.
- A major disincentive for utilities to undertake conservation programs is the very real possibility that a successful program could cause a decline in the utility's revenues. Because fixed operating costs comprise a large proportion of a utility's costs, this threat of revenue erosion may necessitate a rate increase. It has been indicated by some, however, that the percentage increase in price needed would not be great. For example, Milne (1976) has pointed out that a 16 percent decrease in peak seasonal water use might necessitate only a 1 to 2 percent rate increase. An average water conserving homeowner would still experience a reduction in water bills. The public information program should explain to water users what the net effect of the conservation measures, including any rate increase, will be.
- Installation of water saving devices may have little effect on wastewater capacity needs if there is substantial infiltration and inflow into the system. A more complete discussion of the relationship between flow reduction and infiltration/inflow is given in Part I (page 9).
- Some lessons learned from the California DWR Pilot Conservation Program (October, 1978):

Year	Population	Average Daily Indoor Water Use Without Program[a]	 With Program[b]	Percent of Indoor Water Use Saved
1980	18,500	1.203	-	-
1981	19,055	1.239	1.149	7.3
1982	19,627	1 276	1.185	7.1
1983	20,216	1.314	1.223	7.0
1984	20,823	1 353	1.252	7 5
1985	21,448	1.394	1.284	7.9
1990	24,864	1.616	1.453	10.1
1995	28,823	1.873	1.648	12.0
2000	33,414	2.172	1.877	13.6

a. Determined by multiplying average indoor residential water use of 65 gpcd by the population for each given year.

b. Determined by subtracting from the previous column the total water savings calculated in Table 9.

Table 12. Comparison Of Indoor Residential Water Use With And Without Flow Reduction Program For Hypothetical Community (mgd)

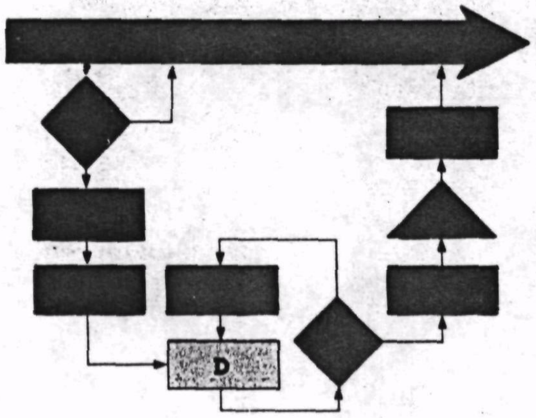
- For a retrofit program, a short intensive distribution of devices is most effective.

- A promotional campaign for the program is essential.

- A telephone hotline is a useful way for the public to get information and answers to questions such as how to install various devices.

- Of all retrofit devices for toilets tried, toilet dams were the most popular and saved the most water. (It should be noted, however, that plastic displacement bottles and, particularly plastic bags are becoming the most popular toilet retrofit devices.)

■ Increasing numbers of municipalities are following the policy of billing the cost of wastewater treatment directly to the homeowner as a percentage of the water bill (Milne, 1976). This helps to increase awareness about the connection between water use and wastewater flows and provides an additional conservation incentive. When and where possible, a more equitable conservation policy would be to bill homeowners for wastewater services as some percentage of indoor water use - outdoor use has little effect on wastewater flows. Since having two meters at a residence is generally impractical, this question of equity may be a key consideration in determining whether wastewater charges will be in proportion to water use or based on a flat rate. A compromise approach is to set wastewater charges as some percentage of average, winter month water use since most of this water is used indoors and is discharged to sewers.



Step D. Determine Costs And Benefits

- Calculate monetary benefits and costs
  - to the wastewater utility
  - to the water supply utility
  - to water users (only those costs and benefits additional to utilities' costs and benefits).
- Identify nonmonetary benefits and costs resulting from environmental/social/economic effects of flow reduction program.
- Qualitatively evaluate relative importance of nonmonetary benefits and costs vis-a-vis monetary benefits and costs.

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D. Determine Costs and Benefits of the Flow Reduction Program

1. Statement of Purpose

In selecting a final flow reduction program, it is essential to have a basis for evaluating each possible program and for comparing the various program alternatives. This step focuses on a method of evaluating the full range of community-wide costs and benefits associated with a given program alternative. These costs and benefits are of two kinds: monetary and nonmonetary. Thus, Step D in the flow reduction analysis has a two-fold objective:

- To develop a comparison of the monetary benefits and costs of the flow reduction program from a community-wide perspective.
- To identify and describe the nonmonetary benefits and costs of the flow reduction program from a community-wide perspective.

2. Monetary Benefits and Costs of the Flow Reduction Program

An evaluation of the monetary benefits and costs of the flow reduction program includes consideration of three community entities:

- The wastewater utility.
- The water supply utility.
- Water users.

Table 13 indicates the scope of these monetary benefits and costs.

a. Monetary Costs

Monetary costs of the flow reduction program will consist of the direct costs of developing and implementing the flow reduction program, including:

- Costs incurred by the wastewater utility for implementing flow reduction measures such as purchasing and installing devices, designing and printing public information material, or conducting in-residence water audits.
- Costs incurred by the water supply utility for implementing measures such as purchasing and installing water meters, and reading and maintaining the meters.
- Extra costs incurred by water users, such as for individual purchase or installation of devices. (Note that these costs do not include any changes in water or wastewater bills since these changes will have already been incorporated in the utilities' cost/cost-savings determinations.)

The timing (i.e., year) of these expenditures should be estimated as accurately as possible and attention paid to whether they are one-time-only capital costs or recurring costs. The costs incurred in each year should be expressed in terms of present worth. The sum of these present worth values will yield the total present worth of the monetary costs of the flow reduction program to the community.

b. Monetary Benefits

The monetary benefits of the flow reduction program will consist of the total cost-savings (expressed in terms of present worth) to:

- The wastewater utility due to net reductions in capital, and operation and maintenance (O & M) costs resulting from decreased wastewater flows.
- The water supply utility due to net reductions in capital, and O & M costs resulting from decreased water demand.
- Water users, due to decreased energy costs resulting from hot water savings.

Benefits to these three community entities are discussed in the following subsections.

1) Cost Savings to the Wastewater Utility

a) Savings in Capital Costs. Reductions in wastewater flows may alter the sizing and/or staging of specific construction efforts in developing a community's wastewater treatment facilities. Certain process units are designed according to hydraulic loading (the rate of wastewater flow to the treatment plant) while others are designed according to organic loading (the concentration of wastes in the influent). The unit processes sized hydraulically have the primary potential for being sized smaller due to flow reduction. Since the amount of organic material entering the plant will not change (barring increased solids deposition in sewer pipes due to reduced flows), the capacity of the solids-handling equipment, such as aeration tanks and digesters, will remain the same.

In a typical activated sludge wastewater treatment facility, the process units that potentially can be sized smaller as a result of flow reduction constitute approximately 40 percent of the facility's total capital costs (Davis and Bursztynsky, 1980). These units include:

- headworks (i.e., receiving wells, lift pumps, screens, grit-removal chambers);
- primary and secondary clarifiers;
- effluent chlorination facilities;
- effluent outfall.

In addition to these potential savings in waste-

	Costs of Flow Reduction Program	Benefits (Cost Savings) of Flow Reduction Program
Wastewater Utility ▪ Capital ▪ O & M	Costs directly tied to program (e g., purchase and installation of devices, public information program).	Smaller or delayed expansion of capacity. Lower costs of pumping, chemicals, labor, and the like
Water Supply Utility ▪ Capital ▪ O & M	Costs directly tied to program (e g., meter purchase and installation, meter reading).	Smaller or delayed expansion of capacity Lower costs of pumping chemicals, and the like
Water Users	Additional costs such as individual purchase and installation of devices.	Lower energy bills from less use of hot water.

*The discount rate to be used throughout the analysis is that set by the Water Resources Council for water-related projects

Table 13. **Scope Of Community-Wide Monetary Benefits And Costs (Present Worth*)**

water treatment capital costs, capital cost savings may also result from the ability to size the wastewater collection system smaller. Sewer design flow is directly proportional to average dry weather flow which is similar to indoor water use (Koyasako, 1980). Thus, reductions in indoor water use proportionately reduce the sewer design flow and allow sewer pipes to be sized smaller.

Reduced wastewater flows may cause problems in the collection system, however, which will partially offset these cost savings. Solids may settle out and accumulate in the sewer lines and anaerobic decomposition may begin to take place, resulting in the production of methane and hydrogen sulfide gases. Along with significant odor problems, these gases may cause corrosion of sewer pipes (DeZellar and Maier, 1980). These problems have been mitigated in existing collection systems by adding chlorine dioxide, hydrogen peroxide, or by cleaning the sewer lines more frequently (Koyasako, 1980). To avoid these problems in new collection systems where long-term flow reduction is expected, sewer pipes may need to be designed with greater slopes to maintain an adequate scouring velocity (DeZellar and Maier, 1980). Where these effects occur or must be planned for, they will reduce the O & M and capital cost savings related to the wastewater collection system.

The capacity requirements of these treatment unit processes and collection systems are determined by peak-day wastewater flows. Thus, determining the capital cost savings to the wastewater utility involves first estimating how the flow reduction program will alter the peak-day flow projections made for the without-flow-reduction condition. The effect of these reduced peak-day flows on the sizing and staging of the hydraulically determined wastewater treatment and collection facilities is then estimated. There are four possible outcomes of this analysis:

- Neither the sizing nor staging requirements change as a result of the program.
- A new staging period is used, but the sizing of the proposed facility and expansions remains the same.
- The sizing of the proposed facility and expansions is reduced, but the staging period remains the same.
- Both a new staging period is used and the sizing of the facility and expansions change.

The three possible sizing/staging changes resulting from the flow reduction program are depicted in Figure 9. This figure can be used along with Figure 8 (page 26) to display the results of comparing the with- and without-flow-reduction conditions. (In this and subsequent diagrams, discussions and examples, it is to be understood that decreased capacity requirements or smaller sizing of facilities due to flow reduction refers only to those unit processes which are sized according to hydraulic flow.) Note that there are several ways to accommodate the with-flow-reduction condition. For example, rather than planning for two expansions, each somewhat smaller in size than under the without-flow-reduction condition, the first expansion may increase capacity sufficiently to eliminate the need for the second expansion. All sizing/staging options should be considered in light of Section 8e of the Cost-Effectiveness Guidelines.

Because flow reduction decreases only the rate of wastewater flow and not organic loading, it generally causes wastewater influent to be of higher solids concentration. The efficiency of the treatment plant may therefore need to be improved if effluent quality is to be maintained under conditions of flow reduction. It is possible therefore that some of the biological treatment units may need to be modified to maintain plant efficiency. The analysis of capital cost saving must consider the effects of flow reduction on the sizing and staging of each unit process.

The present worth of the capital and associated construction interest costs should be calculated for both the with- and without-flow-reduction conditions. The difference between these two values is the present worth of the capital cost savings to the wastewater utility. An alternative and perhaps easier way to proceed is to estimate only the difference in capital costs, determine the difference in associated interest costs, and then convert these cost differences to present worth. The sum of these present worth capital (and interest) cost differences gives the total capital cost savings.

b) Savings in Fixed O & M Costs. Reductions in fixed O & M costs due to lower capacity also will result from the flow reduction program. For example, fewer employees may be needed as a result of delayed expansion or smaller facility size. The total present worth of the fixed O & M costs incurred throughout the planning period should be calculated for both the with- and without-flow-reduction conditions. The difference between these two values is the present worth of the fixed O & M cost savings to the wastewater utility. Again, in some instances it may be possible to determine these cost savings by estimating only the difference in fixed O & M costs over the planning period between the with- and without-conditions rather than estimating the costs for each condition separately.

c) Savings in Variable O & M Costs. Reduction in average flow to the wastewater facility due to the flow reduction program may alter variable O & M costs. The direction and magnitude of these costs will vary depending upon the particular characteristics of the wastewater treatment plant, the collection system and the wastewater flow itself. In an analysis of the effect of flow reduction on the variable O & M costs of nine treatment facilities in California, Koyasako (1980) found that the percent change in these costs from a "normal" flow year to years with significant flow reduction ranged from a 5 percent decrease to about a 4 percent increase. Energy and chemicals were the O & M cost categories most affected by flow reduction, with energy costs generally decreasing and chemical costs either increasing or decreasing. Since

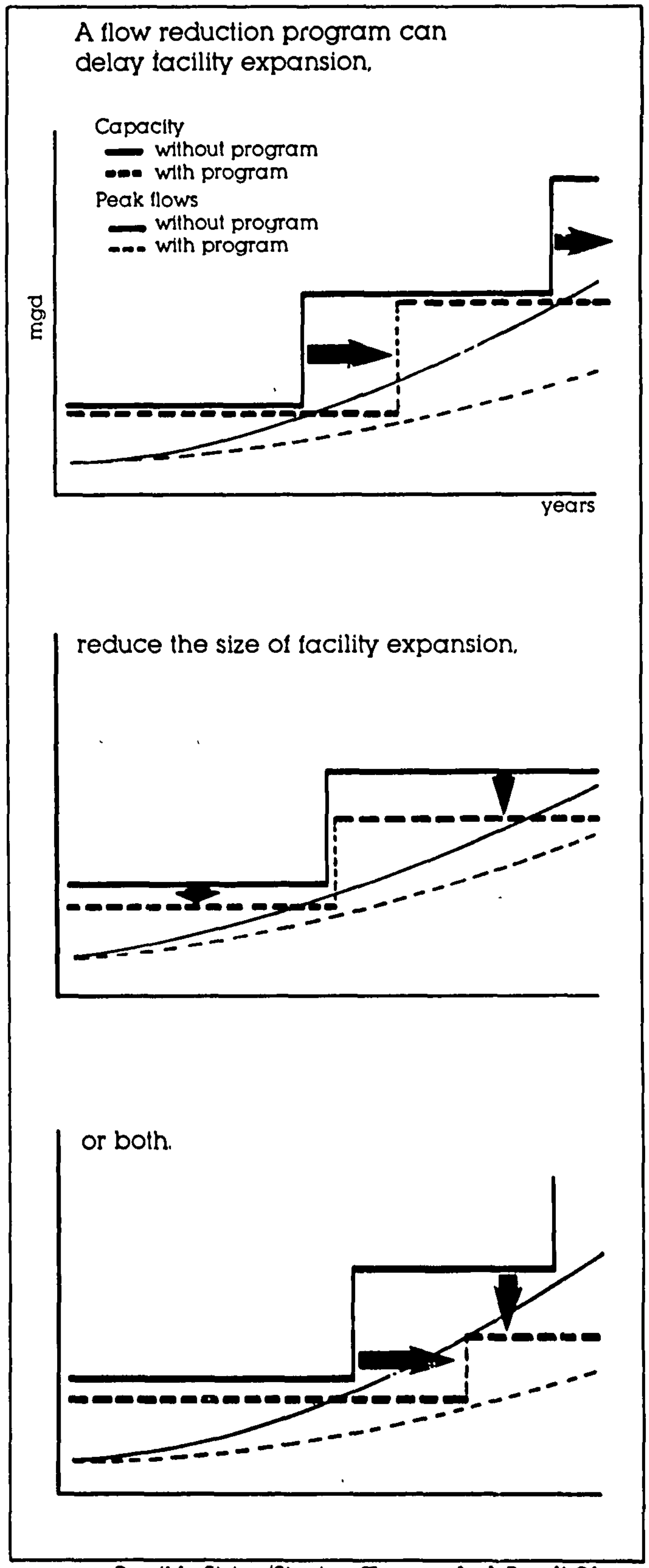


Figure 9. **Possible Sizing/Staging Changes As A Result Of Flow Reduction Program**

Without-Flow-Reduction Conditions

- Existing capacity of facility 1 mgd
- Capacity of proposed facility years 0-10 3 mgd, years 11-20 6 mgd years 21-n 9 mgd
- Projected peak-day flow through plant increases linearly from 1 mgd to 3 mgd from year 1 to 11 and from 3 mgd to 6 mgd from year 11 to 21
- Salvage value at end of 20 years 0
- Initial cost of facility $4 000 000
- Construction period interest associated with initial construction $147,500
- Cost of first expansion (construction begins in year 10) to 6 mgd capacity $3 250 000
- Construction period interest associated with first expansion $119 844
- Cost of second expansion (construction begins in year 20) to 9 mgd capacity $3 500 000
- Construction period interest associated with second expansion $129 063
- Operation and maintenance costs
  - Fixed annual O & M cost years 1-10 $168 000
  - Variable annual O & M cost years 1-10 increases linearly from 0-$60 000 in year 10
  - Fixed annual O & M cost years 11-20 $340 750
  - Variable annual O & M cost years 11-20 increases linearly from 0 $60 000 in year 20
  - Interest rate 7 1/8 percent

With-Flow-Reduction Conditions

- Existing capacity of facility 1 mgd
- Capacity of proposed facility years 0-10 2 5 mgd, years 11-20 5 mgd years 21-n 7 mgd
- Projected peak-day flow through plant increases linearly from 1 mgd to 2 5 mgd from year 1 to 11 and from 2 5 mgd to 5 mgd from year 11 to 21
- Salvage value at end of 20 years 0
- Initial cost of facility $3 600 000
- Construction period interest associated with initial construction $132 750
- Cost of first expansion (construction begins in year 10) to 5 mgd capacity $2 925 000
- Construction period interest associated with first expansion $107 859
- Cost of second expansion (construction begins in year 20) to 7 mgd capacity $3 150 000
- Construction period interest associated with second expansion $116 156
- Operation and maintenance costs
  - Fixed annual O & M cost years 1-10 $150 000
  - Variable annual O & M cost years 1-10 increases linearly from 0-$55 000 in year 10
  - Fixed annual O & M cost years 11-20 $310 000
  - Variable annual O & M cost years 11-20 increases linearly from 0-$55 000 in year 20
  - Interest rate 7 1/8 percent

Table 14 **Assumptions Used To Develop Hypothetical Example Of Cost Savings To A Wastewater Treatment Facility**

energy and chemical costs comprise a relatively small percentage of the total O & M costs, even substantial changes in these costs will alter total O & M costs only slightly Koyasako's analysis also shows that O & M costs associated with the wastewater collection system are likely to decrease slightly as a result of flow reduction

To determine the variable O & M cost savings

- Estimate the effect of flow reduction on the quantity of average daily wastewater flow over the planning period
- Determine the change in variable O & M costs associated with this reduction in average daily flow
- Calculate the present worth of the difference in variable O & M costs between the with- and without-conditions for each year in the planning period
- Sum these cost differences to obtain the total present worth of the variable cost savings to the wastewater utility.

The total present worth of the cost savings to the wastewater utility will equal the sum of the (present worth) savings in capital costs, fixed O & M costs and variable O & M costs

d) Hypothetical Example Showing Calculation of Cost Savings (Monetary Benefits) to a Wastewater Treatment Facility. A simplified hypothetical situation is described to show how one can go about calculating the savings to a wastewater treatment facility resulting from a flow reduction program Modifications in the procedure most likely will be necessary in order to accommodate specific circumstances Assumptions used in this example are depicted in Table 14, and the capacity versus time and staging requirements for these hypothetical with- and without-flow-reduction conditions are displayed in Figure 10 Calculations used to estimate the present worth cost savings associated with the foregoing assumed conditions are demonstrated in Table 15 The total present worth of the cost savings (monetary benefits) to the wastewater treatment utility due to the hypothetical flow reduction program is found to be $940,099

2) Cost Savings to the Water Supply Utility By encouraging reductions in water use, a flow reduction program will decrease the amount of water that needs to be supplied to a given population As was previously described for the wastewater facility, reductions in peak demand will decrease the capacity requirements for water supply over the planning period causing reductions in associated capital, interest and fixed O & M costs, reductions in average daily use will similarly decrease variable O & M costs

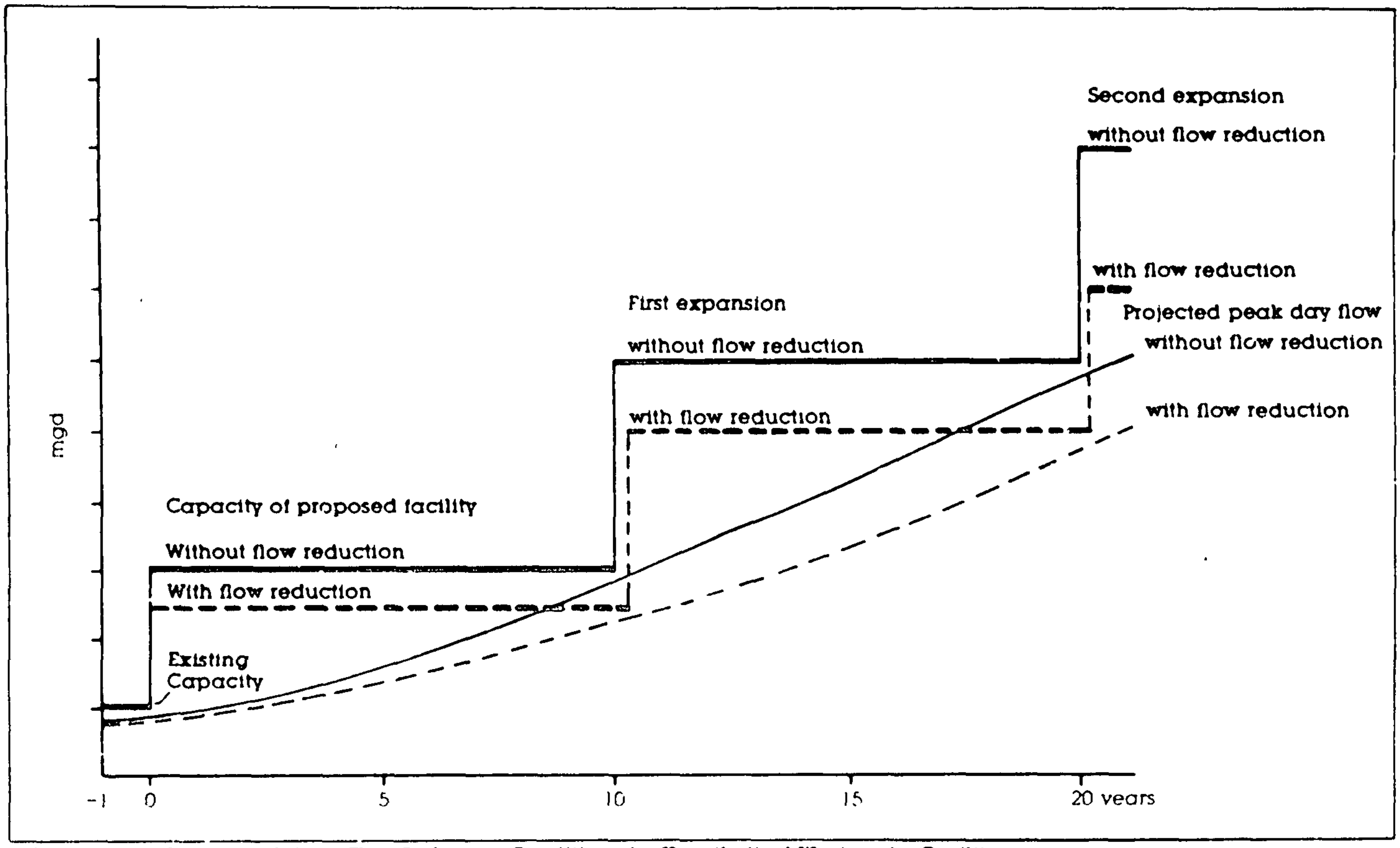


Figure 10 **With- and Without-Flow-Reduction Conditions for Hypothetical Wastewater Facility**

A procedure almost identical to that described for a hypothetical wastewater facility can be used for calculating the cost savings (monetary benefits) to a water supply utility To prevent omitting any potential cost savings, a breakdown of water supply functions into categories similar to the following may be useful

- **Administration** (e.g. management of personnel, accounting, meter reading)
- **Acquisition** (securing the water, storing it and transferring it to the treatment facility)
- **Treatment** (purifying the water)
- **Transmission and distribution** (all activities following treatment associated with supplying water to the service area)

Clearly, the appropriate categorization of functions will depend upon the nature of the water supply For each category of water supply functions, a determination of cost savings from the flow reduction program should be made Using the treatment category as an example

- Determine how estimated reductions in peak demand affect the treatment capacity requirements over the planning period A diagram showing the sizing/staging characteristics for the with- and without-flow-reduction conditions can be developed to graphically depict this comparison As with the wastewater facility, various combinations of sizing/staging changes for the water supply utility may result Figure 11 portrays a with-flow-reduction condition which differs in both sizing and staging from the without condition for a water supply treatment facility
- Calculate the present worth of the capital cost savings resulting from the smaller capacity
- Calculate the present worth of the fixed O & M cost savings resulting from the smaller capacity
- Determine how the projected reductions in average daily demand (i.e. average daily production and supply) affect the variable O & M costs (e.g. chemical costs)
- Calculate the present worth of these variable O & M cost savings
- Sum the present worth values for the capital and interest cost savings, fixed O & M cost savings, and variable O & M cost savings to obtain total cost savings (expressed in present

1 Calculate the present worth of the capital cost savings (including savings in construction period interest)

- Initial (year 0) construction and interest costs

Without flow reduction	= $4 147 500
With flow reduction	= $3 732 750
Cost savings	= $ 414 750
Present worth of cost savings	= $ 414 750

- First expansion (year 10) construction and interest costs

Without flow reduction	= $3 369 844
With flow reduction	= $3 032 859
Cost savings	= $ 336 985
Present worth of cost savings	= $ 165 417

- Second expansion (year 20) construction and interest costs

Without flow reduction	= $3 629 063
With flow reduction	= $3 266 156
Cost savings	= $ 362 907
Present worth of cost savings	= $ 87 444

- Total present worth of capital cost savings = $ 667 611

2 Calculate the present worth of the fixed O & M cost savings

- Fixed annual O & M costs years 1-10

Without flow reduction	= $168 000
With flow reduction	= $150 000
Annual cost savings	= $ 18 000
Present worth of annual cost savings	= $133 424

- Fixed annual O & M costs years 11-20

Without flow reduction	= $340 750
With flow reduction	= $310 000
Annual cost savings	= $ 30 750
Present worth of annual cost savings	= $111 888

- Total present worth of fixed O & M cost savings = $245 312

3 Calculate the present worth of the variable O & M cost savings

- Variable annual O & M costs years 1 10
  - Without flow reduction increase linearly from 0 to $60 000 or by $6 000 per year
  - With flow reduction increase linearly from 0 to $55 000 or by $5 500 per year
  - Annual cost savings increase linearly from 0 to $5 000 or by $500 per year (i e cost savings in year 1 = $500 cost savings in year 2 = $1 000 etc)
  - Present worth of annual cost savings = $18 228
- Variable annual O & M costs years 11 20
  - Without flow reduction increase linearly from 0 to $60 000 or by $6 000 per year
  - With flow reduction increase linearly from 0 to $55 000 or by $5 500 per year
  - Annual cost savings increase linearly from 0 to $5,000 or by $500 per year (i e cost savings in year 11 = $500 cost savings in year 12 = $1 000 etc)
  - Present worth of annual cost savings = $8 984
- Total present worth of variable O & M cost savings = $27 176

4 Sum the total present worth values for the capital and interest cost savings, the fixed O & M cost savings and the variable O & M cost savings to determine the total present worth of cost savings for the wastewater utility due to the hypothetical flow reduction program

$667 611 + $245 312 + $27 176 = $940 099

Table 15 **Calculations For Hypothetical Example Of Cost Savings To A Wastewater Treatment Facility**

worth) for the treatment category

Following the same procedure, the cost savings for the other water supply function categories should be calculated The sum of the present worth cost savings for each category will equal the total cost savings (expressed in present worth) to the water supply utility from the flow reduction program

3) Cost Savings to Water Users As with the monetary costs, the cost savings to water users from a flow reduction program are those which are additional to the cost savings already calculated for the water supply and wastewater utilities. (Note that throughout the analysis, care should be taken to avoid double counting) Savings in water and wastewater costs to water users have already been incorporated into the savings in capital and O & M costs calculated for the two utilities The most obvious remaining cost saving to water users is the saving in energy costs resulting from less use of hot water

To estimate the present worth of the water users' cost savings (monetary benefits), determine the present worth of the cost savings estimated for each year in the planning period and sum these values to get the total cost savings expressed in present worth Care should be taken to ensure that the timing of benefits is determined properly and adjustments made accordingly For example if plumbing code changes which require installation of low-flow shower heads in new construction are part of the program, significant benefits from this measure may only begin to be realized 5-15 years in the future

The EPA's Cost-Effectiveness Guidelines stipulate that no inflation of wages and prices should be allowed except for land and energy At the grantee's option, energy prices may be escalated using the EPA's published energy cost escalation factors developed for each region and energy source (U S. EPA. Proposed regulation. November 3, 1980) Thus, in calculating energy related dollar savings from the flow reduction

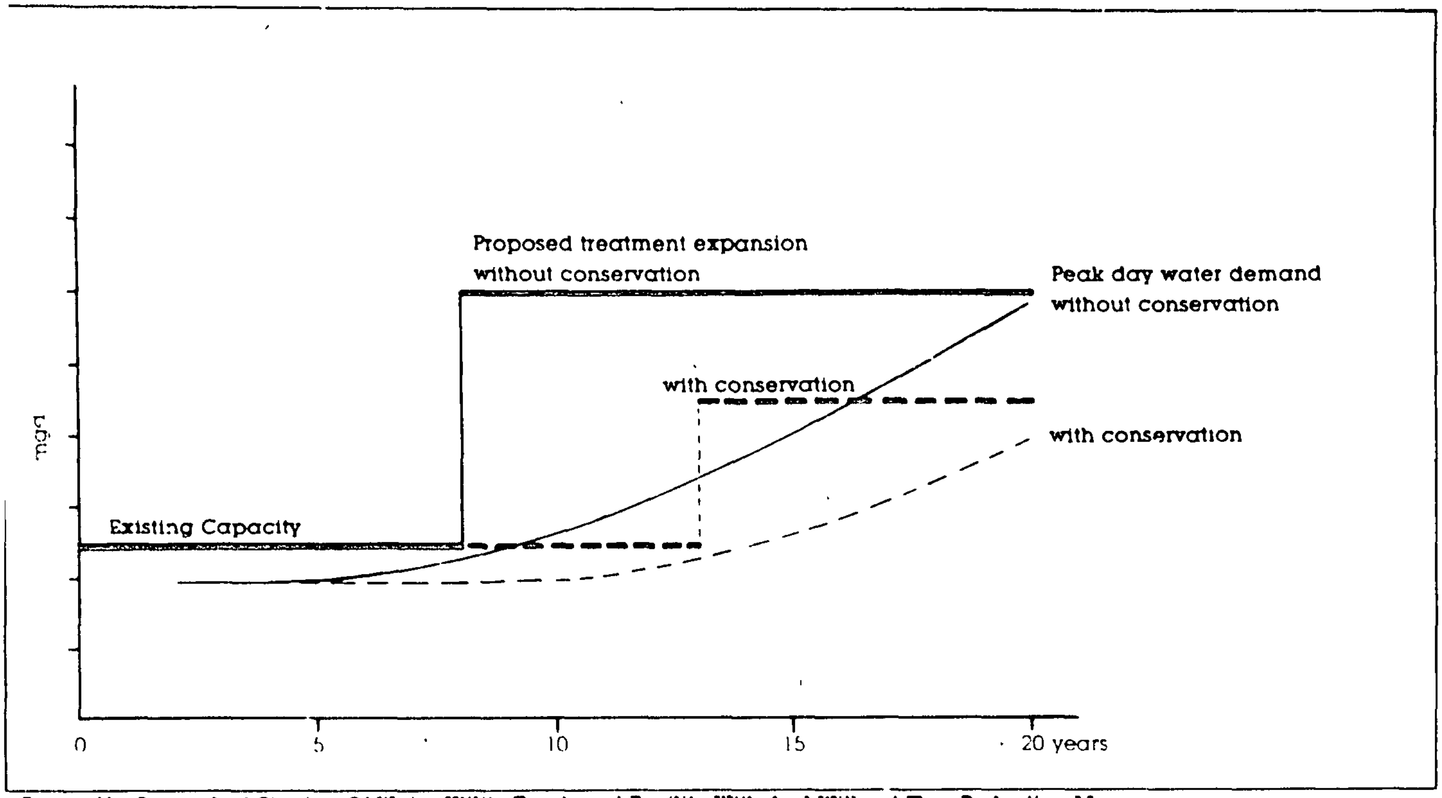


Figure 11 **Sizing And Staging Of Water Utility Treatment Facility With And Without Flow Reduction Measures**

program, this price inflation may be taken into account The effect will be to increase water user's monetary benefits over time The following example shows how to calculate these energy cost savings

Under the assumptions stated and calculations shown in Appendix C, installing a plastic orifice insert in each of two showers in an average four-member household would be expected to save $12.06 in energy costs in the first year in which they were installed To take the inflation of energy prices into account in determining total energy cost savings over the planning period, EPA's published tables of Energy Cost Escalation Factors are used to determine the applicable escalation factors These tables show, for example that the escalation factor for natural gas in Region II is 35 percent for the 1980-1990 period and an additional 1 percent for the 1990-2000 period In other words, if the price of natural gas in 1980 was $1.00, the price in 1990 and 2000 would be $1.35 and $1.36, respectively Using these escalation factors, the present worth of the total energy cost savings over the planning period may be calculated as shown in Table 16

This yields the estimated present worth of energy cost savings resulting from the hot water savings attributed to installation of plastic shower inserts ($750,000) Similar calculations would be made for expected energy savings from other hot water saving aspec the flow reduction program The sum of all these cost savings will equal the total (present worth) energy cost savings at the water user level resulting from the program

c. Determination of Net Monetary Benefits

Using results obtained so far, total monetary costs and benefits (cost savings) to the community can now be summarized and the net monetary benefits (total monetary benefits minus total monetary costs) determined by completing a table such as Table 17

3. Nonmonetary Benefits and Costs of a Flow Reduction Program

Nonmonetary benefits and costs derive from the unquantifiable but nonetheless significant environmental, social, economic, political and institutional effects of a flow reduction program Information needed to assess these costs and benefits will be specific to [illegible] community Much of the relevant inform[illegible] already be available from the Environ[illegible] formation Document required in the facilit[illegible] planning process Other nonmonetary costs and benefits can be qualitatively assessed from information provided under Step C (i e, first-cut program) and from information acquired from public input into the facilities planning process

Information given

- Initial year energy cost savings = $12 06
- Energy source is natural gas
- Geographic area is Region II
- Escalation factors are .35 and .36 for the periods 1980 1990 and 1990 2000 respectively
- Interest rate is 7⅝ percent
- Planning period is 20 years
- EPSPWF = Equal Payment Series Present Worth Factor for 20 years Given 7⅝ percent interest EPSPWF = 10 292
- UGSF = Uniform Gradient Series Factor for 10 years Given 7⅝ percent interest UGSF = 3 918
- EPSPWF = Equal Payment Series Present Worth Factor for 10 years Given 7⅝ percent interest EPSPWF = 6 903
- PWFGS = Present Worth Factor of a Gradient Series for 10 years Equivalent to (UGSF) X (EPSPWF) = 27 04
- SPPWF = Single Payment Present Worth Factor for 10 years Given 7⅝ percent interest SPPWF = 4909
- MPWF = Modified Present Worth Factor This is to compute the present worth at the beginning of the first ten years of an equal payment series occurring during the second ten years Equivalent to (EPSPWF) X (SPPWF) = 3 388
- MPWFGS = Modified Present Worth Factor of a Gradient Series This is to compute the present worth at the beginning of the first ten years of an uniform gradient series occurring during the second ten years Equivalent to (UGSF) X (EPSPWF) X (SPPWF) = 13 277

To calculate the present worth of the total energy cost savings

- Calculate the present worth of saving $12 06 the initial year's savings each year for the 20 year period 1980 2000

  $12 06 X 10 292 (EPSPWF) = $124 12

- Calculate the present worth of the average annual increment in cost savings over the first 10 year period 1980 1990

  $12 06 X 0 35 X 27 04 (PWFGS) = $11 41

- Calculate the present worth of the additional cost savings due to the initial energy price escalation (12 06 X 0 35) which persists for each year for the second 10-year period 1990-2000

  $12 06 X 0 35 X 3 388 (MPWF) = $14 30

- Calculate the present worth of the average annual increment in cost savings over the second 10-year period 1990-2000 due to the second energy price esclation

  $12 06 X 001 X 13 277 (MPWFGS) = $ 16

- Sum these four present worth values to get the total present worth of the energy cost savings over the 20 year planning period

  $124 12 + 11 41 + 14 30 + 16 = $149 99

- Multiply this present worth cost savings by the number of residences estimated to install the shower inserts as a result of the flow reduction program For example if 5000 residences were expected to install the inserts the community-wide energy savings would be

  $149 99 X 5000 = $749 950

Table 16 **Example Of Calculation Procedure To Allow For Energy Price Inflation**

Typical nonmonetary benefits and costs may include

- Effects on groundwater supplies (cost or benefit)
- Effects on multipurpose surface water reservoirs - especially for recreational use (cost or benefit)
- Effects on fish and wildlife (cost or benefit)
- Greater or lesser pollutant discharges entering streams (cost or benefit)
- Odor problems due to more concentrated wastewater flows (cost)
- Transaction effects (e g changing institutional structures, altering public attitudes - cost or benefit)
- Inconvenience costs (e.g. possible public dissatisfaction with flow reducing devices, changes in lifestyle)
- Additional safety value or value of alternative use gained from no longer operating at the margin of the available water supply (benefit)
- Increased public satisfaction from water using fixtures (e.g. faucet aerators may reduce splashing - benefit)
- Others

After identifying all nonmonetary costs and benefits, a qualitative assessment of their magnitudes should be made Although these positive and negative effects cannot be neatly summed as were the monetary costs and benefits, they should be well integrated into the analysis At a minimum, those effects of critical importance should be flagged so that important differences between flow reduction program alternatives can be easily identified

A table similar to Table 18 may be a useful organizing and integrating mechanism

4. Major Observations

- Additional detail on performing cost and cost savings (monetary benefits) analyses is provided in Appendix C
- The nonmonetary costs and benefits should not be translated into dollar values They should be separately determined and their relative importance subjectively evaluated on the basis of a community's goals and characteristics
- It may be useful to describe the full range of benefits and costs together in a set of figures and tables with comments regarding their perceived relative importance This could serve as a mechanism for succinctly

laying results from the technical analysis as a focal point for later communication the public

ssessing the nonmonetary benefits and s, consideration should be given to flow uction program changes that would inate or reduce certain costs (disadvan-eous effects) or enhance certain benefits vantageous effects) This will be useful in rying out Step E - deciding what modifica-ns may improve the first cut flow reduction gram or what alternative program may duce better results

	Monetary Cost (Present Worth)	Monetary Benefits (Present Worth)
Wastewater Utility		
Water Supply Utility		
Water Users		
	Total Monetary Costs	**Total Monetary Benefits (Cost Savings)**

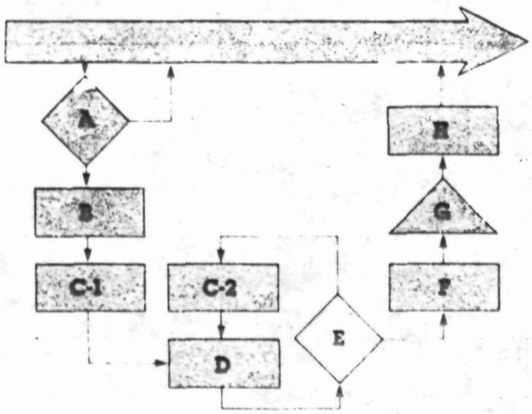
Net Monetary Benefits = Total Monetary Benefits − Total Monetary Costs

Table 17 **Determining Net Monetary Benefits To the Community**

	Cost or Benefit	Assessment of Magnitude of Effect (low med high critical)
nced stream quality from reduced pollutant discharges	Benefit	Medium
ced consumer surplus from dissatisfaction with shower head fit device	Cost	Low
nced groundwater supplies from reduced water demand	Benefit	High
eased odor due to more concentrated wastewater	Cost	Medium
eased public knowledge of the community's water supply wastewater conditions	Benefit	Medium

am quality might be either enhanced or degraded ending on the specific change in effluent quantity and lity and its relationship to stream flow

18 **Example Of A Qualitative Assessment Of Nonmonetary Costs And Benefits Of A Flow Reduction Program**



Step E.

Have All Reasonable Alternatives Been Considered?

- If yes go to Step F.
- If no go back to Step C-2.

E. Have All Reasonable Alternatives Been Considered?

1. Statement of Purpose

An initial evaluation of the first-cut flow reduction program should be complete at this point. Step E is a pivotal step which asks the question Have all reasonable alternatives been considered? An "alternative" may consist of minor modifications to the first-cut program or an entirely new approach. The objective is to ensure that all potentially beneficial program alternatives have been considered before moving into the final selection process.

2. Data and Information Needs

To respond to the question posed in this step, the analyst need only focus on the information obtained thus far, along with his/her additional perceptions about the community's water use and wastewater characteristics.

3. What To Do

Use the insight gained from evaluating the first-cut program, along with input received from the water supply utility, other agencies/entities, and any informal contacts made with the public up to this point in the planning process to answer the following two questions.

- Can the program potentially be improved by altering one or more of its components (i.e., package of flow reduction measures, public information plan, and implementation plan)?
- Can a potentially better program be developed by essentially starting from scratch and taking a whole new approach?

If the answer to either of these questions is "yes", other alternatives should be formulated and evaluated in the same manner as the first-cut program. Thus, a loop is made back to Step C-2 and Steps C and D (program development and cost/benefit analysis) are repeated for different alternatives. The groundwork laid in evaluating the first-cut program should make these successive evaluations substantially easier. (Note that one should keep making this loop back to Step C-2 until all reasonable alternatives have been considered.)

4. Examples

a. A Program Modification Is Indicated

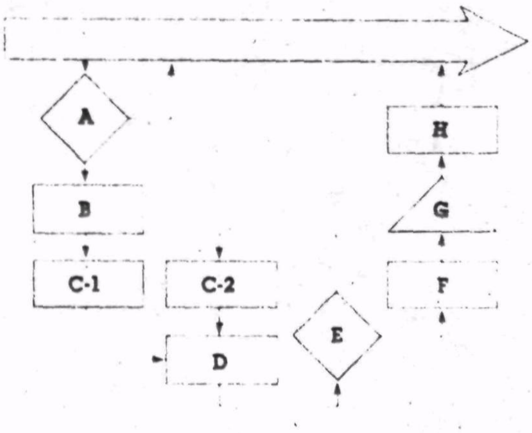
Assume, for example, that the first-cut program included provisions for voluntary retrofitting of toilets and shower heads. Insight gained from the first-cut program evaluation may suggest that greater benefits could be gained from distributing and installing these devices free of charge. The flow reduction measures package from the first-cut program should be reevaluated with this modification in mind.

b. A New Approach Is Indicated

Assume that the first-cut program does not promote the amount of flow reduction required to meet a utility's established target of postponing wastewater facility expansion for the next ten years. In this case, a new approach needs to be identified and a new flow reduction program synthesized. Any or all of the three major program components may need reconsideration to develop a flow reduction program that is more responsive to the situation at hand. The alternative(s) resulting from this effort should then be evaluated in the same manner as the first-cut program.

5. Major Observations

It is tempting to glide over this step with a quick "yes" to its central question. Omitting consideration of either a program modification or an entirely new program may mean losing substantial benefits by implementing a program that does not take full advantage of opportunities (e.g., for reduced water use with the attendant hot water energy savings).



Step F. Conduct Public Participation Meeting (With Facilities Planning)

- Summarize the program alternatives considered and the results of the analysis.
- Communicate findings to the public and obtain public comments.
- Make appropriate changes in program alternatives.
- Reassess both monetary and nonmonetary costs and benefits based on public input and subsequent to any changes made in programs.

F. Conduct Public Participation Meeting

1. Statement of Purpose

As has been repeatedly noted, securing the cooperation of various community groups, agencies, and knowledgeable individuals is essential to effective flow reduction program planning and a basic requirement for program implementation Thus, identifying key groups and individuals and establishing informal contact as soon as possible, are recommended on the basis of pragmatic considerations A mode for formal public participation in flow reduction program development and selection is also deemed desirable Thus, Step F is included as a distinct element in this flow reduction analysis methodology to underscore the importance of obtaining public input and also to guarantee that flow reduction alternatives with their associated costs and cost savings are brought to the attention of the community at large

In view of the above considerations, the primary purpose of this step is three-fold

- To describe to the public the key features of each alternative flow reduction program being considered as these relate to a set of flow reduction measures, a public information plan, and an implementation plan
- To communicate to the public the findings and results of the flow reduction analyses including potential costs and cost savings to the water supply and wastewater utilities and to users of these services
- To obtain public comment on the alternative flow reduction programs being considered and on their associated program components

2. Data and Information Needs

Two types of information needs pertain to this step knowledge about the existing public participation program for facilities planning, and information needed to make the public meeting mutually beneficial (i e, to the public and to the facilities planners)

According to EPA regulations, public participation programs for facilities planning are of two types (U S EPA, February 1979) Each differs in the extent to which it may provide a ready made vehicle for public input into the flow reduction analysis

- Under the requirements for the "Basic Public Participation Program" - the type most commonly used - the grantee is required to "consult" with the public early in the process (before selection of the alternatives to be evaluated in the cost-effectiveness analysis), and then hold a public information meeting when alternatives have been largely developed (i e, and the cost-effectiveness analysis performed) but before an alternative or plan has been selected A public hearing is also required prior to final adoption of the facilities plan (U S EPA, February 1979) Depending upon the precise timing of the public meetings, it may be possible to use the one held early in the facilities planning process as the vehicle for obtaining public input into the latter stages of the flow reduction analysis If, however, the meeting is held after the cost-effectiveness analysis (of which the flow reduction analysis is a part) is complete an earlier meeting will be necessary
- Under certain situations, the Regional Administrator may order a "Full-Scale Public Participation Program" for facilities planning In addition to the components of the basic program, a full-scale program requires the hiring or designation of a public participation coordinator and establishment of an advisory committee An extra meeting to obtain public input into the flow reduction analysis may or may not be necessary when a full-scale program is in operation, depending upon the membership interest, the level of activity of the advisory committee, the timetable of meetings, and the like In either of the above situations, it is desirable to take full advantage of public information activities already planned and available under the public participation program associated with facilities planning Details of such activities are available in the "Public Participation Work Plan" submitted to EPA within 45 days after the date of acceptance of a Step 1 grant award (U S EPA, February, 1979)

The information to be presented at the public meeting (or the flow reduction analysis component of a facilities planning meeting) is available from the flow reduction analysis This information and data must be communicated effectively for the public to become informed and for useful public comments to be obtained Charts figures, tables and other graphic displays that translate the essence of the technical analysis results should be designed to accompany the presentation A concise, written summary of the flow reduction program alternatives and the findings regarding each of them should be prepared for distribution at the meeting

The "Information Program for Citizen Advisory

Groups", developed by Pennsylvania State University, may enhance these public involvement activities The program consists of 18 information units, including units on Water Conservation and Reuse (Unit 8) and Cost-Effectiveness Analysis (Unit 10), geared toward citizens and local officials involved in water quality and wastewater treatment planning EPA's regional offices or individual state water pollution control agencies can be contacted concerning this program

3. What To Do

The public meeting should focus on the following regarding the flow reduction analysis

- Presenting a clear description of the program alternatives and the associated monetary and nonmonetary costs and benefits
- Seeking public comments on issues and concerns which will help evaluate or predict
  - The likelihood of public acceptance of specific flow reduction measures and the program as a whole
  - Ways to enhance the effectiveness of the program
  - Which public information measures are likely to reach and be effective with the most people
  - The ease or difficulty of program implementation
  - Other issues of uncertainty
- Providing an opportunity for open public comment - that is, an opportunity for the public participants to raise issues of concern to them and to make comments and suggestions.

After the meeting, make appropriate changes in program alternatives based upon these public comments Reassess both the monetary and nonmonetary costs and benefits where their initial evaluation has been affected by the public's input and program changes

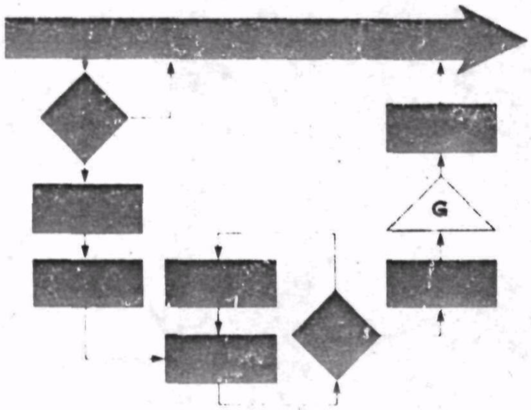
4. Example

Results of a public meeting may reveal that a local institution, such as a university or hospital, is willing to voluntarily undertake an all-out flow reduction/water conservation campaign One or more program alternatives can then be adjusted to accommodate this additional feature For example, the institution may be willing to install water saving retrofit devices in all toilets and shower heads provided that the utility supply the devices In such a case, appropriate adjustments in flow projections, direct program costs and cost savings must be made

5. Major Observations

The example provided above highlights a key feature of the approach mentioned earlier in this document The flow reduction analysis involves an iterative process Changes are constantly made as new information and insight is obtained Only in this way can an effective and broadly acceptable program for the community be synthesized, receive public support, and ultimately be implemented.

- Reasonable costs of public participation as identified in the "Public Participation Work Plan" for Step 1, or as otherwise approved by EPA, are grant eligible (U S EPA, February 1979)
- Public participation in Step 2 (design) and Step 3 (construction) is also grant eligible provided that it is included in an EPA-approved work plan for such activities (U S EPA, February 1979) This is important to keep in mind in contemplating how public participation may be used as a vehicle for continuing public support of a flow reduction program. It may even be a key part of the public information component of the selected program



Step G.

Select A Flow Reduction Program

- Develop selection criteria.
- Display impacts of attractive alternatives.
- Involve appropriate authorities in final selection.

G. Select a Flow Reduction Program

1. Statement of Purpose

The intent of this step is to suggest a general framework for selecting the final flow reduction program It stresses full consideration of all effects pertaining to each alternative program so that a judgment inclusive of all available information will be made

2. Data and Information Needs

Selecting the final flow reduction program requires

- **Criteria** appropriate for the screening of alternatives and selection of the final program Although these criteria will vary depending on a particular community's circumstances, they must incorporate the features required in the EPA's Cost-Effectiveness Guidelines for the recommended program - that is, the recommended program must comprise flow reduction measures which are cost-effective, supported by the public, and within the implementation authority of the grantee or another entity willing to cooperate with the grantee
- **A description** of the major findings and results of the evaluation of each attractive flow reduction program alternative The scope of this information is a matter of subjective judgment, but should be sufficient for weighing the relative merits of each alternative

3. What To Do

Once the selection criteria are made explicit and the information needed to weigh the alternatives is synthesized, a recommended program from among the available alternatives must be selected The two cases described below suggest a framework for program selection appropriate for communities with two different goal orientations

- **Case 1:** A community has set a specific target at the outset of the flow reduction analysis to either reduce wastewater flows a given amount by a certain time, or to hold flows at or below a specified level over a specified period of time This approach could be motivated by the need to avoid capacity overloads which would otherwise occur at some point during the several years of construction needed for a major facility The following steps leading to program selection would be appropriate for such a community

  - Screen out any alternatives which, upon final analysis, appear unlikely to prove effective in meeting the stated target Note that eliminating an alternative for this reason, especially when it offers greater net benefits than an alternative not eliminated, can only be justified if this target absolutely must be met for some critical reason (e.g., resulting capacity overloads would violate permit requirements)

  - From among those alternatives remaining, select as the recommended program one for which the net monetary benefits are positive. Generally, try to maximize net benefits provided that a qualitative assessment of the non-monetary costs and benefits (including public support and implementation considerations) does not point to selection of a different alternative

- **Case 2:** No specific target for reduced flows has been established for the program other than to derive the maximum benefits obtainable An appropriate approach for a community fitting this situation would be the following

  - Select that alternative for which the net monetary benefits are a maximum, provided that a qualitative assessment of the non-monetary costs and benefits (including public support and implementation considerations does not point to selection of a different alternative

The broad framework for selection is thus to maximize net benefits (i.e., cost savings) allowing for the possibility that nonmonetary effects may be overriding

Organizing data along the lines of Table 19 may be useful in making this final progam selection.

4. Major Observations

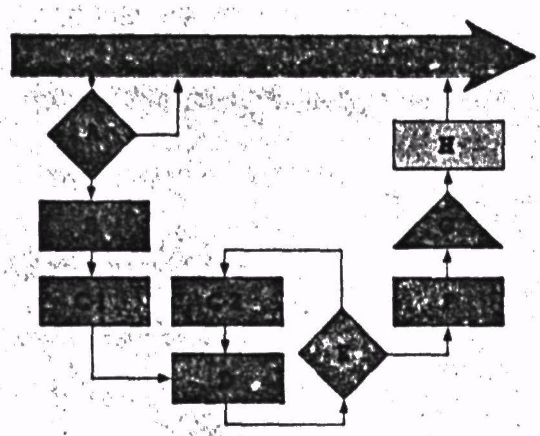
- Clearly, where the authority to implement the measures included in a program alternative is either lacking or insufficient, and there appears to be little hope of obtaining the necessary authority, this alternative should be eliminated. This is a key implementation issue which should have been acted upon earlier
- The final selection of the recommended program cannot be other than subjective due to the qualitative nature and potential importance of the nonmonetary costs and benefits Nevertheless, this selection should be based upon full consideration and knowledge of the complete array of benefits and costs

	Present Worth of Net Monetary Benefits	Important Nonmonetary Costs	Important Nonmonetary Benefits	Public Support	Ability to Implement	Other Comments
Alternative 1						
Alternative 2						
Alternative 3						
Alternative 4						
Alternative 5						

Recommended Flow Reduction Program: Alternative ______.

Table 19. **Organization Of Data For Final Program Selection**

associated with each alternative.



Step H. Incorporate Into Facilities Plan

- Make appropriate adjustments in facility size or staging.
- Document flow reduction analysis and selected program.

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. Incorporate Flow Reduction Program into Facilities Plan

Statement of Purpose

The purpose of this final step is to integrate e selected flow reduction program and its nticipated effects with the other aspects of facil·es planning and to document results of the flow ·duction analysis.

Data and Information Needs

All of the information needed for this step has ·ther been obtained as part of the analysis or is vailable from the rest of the facilities planning rocess.

What To Do

Based on the flow reduction program ·lected and the projected wastewater flows for is "with flow reduction" condition, final adjust·ients are made in the sizing or staging of the cility corresponding to the altered projections. ie appropriate adjustments should already ave been determined in order to perform the ost savings analysis for that program alternative.

Finally, document in the facilities plan:

- An estimate of the costs of the proposed flow reduction measures over a 20-year planning period.
- An estimate of energy reductions, total cost savings for wastewater treatment, water supply and energy use, and the net cost savings from the proposed flow reduction measures over the planning period.
- Provisions for implementing the proposed flow reduction program including a public information program.
- A commitment that the flow reduction program will be carried out as stated if adjustments are made to a facilities plan based on projected water savings (Yeaman, 1980). Appendix A to the handbook provides additional information on the documentation required.

4. Major Observations

As emphasized earlier, the flow reduction analysis is one of three tasks undertaken to refine wastewater flow projections and treatment plant capacity needs. The results of the analysis will not call for fundamental alterations in the type of facility being planned, but rather for marginal changes in the sizing or staging of certain of the facility's unit processes. Thus, incorporating the flow reduction analysis results into the facilities plan near the end of the planning process will not affect the schedule or timing of subsequent construction grant program efforts.

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Appendix A
Sections 8b, c, and d of the Cost-Effectiveness Guidelines for the Construction Grants Program

b. Wastewater flow estimates.

(1) In determining total average daily flow for the design of treatment works, the flows to be considered include the average daily base flows (ADBF) expected from residential sources, commercial sources, institutional sources, and industries the works will serve plus allowances for future industries and nonexcessive infiltration/inflow The amount of nonexcessive infiltration/inflow not included in the base flow estimates presented herein, is to be determined according to the Agency guidance for sewer system evaluation or Agency policy on treatment and control of combined sewer overflows (PRM 75-34).

(2) The estimation of existing and future ADBF, exclusive of flow reduction from combined residential, commercial and institutional sources, shall be based upon one of the following methods:

(a) Preferred method. Existing ADBF is estimated based upon a fully documented analysis of water use records adjusted for consumption and losses or on records of wastewater flows for extended dry periods less estimated dry weather infiltration. Future flows for the treatment works design should be estimated by determining the existing per capita flows based on existing sewered resident population and multiplying this figure by the future projected population to be served Seasonal population can be converted to equivalent full time residents using the following multipliers:

Day use visitor	0.1 to 0.2
Seasonal visitor	0.5 to 0.8

The preferred method shall be used wherever water supply records or wastewater flow data exist Allowances for future increases of per capita flow over time will not be approved.

(b) Optional method. Where water supply and wastewater flow data are lacking, existing and future ADBF shall be estimated by multiplying a gallon per capita per day (gpcd) allowance not exceeding those in the following table, except as noted below, by the estimated total of the existing and future resident populations to be served. The tabulated ADBF allowances, based upon several studies of municipal water use, include estimates for commercial and institutional sources as well as residential sources. The Regional Administrator may approve exceptions to the tabulated allowances where large (more than 25 percent of total estimated ADBF) commercial and institutional flows are documented.

Description	Gallons per capita, per day
Non SMSA cities and towns with projected total 10-year populations of 5,000 or less	60 to 70
Other cities and towns	65 to 80

c. Flow reduction.

The cost effectiveness analysis for each facility planning area shall include an evaluation of the costs, cost savings, and effects of flow reduction measures unless the existing ADBF from the area is less than 70 gpcd, or the current population of the applicant municipality is under 10,000, or the Regional Administrator exempts the area for having an effective existing flow reduction program. Flow reduction measures include public education, pricing and regulatory approaches or a combination of these In preparing the facilities plan and included cost effectiveness analysis, the grantee shall, as a minimum:

(1) Estimate the flow reductions implementable and cost effective when the treatment works become operational and after 10 and 20 years of operation. The measures to be evaluated shall include a public information program, pricing and regulatory approaches; installation of water meters, and retrofit of toilet dams and low flow shower heads for existing homes and other habitation, and specific changes in local ordinances, building codes or plumbing codes requiring installations of water saving devices such as water meters, water conserving toilets, shower heads, lavatory faucets, and appliances in new homes, motels, hotels, institutions, and other establishments.

(2) Estimate the costs of the proposed flow reduction measures over the 20-year planning period, including costs of public information, administration, retrofit of existing buildings and the incremental costs, if any, of installing water conserving devices in new homes and establishments.

(3) Estimate the energy reductions; total cost savings for wastewater treatment, water supply and energy use; and the net cost savings (total savings minus total costs) attributable to the proposed flow reduction measures over the planning period. The estimated cost savings shall reflect reduced sizes of proposed wastewater

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treatment works plus reduced costs of future water supply facility expansions.

(4) Develop and provide for implementing a recommended flow reduction program. This shall include a public information program highlighting effective flow reduction measures, their costs, and the savings of water and costs for a typical household and for the community. In addition, the recommended program shall comprise those flow reduction measures which are cost effective, supported by the public and within the implementation authority of the grantee or another entity willing to cooperate with the grantee.

(5) Take into account in the design of the treatment works the flow reduction estimated for the recommended program.

d. Industrial flows.

(1)The treatment works' total design flow capacity may include allowances for industrial flows. The allowances may include capacity needed for industrial flows which the existing treatment works presently serves. However, these flows shall be carefully reviewed and means of reducing them shall be considered. Letters of intent to the grantee are required to document capacity needs for existing flows from significant industrial users and for future flows from all industries intending to increase their flows or relocate in the area. Requirements for letters of intent from significant industrial dischargers are set forth in § 35.925-11(c)(40 CFR Part 35).

(2) While many uncertainties accompany forecasting future industrial flows, there is still a need to allow for some unplanned future industrial growth. Thus, the cost effective (grant eligible) design capacity and flow of the treatment works may include (in addition to the existing industrial flows and future industrial flows documented by letters of intent) a nominal flow allowance for future nonidentifiable industries or for unplanned industrial expansions, provided that 208 plans, land use plans and zoning provide for such industrial growth. This additional allowance for future unplanned industrial flow shall not exceed 5 percent (or 10 percent for towns with less than 10,000 population) of the total design flow of the treatment works exclusive of the allowance or 25 percent of the total industrial flow (existing plus documented future), whichever is greater.

Source: U.S. EPA September 27, 1978. 40CFR Part 35, Subpart E. "Municipal Wastewater Treatment Works Construction Grants Program." **Federal Register** Vol. 43, No. 188.

Appendix B
Detailed Descriptions of Selected Flow Reduction Measures

This appendix supplements the discussion of flow reduction measures provided under Step C in Part II of this document with more detailed descriptions of specific individual measures that may be included in a flow reduction program. Three types of methods are discussed:

- Structural methods - water saving devices and appliances that can be installed in new and existing construction (see below).
- Economic methods - common types of water rate structures and the relative extent to which they encourage or discourage conservation (page 79).
- Legal methods - detailed descriptions and examples of code changes that have been implemented (page 81).

1. Water Saving Devices and 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. Many devices are also economically attractive; the water efficient models are often available for about the same cost as the conventional models. Furthermore, conventional models already installed can often be made more efficient with simple, inexpensive retrofit devices.

With increasing attention being given to water and energy conservation, and with the added incentives of natural limits to water supplies and ever increasing costs for water, wastewater, and energy services, water efficient fixtures and devices have received substantial attention. Several publications have provided intensive reviews of the types, sources, and costs of water saving hardware available. Notable examples include:

Milne, Murray. 1976. **Residential Water Conservation.** Report No. 35. California Water Resources Center, University of California/Davis.

Nelson, J. O., 1977. **North Marin's Little Compendium of Water Saving Ideas.** North Marin County Water District. Novato, California.

California (State of), Department of Water Resources. 1978. **A Pilot Water Conservation Program.** Bulletin No. 191 (especially Appendices G and H on Device Testing and Selection). Sacramento, California.

Consumers Reports (staff). 1978. "Water: Time to Start Saving?" **Consumer Reports,** 43(5): 294-302 and 43(10): 572-577.

It is important to recognize that rapid changes are occurring in the water use efficiencies and costs of relevant hardware. Over the past several years, essentially all major plumbing and appliance manufacturers have begun offering a complete line of water saving products; indeed, some manufacturers have switched their product lines to such an extent that water efficient models are now the norm and may even be less expensive than the old "conventional" models. The changes are major and are continuing. Thus one important aspect of flow reduction analysis will be to make sure that available information on hardware performance and cost is up-to-date. This will require selective inquiries to manufacturers and distributors in addition to utilization of the most current compilations of available hardware information.

The following paragraphs briefly introduce and summarize the status of many devices and appliances which may be of interest. It is intended that this be a starting point for those performing flow reduction analyses. This information should be used to develop more specific, up-to date information in the context of individual analysis efforts.

a. Products for Installation in New Construction, Remodeling, and Replacement

1) Shower Heads. Conventional shower heads are usually used at water delivery rates of approximately 5 to 6 gallons per minute. Maximum flow rates sometimes exceed 12 gpm. Several different types of low flow shower heads are available which reduce the maximum possible flow rate to between 0.5 and 4.5 gpm, the average rate being approximately 2.5 gpm. The California Department of Water Resources (1978) recently conducted extensive tests with conventional (control) and low flow shower heads. Figure B-1 summarizes their results. Note the wide variability among maximum flow rates for conventional shower heads; in some cases they obviously were designed with little concern about using water efficiently. On the other hand, the group of thirteen low flow shower heads tested indicates that manufacturers are now making available a selection of fixtures incorporating more concern for wise energy and water use. Some states are now requiring that all shower heads sold have maximum flow rates (at a specific pressure) below some standard value,

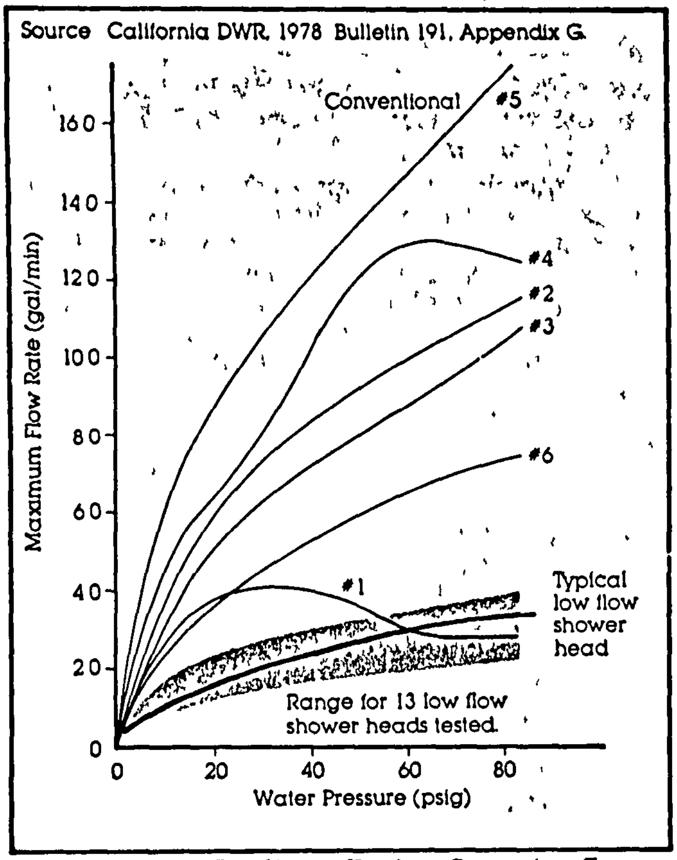


Figure B 1 Low Flow Shower Heads — Comparison To Conventional Models

usually about 3 gpm. In California, for example, this requirement was adopted in 1977

Most low flow shower heads incorporate a flow restrictor and aerator In addition, some are equipped with cut off valves which allow the flow to be stopped temporarily while soaping without altering the hot/cold water mixture at the on/off valves. In addition to the water savings from low flow shower head use, substantial energy savings result from less hot water being used. Generally between 50 to 75 percent of shower water is hot water, the exact amount depends upon the distance between the shower and hot water heater, the amount of insulation on pipes transporting hot water to the shower, the ambient water temperature, the temperature setting of the hot water heater, and the user's habits. In California, the new shower head flow limit was adopted as an energy conservation measure rather than as a water conservation measure.

Low flow shower heads are competitive in cost with conventional shower heads and many manufacturers' lines now feature low flow models. Costs for both conventional and low flow models range from $4.00 for plastic models up to $20.00 for metal alloy versions. Some low flow shower heads presently on the market do not satisfactorily reduce flows and maintain shower quality It is suggested that particular devices be tested or the results of tests by other agencies be reviewed before recommending specific brand names or models. For example, tests have been conducted and reported in **Consumer Reports** (May 1978) and by the California Department of Water Resources (1978).

2) Faucets. Conventional domestic faucets normally provide a maximum discharge of 4 to 5 gpm. Low flow faucets deliver a maximun flow of 0.5 to 2.5 gpm depending on the flow control type and specific design. They typically cost between 5 and 10 percent more than conventional faucets (Nelson, 1977), this usually amounts to a difference of one to six dollars. In addition to the water savings provided by these faucets, the savings in energy for heating hot water are substantial. The mechanisms by which low flow faucets achieve water savings vary:

- **Flow restrictors** may be incorporated into faucets with resulting maximum flows increasing roughly in proportion to water pressure
- **Flow controllers** are an alternative approach incorporating pressure activated, variable size orifices designed to provide a constant maximum discharge, even with increasing pressure
- **Thermostatic mixing valves** reduce faucet flows by automatically mixing water to a desired temperature, thereby saving water that would otherwise be wasted while the user adjusts the independent hot and cold controls to obtain a desirable temperature These valves are already being installed in a large percentage of new construction.
- **Automatic shut-off valves,** available on some thermostatic mixing valves, help to prevent overuse and water loss from water left running accidently.
- **Spray tap faucets,** which cost only slightly more than conventional faucets, deliver water in a broad pattern of droplets and are capable of reducing the flow rate to 1 or 2 gpm. They are actually more efficient for washing and thus have a high potential for public acceptance.
- **Aerators** reduce flow by introducing bubbles into the water stream thereby reducing the degree of splashing and creating the appearance of a greater flow than actually exists. Water conserving aerators may reduce flow rates to 0.75 gpm at supply pressures from 20 to 100 psig (Milne, 1976).

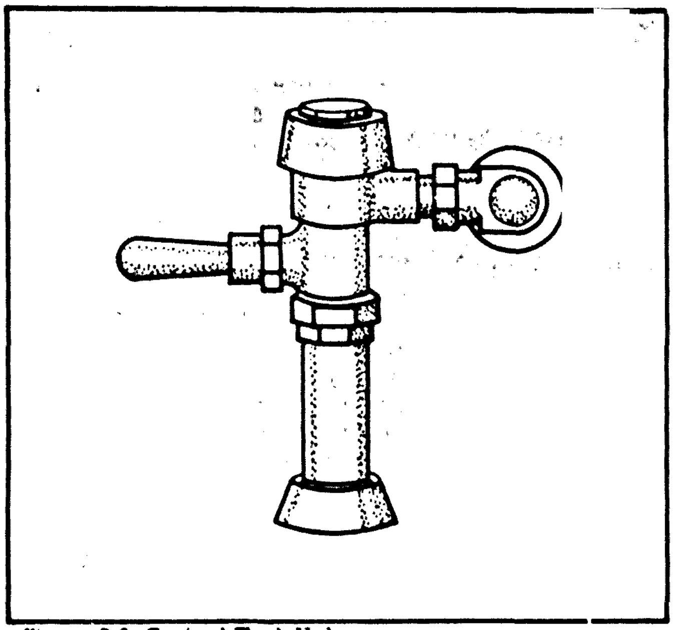


Figure B-2. Typical Flush Valve

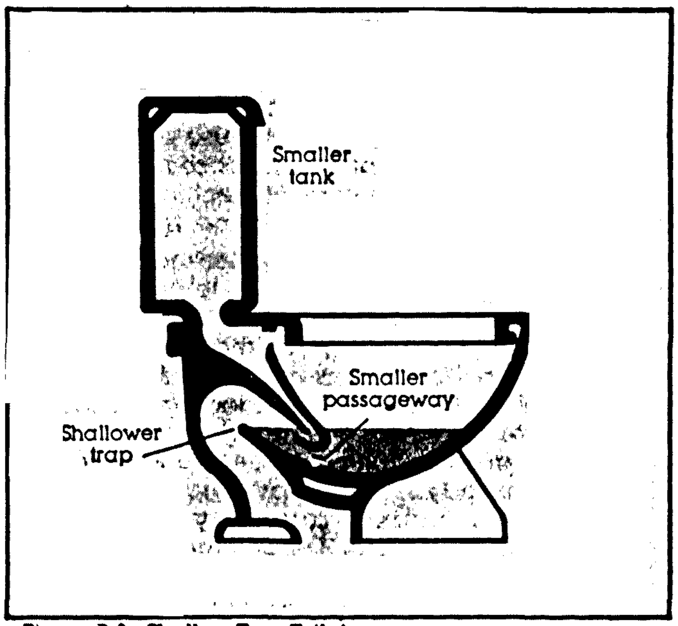


Figure B-3. Shallow Trap Toilet

3) **Toilets.** There are a variety of water-saving toilets on the market as evidenced by the following discussions of types available.

a) **Flush Valve.** Flush valve toilets (see Figure B-2) are commonly found in commercial establishments where their use is frequently required by code. Residential use is inhibited by the need for a larger-than-usual water service line, the installation of which becomes economically justified only when a large number of uses is expected (Metcalf & Eddy, 1976). Flush valve toilets are characterized by a very forceful flushing action made possible by an oversize water feed line (usually one inch) and a quick release valve. Flush valves usually require 3 to 4 gallons of water per flush compared to the 5 gallon average for standard toilets (Nelson, 1977).

b) **Water Saving Tank Type (Shallow Trap).** While conventional tank toilets require 5 to 6 gallons per flush (with "quiet models" requiring as much as 9 gallons per flush), shallow trap toilets utilize only 3.5 gallons per flush. The shallow trap toilet is a variation of the conventional floor mounted close-coupled toilet. Other than the reduced size of its tank, it outwardly appears and operates like other conventional water flushing toilets (see Figure B-3). The water saving features are achieved by modified design of the toilet bowl. Although the common siphon jet flushing action is utilized, (Milne 1976), 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 (U.S. EPA, 1980). The result is that significantly less water and a smaller tank can be used. The cost of a shallow trap toilet is comparable to that of a conventional tank model. Although they had been slightly more expensive (up to $5) than conventional models, the shallow trap model is now becoming the norm and its cost is equal to or less than that of conventional models in many areas.

c) **British Style Dual Cycle.** Dual cycle toilets are designed with a dual flush mechanism which allows less water to be used in flushing liquid wastes (1.25 gallons/flush) than solid wastes (2.5 gallons/flush). The user, for example, may pull the handle up for flushing liquids and push down for solids, or may simply hold the handle down for the complete flush cycle needed for solids disposal. Few dual cycle toilets are manufactured in the United States. Moreover, the added complexity in operation makes them somewhat less socially acceptable (Metcalf & Eddy, 1976). It was concluded by Milne (1976) that the dual cycle toilet must be regarded as highly dependent on individual preferences and would require an intensive public information component. Still, a dual flush toilet is not costly and could result in savings of one gallon or more per flush (about 4 gpcd or 6 percent of present indoor water use) over the savings achieved by a shallow trap toilet. In communities with limited water supplies or severe quantitative restrictions on wastewater disposal, dual cycle toilets could be attractive.

d) Oil-Flush. A clear, odorless mineral oil is used for waste transport in this comparatively expensive toilet system. Although clearly an effective water saving appliance (water use is zero), this system requires greater use of electricity The approximate cost of $2,500 does not include installation or the extra costs of electricity, chemicals and maintenance (Milne, 1976).

e) Composter This toilet system relies on aerobic biological decomposition to eliminate organic wastes. A rich humus soil conditioner is the end product of the organic matter decomposition. No water is used, thus savings of approximately 40 percent of indoor water use may be achieved. Along with reducing wastewater flows and producing a useful end product, these systems may help improve groundwater supplies. Operational problems may in some cases be a limiting factor Despite the relatively high cost (approximately $950, not including installation), substantial savings could result if installed as original equipment (Milne, 1976).

f) Incinerator This is a self contained toilet system operated by electricity and gas. Burning eliminates all liquids and bacteria and reduces solids. Although possibly desirable where water shortages exist or where central sewer systems are unavailable, the high capital and operating costs and the need for regular cleaning make public acceptance quite limited (Milne, 1976).

g) Vacuum. Operation of this type of toilet relies on vacuum action combined with a small water flush. Since it requires only about 6 percent of the water used by conventional toilets, substantial savings in indoor water use would result The cost of these systems varies, depending upon such factors as the total number of homes, housing density, and type of soil. This system is not appropriate for installation in a single housing unit. Instead, it is efficient when installed in community sized developments and in commercial or institutional settings. Again, although this system uses less water, it requires greater consumption of energy (Milne, 1976).

It is important to note that some of the more exotic systems (freezing, composting, incineration units) are often not recognized by codes due to their recent development and to uncertainties on potential health hazards. Use of these systems is usually reserved for remote locations where water supplies are severely limited, or sewers are not available and septic tank soil absorption systems are not functional (Milne, 1976).

4) Home Appliances. Dishwashers and washing machines are the two major water using home appliances. Both appliances also significantly affect home energy consumption due to the amount of hot water they require.

a) Clothes Washers. Conventional full size washing machines use between 40 to 55 gallons for a full wash load. Most manufacturers now provide models that are designed with water and energy saving in mind. In addition to improved consideration of water use with full loads and complete cycles, many models now allow the user to make load size, cycle, and water temperature adjustments which can result in substantial savings. "Suds saver" models are also available; they utilize a separate holding sink to store and then recycle wash water for subsequent loads. Consumer Reports (1978) provides a recent review of washing machine models including water and energy efficiency

b) Dishwashers. These appliances use 12 to 18 gallons per full cycle Many models feature cycle adjustments controls which can reduce water use to as low as 7 gallons per cycle by eliminating a wash/rinse cycle from the full cycle Many new appliances are now labeled according to the amounts of water and energy they require in operation.

5) Pressure Reducers. Pressure reducing valves can be installed either in individual homes or in the distribution system servicing a number of homes. The pressure in a distribution zone often must be maintained at a higher level than is necessary for residences - usually to insure adequate supplies for fire fighting Pressures around 40 psig are sufficient for residences, while business or downtown regions may require pressures of 60-75 psig (Fair and Geyer, 1965). For new single-family residences, it will generally be practical to install a pressure reducing valve (such as that shown in Figure B-4) in home service lines to reduce pressure to 40 psig, wherever it exceeds 60 psig For businesses and high rise living complexes, higher pressures may be required and the practicality of installing a pressure reducer would have to be decided on a case-by case basis. Pressure reducers may cost from $30 to $50, but when installed as part of new buildings, the labor cost for installation should be insignificant.

Homes being fitted with water saving fixtures and appliances would not experience as great a decrease in water use from installation of a pressure reducer as would a home without water saving features. For example, a reduction in line pressure from 60 to 40 psig would reduce the maximum flow rate of a low flow shower head on the average from 2.9 gpm to only 2.4 gpm, while the reduction with a conventional shower head may be several gpm. (Double counting is discussed more fully in Appendix C.) Estimated

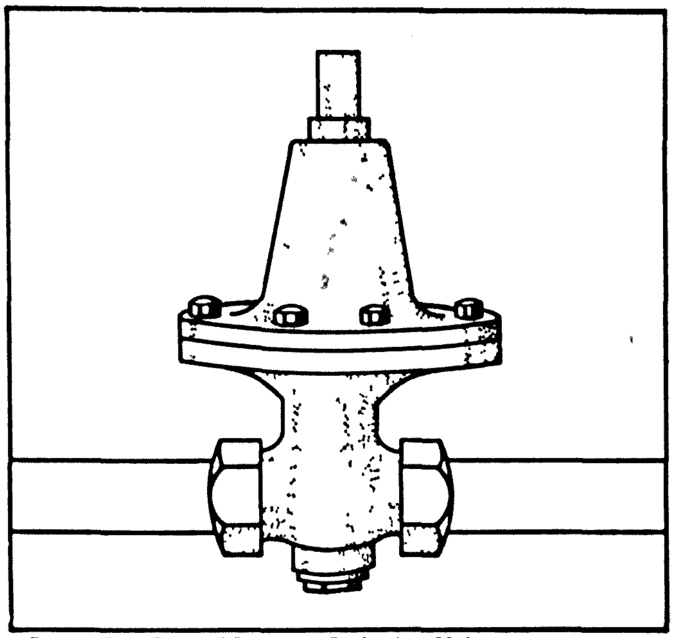


Figure B-4 Typical Pressure Reducing Valve

savings from pressure reducers must be based on both the amount of pressure reduction accomplished and the types of water using fixtures in the buildings.

b Installation of Flow Control and Water Saving Devices in Existing Residences and Businesses (i.e., Retrofitting).

Until recently, say 1975, most water using fixtures were designed with little attention placed on efficient water and energy use This fact is dramatized by Figure B-1 which illustrates the difference between old, "conventional" shower heads and new, low flow shower heads. Now, even though awareness of water efficiency has increased, manufacturers and builders are still in transition toward products that are more water and energy efficient Thus, essentially all buildings constructed before 1975 and most built prior to 1980 have fixtures and appliances which utilize relatively large amounts of water. However, many of these fixtures can be easily retrofit with water saving devices which are relatively inexpensive, maintain the quality of service, and result in significant water and energy savings and wastewater flow reduction.

Motivated by limited water supplies, drought, energy shortages, and the increasing cost of various community services, many governmental units have begun to spotlight the potential savings from retrofitting and some have conducted major retrofit campaigns. Several different approaches are available including:

- Public information on potential benefits - but reliance on property owners to purchase and install appropriate retrofit devices.
- Free inspection and retrofit installation at the request of the property owner.
- Public information and free distribution of devices at a central location where property owners can obtain them.
- Mass distribution of retrofit kits by hanging them on door knobs with suitable accompanying installation instructions and a public information campaign.
- Mass mailing of devices with instructions and a simultaneous public information campaign.
- House-to-house visitation and free installation of the retrofit devices (at the initiative of a government agency or utility, but with the property owner's permission).

The last two approaches - mass mailing and house to-house free installation - are really the only approaches that have achieved consistently positive results in terms of significant percentages of implementation.

Three examples of large, successful retrofit programs are the following:

- **California Department of Water Resources.** During the 1976-1977 drought, DWR (1978) conducted "A Pilot Water Conservation Program" in which it experimented with various retrofit program approaches. Based on that experience, DWR is continuing its retrofit efforts with mass mailings of kits to residents in selected county/municipal areas. This program is funded by several million dollars of special state appropriations.

  One of the six areas comprising DWR's 1976-1977 pilot study was the primarily residential community of Oak Park, a relatively new development of approximately 750 single family houses. The Oak Park retrofit program consisted of free, door to-door installation of free toilet dams and shower head flow restrictors. By June 1977, 88.6 percent of the total community had been retrofitted. A survey conducted nearly two years later (April 1979) revealed that 59 percent of the total residences in the community had toilet retrofits in place and 56.8 percent had shower retrofits in place. Dry weather wastewater flows are reported to have decreased by 25 percent (California DWR, September 1979).

  DWR's recent efforts have involved mailing retrofit kits to 1.6 million households. In May 1980, the program's effectiveness was determined for the community of Santa

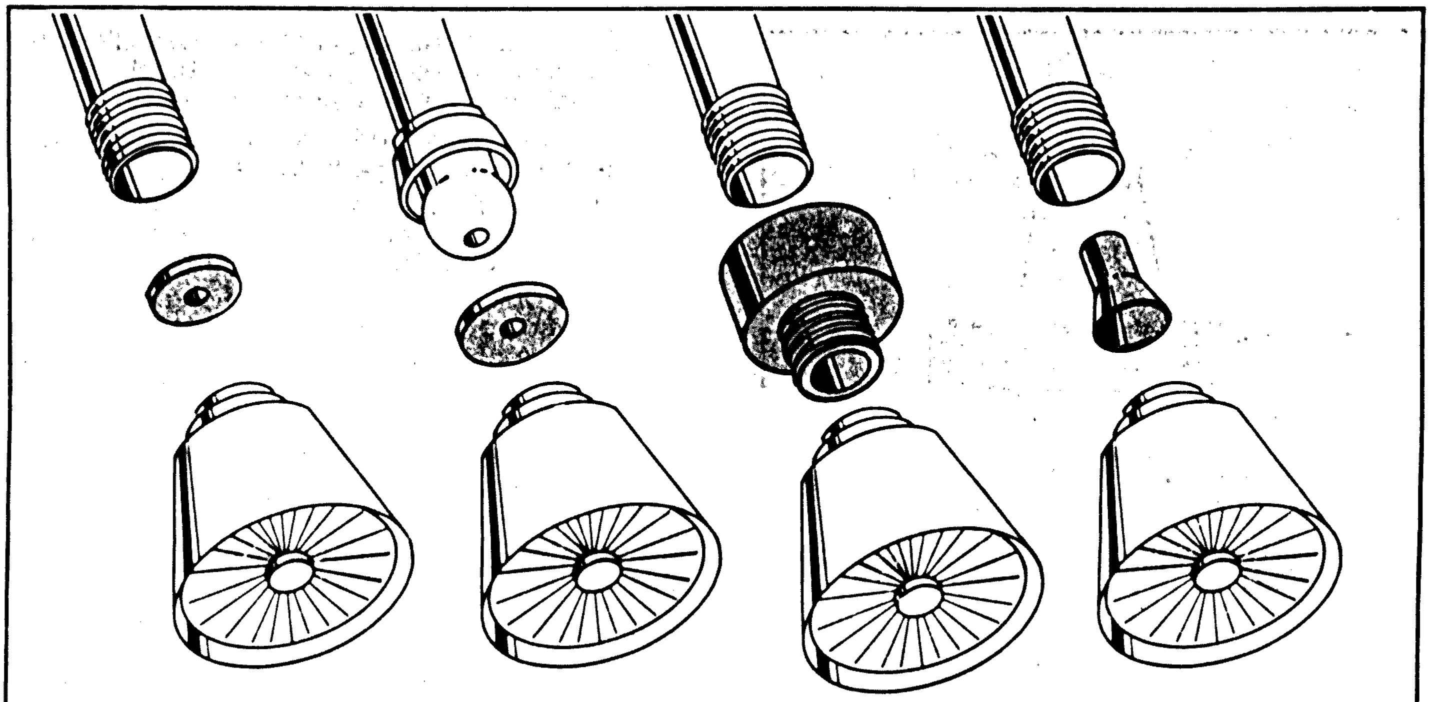


Figure B-5. Typical Shower Retrofit Devices

Barbara. It was found that 37 percent of the total population had installed the toilet bags and 17 percent had installed the shower inserts (Heath, September 1980).

- **Washington Suburban Sanitary Commission.** Over the past 10 years the WSSC has conducted an intensive conservation campaign to alleviate water supply shortages and avoid major capital expenditures. Among the major components of the campaign were the bottle kit and shower device distribution programs. In 1973, over 300,000 kits containing three plastic bottles (for use in toilet tanks), dye pills for toilet leak detection and an instruction booklet were distributed, including door-to-door distribution to nearly all of the 200,000 single-family homes in WSSC's service area. In a follow-up survey, 93 percent of the respondents indicated that they had used one or more of the bottles in their toilet tanks.

  Another program was initiated in 1974 involving the free distribution of shower flow control devices to those WSCC customers who requested them. Between 75,000 to 100,000 WSSC customers were estimated to have received the shower devices. Thirty-six percent of those responding to a follow-up survey indicated they had received the devices, and 41 percent of these (i.e., 15 percent of the respondents) indicated that the device was installed. The large yearly fluctuations in water use as well as the implementation of other conservation measures makes it difficult to assess the effectiveness of the device distribution programs in reducing water use. However, a comparison of water use between 1968 and 1975 among those water users surveyed indicated an overall water use reduction of 10 percent (Sharpe and Fletcher, 1977).

- **U.S. Department of Energy.** The DOE conducted a massive "Low Cost/No Cost" energy conservation campaign in New England during the Fall of 1979. Their mass mailing campaign of a booklet with energy saving tips featured "hot water" energy conservation as a "new thrust" for the energy saving message. In order to give this thrust added emphasis and to provide added motivation to homeowners, they included a flow restricting shower insert. A follow-up evaluation of the campaign (U.S. DOE, 1980) has shown homeowner response to be very favorable with over 29 percent of the households sampled reporting they had installed the shower inserts.

In summary, retrofitting is extremely attractive in terms of potential water and energy savings and cost-effectiveness. Retrofit materials can be obtained inexpensively either by individual property owners or in the form of retrofit kits assembled and distributed by public agencies. Several approaches are available for distribution of retrofit materials - mass mailing is one straightforward and effective technique. The major hurdle is achieving a high percentage installation rate. The significant choice in designing a retrofit campaign is (1) relying on property owners to install the devices (20 to 30 percent installation) or (2) organizing free installation utilizing trained personnel (80 to 90 percent installation). In either case a carefully designed public information program is crucial; this topic will be treated extensively in Part IV of this flow reduction series which is to be published as a separate volume.

The following subsections focus on the nature and effectiveness of available retrofit devices which could be used in a retrofit program.

1) **Shower Retrofits.** A variety of devices for retrofitting showers exists as is illustrated by Figure B-5. They can result in major reductions from the typical 5 to 6 gpm flows.

Plastic flow restrictors or orifice inserts reduce maximum flow rates to 2.5 to 4.5 gpm, depending upon the particular device and line pressure. Figure B-6 shows the range of effectiveness for restrictors tested by California DWR (1978). Installation involves placing the device in the water line before the shower head and is usually easy to accomplish.

Sometimes different device designs are required depending on whether a ball and swivel shower arm is present. California DWR has addressed this problem by distributing two different restrictors (Figure B-5), one for ball and swivel pipes and one for threaded pipes. Such devices can be purchased for less than one dollar; for bulk purchases in mass distribution programs the price may be less than ten cents each (California DWR, 1978).

Pressure compensating external flow controllers (Figure B-5) deliver flow at a constant rate regardless of line pressure (Figure B-6) and can be chosen to provide any of several desired maximum flows. The available range of flow rates is 1 to 4.5 gpm. These devices are more expensive (two to eight dollars) than the plastic restrictors. They are screwed into the lead-in pipe ahead of the shower head and are generally incompatible with a ball and swivel type of shower arm.

Source: California DWR, 1978, Bulletin 191, Appendix G.

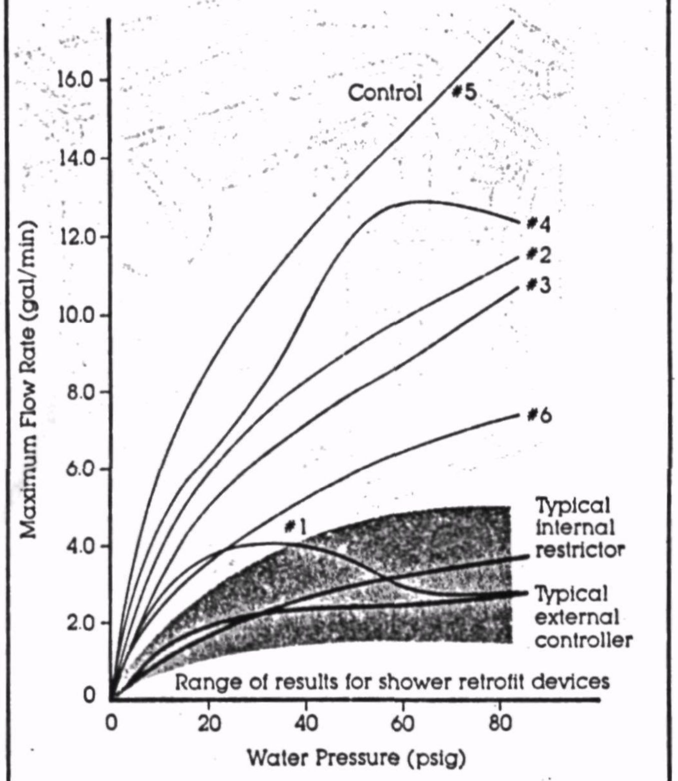


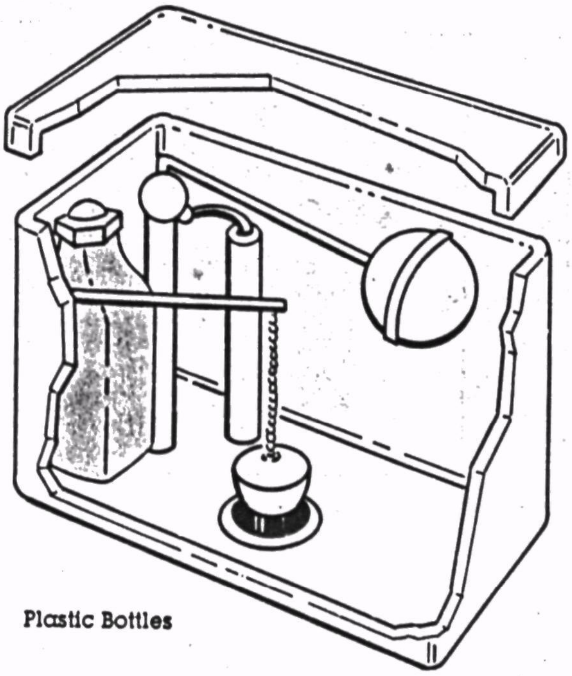
Figure B-6. Shower Retrofit Devices — Comparison To Conventional Shower Heads

Due to their low capital cost ($4-$20), new low flow shower heads, which were discussed previously under new construction, can also be considered for retrofit. Low flow shower heads may provide a more acceptable shower than orifice inserts or flow controllers, especially if the existing "conventional" shower head needs a high flow rate to provide a dispersed spray.

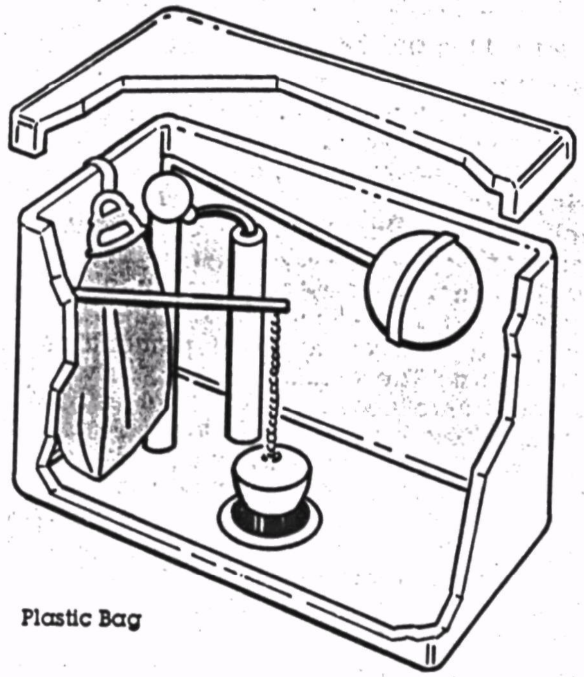
2) **Faucet Retrofits.** Devices for reducing faucet flow are of two main types, designed for in-line placement or attachment at the faucet outlet.

In-line devices are placed ahead of the faucet to reduce the opening through which the water passes. Usually these are restrictors or flow controllers such as those used for showers (Figure B-5). The inserts can be purchased for approximately $1.00 each and often are distributed free in retrofit campaigns. The flow controllers are usually more expensive ($2 to $8) but are usually designed to compensate for pressure variations. In-line devices can reduce faucet flows from the normal flow average of 5 gpm to 0.5 to 4 gpm, averaging about 2 gpm.

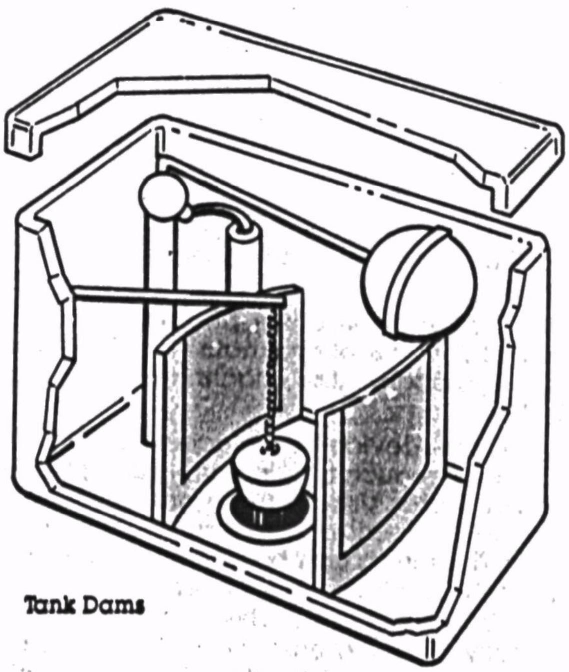
Aerators and spray taps used in retrofitting



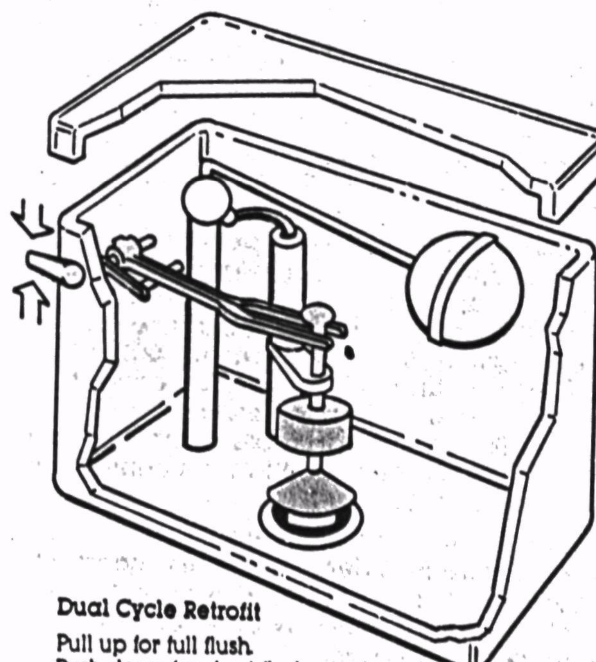
Plastic Bottles



Plastic Bag



Tank Dams



Dual Cycle Retrofit
Pull up for full flush.
Push down for short flush.

Figure B-7. Toilet Retrofitting Techniques

operate in the manner discussed previously They are attached to the faucet outlet (in compatible situations) and can reduce flow rates to between 0.75 and 3 gpm, averaging 1.5 to 2 gpm. They are inexpensive retrofit devices and, as in new construction, can provide faster washing and rinsing thereby contributing additional water savings.

3) Toilet Retrofits. Toilet retrofit devices are specifically designed to reduce the volume of water used for flushing in existing conventional tank type toilets. They can be any of several types, as indicated by Figure B-7 Plastic bottles containing a weight and 0.5 to 1 gallon of water can be placed into the tank, thereby displacing an equal volume of water from the active flush mode Plastic bags, which hang inside the toilet tank and function in the same manner are also widely utilized, especially in mass mailings. They save about one half gallon per flush. Tank dams (usually installed in pairs, as shown in Figure B-7) are pieces of plastic or rubber-coated metal which can be shaped into an arch and inserted vertically between the tank walls and abutting the tank base This creates a pocket of water which is precluded from draining into the bowl, saving approximately 1.5 gallons per flush Installation is not difficult and the dams can easily be adjusted to satisfy the householder

Of course water can also be displaced with bricks and other objects. Savings from these retrofit efforts are variable depending on the specific technique used and adjustments needed to maintain satisfactory flushing Savings are usually between 0.5 and 1.5 gallons per flush Use of bricks is frequently not recommended because of their tendency to disintegrate in the toilet tank

Dual cycle tank inserts can also be used to retrofit conventional toilets. They operate similarly to the dual cycle toilets for new construction discussed in the previous section This retrofit device can generally alter a toilet so that 2 gallons will be used for flushing liquids and 3 gallons for flushing solids, a savings of at least 3 and 2 gallons per flush, respectively (Metcalf & Eddy, 1976)

Comparisons of available toilet retrofit devices show costs to vary from less than $1 up to $10, with most not exceeding $5. Of course home improvised devices are generally free Given their low cost and relatively long expected life, toilet retrofits are attractive water conserving devices.

4) Other Retrofitting. Additional physical devices to lessen wastewater flows from existing buildings tend to be more costly undertakings. The four major items which could be considered are water meters, pressure reducers, and water efficient clothes washers and dishwashers. Of these the pressure reducer is the next most practical item provided the building's main supply line is readily accessible such as in a basement. These devices cost $30 to $50 and generally should be installed by trained professionals, thus their cost-effectiveness may be marginal depending on the labor cost involved. Nonetheless, in situations with high pressures in the water main they can result in significant, cost effective saving (See the discussion in the section on new construction for further details on performance) Where pressure reducers are installed in existing buildings care must be taken to avoid interference with lawn sprinkling systems or other water using features designed to utilize the existing high pressures.

Installation of water meters in existing buildings is dependent on a number of considerations which go beyond reductions of indoor water use and the resultant wastewater flows. They are discussed in more detail in the following section on water pricing and rate structures.

Retrofitting with water and energy efficient clothes washers and dishwashers in existing buildings is generally cost-effective when purchasing new or replacement models for other reasons. It may be a relevant consideration in deciding whether to replace a machine or undertake a major repair effort

2. Types of Water Pricing Structures

Water pricing is the primary economic method of achieving water conservation and thereby flow reduction. For pricing to be an effective conservation incentive, however, meters must be installed to establish the essential link between the price users pay for water and the quantity of water they use Thus cost-effectiveness may not be the only relevant criterion in deciding whether to install meters in presently unmetered areas. Equity considerations may lead to meter installation despite its relatively high cost

Residential water prices are usually established so that the revenues obtained cover the cost of supplying water to customers. This can be accomplished using a variety of rate structures, although these structures differ greatly in the degree to which they provide an incentive to reduce water use. Essentially three elements must be present for even a conservation-oriented rate structure to be an effective conservation measure, utility knowledge of customer water use,

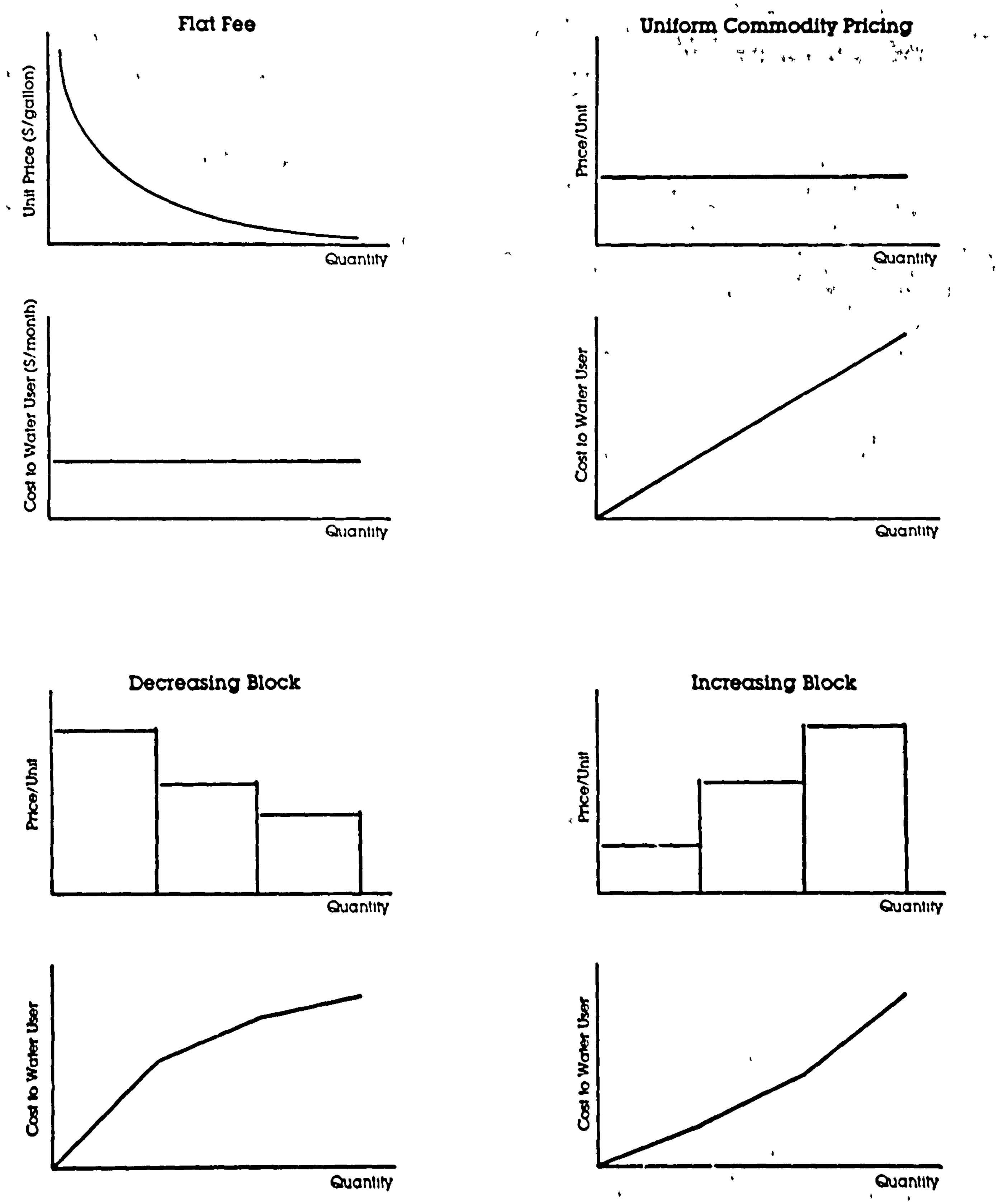


Figure B-8 Four Water Pricing Structures

customer knowledge and understanding of the rate structure, and customer ability to assess the economic impact that this rate structure will have on an individual residence (Rice and Shaw, 1978). Therefore, an effort to motivate water conservation through a rate structure must be carefully planned. Specifically:

- There must be metering
- Meter reading must be reflected on the bill and usage must be compared to some norm.
- A new rate structure must be accompanied by an intensive public information campaign to draw awareness to the water usage/cost relationship
- Care must be taken that the new rate structure produces enough revenue, even when people respond by conserving, so that rate increases do not become necessary so soon that they disrupt the water users' enthusiasm for conservation.

Several types of water pricing/rate structures which are now utilized are described below and some are illustrated in Figure B-8. They obviously provide differing incentives for and against wise water use

- **Flat fee pricing** involves charging customers a set fee per unit of time (e.g., monthly, quarterly) regardless of how much water is used. This constant charge may be varied according to the class of use or size of the service line (Nelson, 1977). It is usually used where meters are not installed thus neither the utility nor the water user knows how much waste occurs. Flat fee pricing provides no conservation incentive and actually encourages water wastage since the cost is not affected by the quantity used.
- **Decreasing block rate**, the traditional form of water pricing, consists of a series of prices per unit volume for blocks of water used. The applicable price decreases as the quantity of water used increases. This price structure favors large water users such as water intensive industries since they will pay substantially less per unit than do smaller users. The incentive to conserve diminishes as water use increases since total water cost is increasing at a decreasing rate.
- **Uniform commodity pricing** involves charging the same price per gallon regardless of the quantity of water used or the size of meter service. Since the total cost of water used increases at a constant rate, this pricing scheme does provide a significant incentive to conserve. If one customer uses only half as much water as another, the water bill is only half as much as well.
- **Peak demand pricing**, commonly implemented as summer surcharges for water use exceeding some baseline amount, is designed to promote conservation during those periods when the utility experiences the greatest demand or its most limited supply. This pricing scheme usually focuses on reducing outside water use for landscape irrigation – the category of use thought to be most sensitive to price. It should be pointed out that this pricing scheme will have little effect on wastewater flows if reductions occur mostly in outdoor water use
- **Increasing block rate** is the most conservation oriented rate structure currently in practice. Increasing numbers of utilities are adopting this form of pricing schedule as an effective means of reducing water use. In contrast to the decreasing block rate structure, the unit price of water increases in a step-like fashion as the quantity of water used increases. Many communities have achieved substantial reductions in water use by instituting increasing block pricing. Evidence of the effect of instituting this pricing structure in the Washington Suburban Sanitary Commission service area indicates that significant reductions are occurring in residential use (McGarry, 1976).
- **Wastewater service pricing** in some areas underscores the link between water use and wastewater flow and provides additional incentive for water use reduction. One approach is to make wastewater charges dependent on the metered level of total water use. For an increasing block rate, this would mean wastewater rates as well as water rates would increase with increased water use, thereby increasing the overall incentive to conserve (Citizens Advisory Committee, WSSC, 1977). However, in areas which use large amounts of water for lawn sprinkling, this pricing approach would be regarded as unfair by many people. They would be paying large unit prices for wastewater service when that water was not contributing to wastewater flows to the treatment plant.

3. Building and Plumbing Code Changes

Legally mandating the installation of water saving devices by making appropriate changes in building or plumbing codes is an effective way of reducing water use and wastewater flows. Water saving toilets are now required by local plumbing codes in several areas and by several states. For example, the California legislature enacted a bill in 1976 which provides for the use of water saving toilets in all new buildings (Nelson, 1977). Regulations can also be set requiring the installation of devices such as low flow shower heads, faucet aerators and pressure reducers in new construction, and such rules have been adopted to varying extents in several states. Unlike some of the other flow reduction measures, the effectiveness of code changes is not strictly dependent upon consumer response Once water saving devices are installed in new construction, conservation and flow reduction are automatic. This contrasts with other programs where retrofit devices may be distributed but not installed, or consumers may respond little to a change in price

Changes in building and plumbing codes will produce results more significant over the long term than short term. Benefits from implementing these legal measures will usually be greatest in areas experiencing growth. Due to sociopolitical acceptability, costs, and enforcement problems, the use of code modifications to require retrofitting of existing residential units is likely to be impractical (Flack, et al., 1977).

Any code changes to encourage water savings should be accompanied by an effort to obtain the support of professional plumbers and building inspectors who will be close to, and impacted by, these changes. This is just one aspect which can be covered in a public information program. One survey of professional plumbers on the rolls of the Washington Suburban Master Plumbers Association, Inc. indicated substantial plumber knowledge of and support for code changes requiring installation of water saving devices (Sharpe and Fletcher, 1977). Two examples of code changes which have been implemented are provided in the next two subsections. Subsection c presents the standards advocated by the Plumbing Manufacturers Institute as suitable for nationwide application.

a. Excerpt From the Fairfax County (Virginia) Plumbing Code.

As quoted in McGhee et al. (1978), the following is an excerpt from the above referenced code:

Water Conservation

In all new construction and in all repair and/or replacement of fixtures or trim, only fixtures and trim not exceeding the following flow rates and/or water usage shall be installed. These rates are based on a pressure at the fixture of 40 to 50 psi.

Water closets, tank type:	3.5 gal. per flush
Water closets, flushometer type:	3.0 gal. per flush
Urinals, tank type:	3.0 gal. per flush
Urinals, flushometer type:	3.0 gal. per flush
Shower heads:	3.0 gpm
Lavatory, sink faucets:	4.0 gpm
Lavatories for public use:	Faucets of lavatories located in rest rooms intended for public use shall be of the metering, or self closing type.

b. Authorization and Connection Requirements Issued by the Washington Suburban Sanitary Commission

As quoted in Metcalf and Eddy (1976), the following is an excerpt from the above-referenced requirements:

1) Tank type toilets for new single family homes, apartments, rental townhouses, motels, hotels and commercial buildings will be required to be of a design that provides a maximum flush not to exceed three and a half gallons, or, if a conventional toilet is used, must be equipped with an available water closet reservoir device designed to reduce the flush to three and a half gallons or less. After July 1, 1973, the toilet designed for the maximum three and a half gallon flush will be required in the installation of all tank type toilets.
2) Water saving shower heads to limit flow to a maximum of three and a half gallons a minute will be required in all units.
3) Aerators, which result in a flow reduction to approximately four gallons a minute, will be required on all kitchen sinks and lavatories.
4) Installation of a pressure reducing valve on the incoming service to the structure will be required for all properties where the incoming water pressure is expected to exceed 60 pounds per square inch. The Pressure Reducing Valve must provide adjustment of the pressure for the household service to within the range of 50 to 60 psi.
5) Cellar floor drains may not be connected to the sanitary sewerage system. When floor drains are installed, they must discharge to an approved storm drain. Discharge to the surface of a lot would be permitted only when a storm drain is not available to receive drainage. All buildings erected with cellars or basements in areas known to have

a water table above the basement floor will be required to have foundation drains around the outside of the building with a satisfactory point of discharge This requirement is included as a recent revision in the WSSC Plumbing Code and is mandatory for all new structures.

c. Water Conservation Plumbing Code Recommendations of the Plumbing Manufacturers Institute (Church, 1980).

- **Water closet – tank type** Tank type water closets shall flush with an average of 3.5 gallons and a maximum of 4 gallons.
- **Water closet – flushometer type.** Water closets flushed with a flushometer valve shall flush with an average of 3.0 gallons and a maximum of 3.5 gallons.
- **Shower heads.** Maximum flow from shower heads shall not exceed 2.75 gpm (+ .25 gpm) at pressure ranges from 20 to 80 psig Water supply will be provided at temperatures not to exceed 120° F at the showerhead in public use installations.
- **Lavatory and kitchen faucets.** Faucets will not exceed a flow rate of 2.75 gpm (+ .25 gal) at pressure ranges from 20 to 80 psig where hot and cold water supply are in the full open position.
- **Pressure regulating valves.** Where the service water pressure to a building is in excess of 60 psig, an approved water pressure regulator with strainer shall be installed to reduce the pressure in the building water distribution piping to 60 psig or less. Exceptions to this requirement are service lines to sill cocks and outside hydrants, and main supply risers in tall buildings where pressure from the mains is reduced to 60 psig or less at the fixture branches or at individual fixtures. (This language is edited from the Standard Plumbing Code)
- **Other.** It is suggested that all other water using fixtures or devices be evaluated for water usage on the basis of the actual requirements of the installation, with the subsequent setting of maximum usage limits by the local jurisdictions and engineering practices. (Water softeners, wash sinks, special fixtures, etc)

Note that the references for this appendix are included in the list of References, beginning on page 65

Appendix C
Relative Economic Benefits of Selected Water Saving and Flow Control Devices

This appendix provides additional information for the flow reduction analyst/planner to use in developing and evaluating a first cut program and becoming sensitive to potential modifications or alternatives to the program Information herein supplements Step C and Step D in Part II and Appendix B by providing the following information:

- A measure of the relative monetary benefits of various water saving and flow control devices (see below).
- Examples of methods for calculating annual water savings, annual energy savings and the annual net monetary benefits associated with various water saving devices (page 87).
- The effect of combining various flow reduction measures and how to deal with double counting in calculating water and energy savings and their associated monetary benefits (page 87).

1. Relative Monetary Benefits Of Flow Control Devices

This section provides information on a group of water saving and flow control devices that generally provide monetary benefits justifying their cost The primary intention is to indicate a way that their relative cost effectiveness can be evaluated The annual net monetary benefits (annual monetary benefits minus annual equivalent monetary costs) are calculated for each device, where:

- **Monetary benefits** are the savings in water supply, wastewater and energy (to heat water) costs associated with the reduction in water use and wastewater flow brought about by the device.
- **Monetary costs** are the additional costs, over the costs of the conventional fixture or appliance, of purchasing, installing and maintaining the water conserving device.

In calculating the net monetary benefits, costs are expressed in terms of the annual equivalent cost over the service life of the device, and subtracted from the annual savings in water supply, wastewater and energy costs. Thus, any device for which the net monetary benefits are positive produces dollar savings which economically justify the additional investment costs.

This analysis emphasizes the relative economic benefits of various devices. The assumptions made here may not be appropriate for determining the cost effectiveness of devices within the context of a particular community These assumptions should be carefully examined and altered where necessary to reflect the situation in a given community

a. Major Assumptions

The net monetary benefits of each water saving device or appliance are determined within the setting of a four member household. Note that the net benefits do not represent net monetary savings to the household unless the community is able to achieve 100 percent implementation. Interest here is in maintaining a community viewpoint Therefore the water supply, waste water and energy costs used in the analysis are representative of the utilities' (and thus the community's) marginal costs of providing these services. The intention is to provide a measure of the relative cost effectiveness of the devices within a community flow reduction program. It is emphasized that these numbers are appropriate only for an approximate comparison of devices. A full cost effectivenesss calculation would require figures which are much more precise

Assumptions generally applicable to the analysis include:

- A combined marginal cost of water supply and wastewater treatment equal to $0.30/1000 gallons. This figure is only a rough estimate of the marginal cost of providing these services and is sufficient for the comparative purpose of this analysis. It is based on a typical average cost of $0.60/1000 gallons for water supply and a typical average cost of $0.90/1000 gallons for collecting, treating and disposing of wastewater (U.S. EPA, 1979). Marginal cost is assumed equal to 20 percent of average cost to reflect the large proportion of capital costs involved Of course, for the marginal costs to be even this substantial, implementation and effects must be community wide and long term.
- A marginal cost of supplying energy to water users equal to $0.45/therm. This is the approximate amount that Pacific Gas and Electric, a northern California utility, now pays at the margin for Canadian gas. Note that inflation of natural gas prices over and above inflation of other prices is not taken into account in this analysis. Thus, the monetary benefits indicated for those devices inducing significant energy (from hot water) savings are conservative.

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Fixture	Type/Device[a]	Approximate Cost over Conventional ($ s per device)	Annual Household Water Savings over Conventional (gallons)	Annual Household Energy Savings over Conventional (BTU s)	Annual Net Monetary Benefits ($ s)[b c d]	Payback Period (years)
Toilet	Water saving tank type (NC)[a]	0	11 000	—	3 30	0 0
	Dams (R)[a]	5	11 000	—	2 30	3 6
	Plastic bottles (R)	0	5 500	—	1 60	0 0
	Flush valve restrictor (R)	5	14 600	—	3 40	2 6
Shower head	Low flow without cutoff (NC)	0	5 800	2 680 000	13 80	0 0
	Low flow with cutoff (NC)	3	7 300	3 350 000	16 68	0 4
	Plastic insert flow varies with pressure (R)	1	5 800	2 680 000	13 60	0 2
	Pipe fitting controller constant flow rate (R)	5	5 800	2 680 000	12 90	0 8
Faucets	Spray tap (NC)	5	2 900	804 000	3 00	4 0
	Plastic insert reduces orifice (R)	1	2 900	804 000	4 20	0 7
	Aerator — flow varies with pressure (R)	2	2 900	804 000	3 90	1 5
Pressure Reducing Valve	In new construction	30	9 500	2 610 000	12 00	2 3
	As retrofit	60	9 500	2 610 000	8 80	5 1
Washing Machine	New construction	25	4 400	1 510 000	5 70	3 6
Dishwasher	New construction	5	1 500	1 100 000	4 90	1 0

a NC For use in new construction
R For use as retrofit device
b Assumes 20-year service life and interest rate of 7⅜% in calculating annual equivalent cost and payback period
c Assumes 2 toilets, 2 showers and 3 faucets per 4 member residence
d Does not make allowances for future increases in energy prices over and above inflation in other prices

Table C 1. The Relative Economic Benefits From A Community Viewpoint Of Common Water Saving Devices And Appliances

- An interest rate of 7.375 percent, the WRC rate which the EPA has stipulated for use in its Cost Effectiveness Guidelines.

b. Results of the Analysis

Table C-1 shows the results of the analysis for common water saving fixtures and devices. In addition to the annual net monetary benefits, the table shows the payback period associated with each device. As used here, the payback period is the time in years required to recover the cost of the device from the savings in water, wastewater and energy costs brought about by the device, using an interest rate of 7.375 percent. (Note that this differs from another interpretation of payback period which does not take into account the time value of money).

The following section sets forth the assumptions made for each device in Table C-1 and provides examples of calculation methods used. As additional and improved data regarding the effectiveness of certain devices and their water and energy saving consequences become available, the assumptions and results expressed here should be updated accordingly.

2. Examples Of Calculation Methods Used

This section provides a series of tables indicating the assumptions used for each generic type of device listed in Table C-1 These assumptions are in addition to major assumptions for the overall analysis provided in Section la above Tables C-2 through C-7 also provide examples of calculation methods used for specific devices within each generic type These sample calculation methods for water and energy savings and the annual net monetary benefits can be applied using any appropriate set of assumptions.

3. Consideration Of Double Counting

Table C-1 presents the estimated savings in water, energy and costs for particular devices and appliances considered individually Because some of the devices reduce water use in the same manner, the savings that should be expected from combinations of two or more of these devices does not necessarily equal the sum of the estimated individual savings. Failure to take these duplicative functions into account will result in double counting and therefore an exaggerated estimate of the potential savings from this combination of measures.

Double counting will be most significant when considering installation of a pressure reducing valve in combination with a faucet flow control device or a shower flow control device. Both 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. At best, only a rough and very simple method of dealing with double counting can be described Assume, for example, that the following three devices are to be installed.

- A plastic shower head insert individually saving 4 gpcd.
- A faucet aerator individually saving 2 gpcd.
- A pressure reducing valve individually saving 6.5 gpcd

Since the shower and faucet devices produce water savings which are fully additive, they may be considered as a single measure, producing savings of 6 gpcd. If the pressure reducing valve were the only device installed it could be expected to save 6.5 gpcd. The water savings expected from the combination of the three devices must be greater than 6.5 gpcd (the savings expected from installing the device which produces the maximum savings when installed alone) and less than 12.5 gpcd (the sum of the savings from all three devices) A rough estimate of the combined savings can be made by taking half of the difference between these values and adding it to the minimum value In this example, 3 gpcd (which is half of (12.5 minus 6.5)) would be added to 6.5 gpcd, the minimum value, producing an estimated combined savings of 9.5 gpcd.

For alternative estimates of water saving effects of combinations of measures, see Flack et al., 1977 References for this Appendix are included in the list beginning on page 65

Assumptions [1]

- Each house has 2 showers.
- 50% of bathing is showers
- Water used for all bathing is 20 gpcd therefore water used for showers is 10 gpcd.
- Low flow shower head without cutoff saves 40% of water used in showers or 4 gpcd.
- Low flow shower head with cutoff saves 50% of water used in showers or 5 gpcd.
- Plastic insert flow varies with pressure saves 40% of water used in showers or 4 gpcd.
- Pipe fitting controller with constant flow rate saves 40% of water used in showers or 4 gpcd
- Water is heated from 50°F to 105°F

[1] Note that these are very conservative assumptions

Sample Calculation

- Annual water savings = $4 \text{ gpcd} \times 4 \frac{\text{persons}}{\text{house}} \times 365 \frac{\text{days}}{\text{year}} = 5\,840 \frac{\text{gallons}}{\text{year}}$
- Annual energy savings = $5\,840 \frac{\text{gallons}}{\text{year}} \times 8\,34 \frac{\text{BTU s/gallon}}{\text{degree}} \times 55 \text{ degrees} = 2\,678\,808 \frac{\text{BTU s}}{\text{year}}$
- Annual monetary benefits = $\left(5\,840 \frac{\text{gallons}}{\text{year}} \times \frac{30}{1000 \text{ gallons}}\right) + \left(2\,678\,808 \frac{\text{BTU s}}{\text{year}} \times \frac{\$\,45}{100\,000 \text{ BTU s/therm}}\right) = \$1\,76 + \$12\,06 = \$13\,82$
- Annual equivalent cost (for 2 inserts) = $ 19
- Annual net monetary benefits = $13 82 − 19 = $13 63
- Payback period (assuming 7⅜% interest) = 15 years

Table C 2 **Example Calculation For Shower Head With Plastic Insert and Flow Varying With Pressure**

Assumptions

- Each house has 3 sinks
- With conventional fixture water used for cooking drinking and lavatory use is 7 gpcd.
- Each faucet water saving device reduces conventional use by 2 gpcd
- Cold water temperature is 50 F 60% of use is warm water at 105°F

Sample Calculation

- Annual water savings = $2 \text{ gpcd} \times 4 \frac{\text{persons}}{\text{house}} \times 365 \frac{\text{days}}{\text{year}} = 2\,920 \frac{\text{gallons}}{\text{year}}$
- Annual energy savings = $2\,920 \frac{\text{gallons}}{\text{year}} \times 60 \text{ warm water} \times 8\,34 \frac{\text{BTU s/gallon}}{\text{degree}} \times 55 \text{ degrees} = 803\,642 \frac{\text{BTU s}}{\text{year}}$
- Annual monetary benefits = $\left(2\,920 \frac{\text{gallons}}{\text{year}} \times \frac{30}{1000 \text{ gallons}}\right) + \left(803\,642 \frac{\text{BTU s}}{\text{year}} \times \frac{\$\,45}{100\,000 \text{ BTU's/therm}}\right) = \$\,88 + \$3\,62 = \$4\,50$
- Annual equivalent cost (for 3 aerators) = $ 58
- Annual net monetary benefits = $4 50 − 58 = $3 92
- Payback period (assuming 7⅜% interest) = 1 5 years

Table C 3 **Example Calculation For Faucet Aerator**

Assumptions

- Each house has 2 toilets
- Each member of household flushes toilet 5 times per day

Sample Calculation

- Annual water savings = $1\,5 \frac{\text{gallons saved}}{\text{flush}} \times 5 \frac{\text{flushes}}{\text{day}} \times 365 \frac{\text{days}}{\text{year}} \times 4 \frac{\text{persons}}{\text{house}} = 10\,950 \frac{\text{gallons saved}}{\text{year}}$
- Annual monetary benefits = $10{,}950 \frac{\text{gallons}}{\text{year}} \times \frac{30}{1000 \text{ gallons}} = \$3\,29$
- Annual equivalent cost (for 2 pair at $5 00 per pair) = $ 97
- Annual net monetary benefits = $3 29 − 97 = $2 32
- Payback period (assuming 7⅜% interest) = 3 6 years

Table C-4 **Example Calculation For Toilet Dams.**

Assumptions.

- Saves 10% of in house water use or 6 5 gpcd.
- 60% of water saved is warm raised to 105°F from 50°F

Sample Calculation

- Annual water savings = 6 5 gpcd $\times$ 4 $\frac{\text{persons}}{\text{house}}$ $\times$ 365 $\frac{\text{days}}{\text{year}}$ = 9 490 $\frac{\text{gallons}}{\text{year}}$
- Annual energy savings = 9 490 $\frac{\text{gallons}}{\text{year}}$ $\times$ 60 warm water $\times$ 8 34 $\frac{\text{BTU s/gallon}}{\text{degree}}$ $\times$ 55 degrees = 2 611 838 $\frac{\text{BTU s}}{\text{year}}$
- Annual monetary benefits = $\left(9\,490 \frac{\text{gallons}}{\text{year}} \times \frac{30}{1000 \text{ gallons}}\right) + \left(2\,611\,838 \frac{\text{BTU s}}{\text{year}} \times \frac{\$\,45}{100\,000 \text{ BTU's/therm}}\right)$ = \$2 85 + \$11 75 = \$14 60
- Annual equivalent cost = \$2 90
- Annual net monetary benefits = \$14 60 − 2 90 = \$11 70
- Payback period (assuming 7⅛% interest) = 2 3 years

Table C 5 Example Calculation For Installing Pressure Reducing Valve in New Construction.

Assumpuons

- Water use with conventional type is 9 gpcd
- Water saving type saves 33% of water use or 3 gpcd.
- 75% of laundry washing uses warm water heated from 50°F to 105°F

Sample Calculation

- Annual water savings = 3 gpcd $\times$ 4 $\frac{\text{persons}}{\text{house}}$ $\times$ 365 $\frac{\text{days}}{\text{year}}$ = 4 380 $\frac{\text{gallons}}{\text{year}}$
- Annual energy savings = 4 380 $\frac{\text{gallons}}{\text{year}}$ $\times$ 75 warm water $\times$ 8 34 $\frac{\text{BTU s/gallon}}{\text{degree}}$ $\times$ 55 degrees = 1 506 830 $\frac{\text{BTU s}}{\text{year}}$
- Annual monetary benefits = $\left(4\,380 \frac{\text{gallons}}{\text{year}} \times \frac{30}{1000 \text{ gallons}}\right) + \left(1\,506\,830 \frac{\text{BTU s}}{\text{year}} \times \frac{\$\,45}{100\,000 \text{ BTU s/therm}}\right)$ = \$1 31 + \$6 78 = \$8 09
- Annual equivalent cost = \$2 43
- Annual net monetary benefits = \$8 09 − 2 43 = \$5 66
- Payback period (assuming 7⅛% interest) = 3 6 years

Table C 6 Example Calculation For Clothes Washer

Assumptions.

- Water use with conventional type is 4 gpcd.
- Water saving type saves 25% of water use or 1 gpcd.
- Water is heated from 50°F to 140°F

Sample Calculation.

- Annual water savings = 1 gpcd $\times$ 4 $\frac{\text{persons}}{\text{house}}$ $\times$ 365 $\frac{\text{days}}{\text{year}}$ = 1,460 $\frac{\text{gallons}}{\text{year}}$
- Annual energy savings = 1 460 $\frac{\text{gallons}}{\text{year}}$ $\times$ 8 34 $\frac{\text{BTU s/gallon}}{\text{degree}}$ $\times$ 90 degrees = 1 095,876 $\frac{\text{BTU's}}{\text{year}}$
- Annual monetary benefits = $\left(1{,}460 \frac{\text{gallons}}{\text{year}} \times \frac{30}{1000 \text{ gallons}}\right) + \left(1\,095{,}876 \frac{\text{BTU's}}{\text{year}} \times \frac{\$\,45}{100\,000 \text{ BTU's/therm}}\right)$ = \$ 44 + \$4 93 = \$5 37.
- Annual equivalent cost = \$ 50
- Annual net monetary benefits = \$5 37 − 50 = \$4 87
- Payback period (assuming 7⅛% interest) = 1 0 years

Table C 7. Example Calculation For Dishwasher.

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