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WASTEWATER FLOW REDUCTION IN THE HOME

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ABSTRACT

The increasing pollution of our national water resources, the rising cost of water treatment, and our growing population, all point to a shrinking per capita availability of high quality water supply. The resultant disruption can be eased considerably by judicious conservation of this limited natural resource through a reduction of household water usage. This article presents a general introduction to residential wastewater flow reduction.

General Background

This section sets the scene for a more thorough treatment of flow reduction approaches and benefits by reviewing briefly the concept of water usage and past studies of wastewater flow reduction.

WATER USAGE

The overall water needs of an average community amount to 150 gallons per capita per day (gpcd). Over 60 gallons are used for residential purposes, 50 gallons for industrial applications, 20 gallons for commercial uses, 10 gallons for public purposes (e.g., fire fighting and street cleaning), while about 10 gallons remain unaccounted for, primarily through unmetered use. This breakdown does not take into account water used for agricultural irrigation, or outdoor recreation.

With the 1985 "zero-discharge" goal established by the Federal Water Pollution Control Act of 1972, industry is expected to turn increasingly to recycling of its water supply. Clearly, then, residential water usage qualifies as a prime target for massive conservation measures, both by virtue of its current and

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projected share of overall requirements and the magnitude of the educational and legislative effort involved. Many of these measures will be applicable to commercial establishments, as well.

Residential water requirements vary widely with property valuation, the number of occupants per household, type of dwelling, rate structure, climate, as well as educational status and age of the occupants. Property valuation and social status are directly proportional to per capita consumption, whereas the number of occupants per household shows an inverse relationship, with a peak for two occupants. A number of studies of residential water consumption have been performed, and most reported amounts vary between 40 and 80 gpcd.

The major residential uses of water are for toilet flushing, bathing, laundering, cleaning, cooking, drinking, and lawn watering. The distribution of water among these uses, also known as the household water budget, again shows considerable variations. Some of the values reported in the literature are given in Table 1. Cleaning, here, includes laundry, scrubbing, and car washing, whereas cooking takes in drinking, preparation of food, and washing dishes. Lawn watering is not included in these figures, because the practice exhibits exceedingly large fluctuations.

LITERATURE REVIEW

Widespread interest in residential wastewater flow reduction in the United States has developed only over the past decade, so that the body of literature on this subject is not very comprehensive. Of the 50 publications listed at the end of this chapter, only a handful contain substantive original research, mostly dealing with the household water requirements in various areas of the country.

The principal surveys of residential quantitative water requirements and household water budgets were performed by Anderson and Watson (1967), Andrews and Hammond (1970), Campbell and Smith (1964), Linaweaver *et al.* (1967), McPherson (1967), Olsson *et al.* (1968), Reid (1965), Thomas and Bendixen (1962), and Watson *et al.* (1967). The relationship of residential water

Table 1. Residential Water Usage

Usage (%)	*Reid, 1965*	*Bailey et al., 1969*	*Renman et al., 1972*
Toilet flushing	39	39	41
Bathing	33	35	24
Cleaning	18	16	23
Cooking	10	10	12
Requirements (gpcd)	61.5	64	49

use to assessed valuation and rate structure was investigated by Dunn and Larson (1963), Howe and Linaweaver (1967), and McCabe *et al.* (1970).

The first comprehensive study of household wastewater flow reduction equipment was performed in 1969 by the General Dynamics Corporation under contract to the Federal Water Quality Administration of the Department of the Interior (Bailey *et al.*, 1969). The study reviewed the current qualitative and quantitative water requirements to determine areas where better water and waste management would be most beneficial.

Much helpful material was gathered from a review of previous studies on the problems of individual household waste treatment. More recent information was obtained from manufacturers of plumbing devices and waste treatment equipment who were surveyed for available water-saving plumbing devices and individual waste treatment units. Also, the literature on advanced water and waste treatment was reviewed for processes that might be applicable to individual home usage. The information collected was then analyzed to determine the most practical methods for decreasing the waste volume flow from individual households. Homeowners, plumbers, architect-engineers, and equipment manufacturers were surveyed to obtain representative opinions from the people who would control the use of any flow reduction or treatment schemes.

The results of the study indicated that quality requirements for specific household tasks, such as general cleaning or toilet flushing, can be safely lowered; that household water usage could be economically reduced by 35 per cent through the use of currently available technology; that there is general public acceptance of the use of most flow reduction devices. The use of most advanced waste treatment techniques and the reuse of wastewater was not considered practical except for cases of unusual problems and extremely high water or waste disposal costs.

More recently, three parallel studies were performed for the Manned Spacecraft Center of the National Aeronautics and Space Administration by the Grumman Aerospace Corporation (Renman *et al.*, 1972), the Martin Marietta Company (Murawczyk and Ihria, 1973), and the General Electric Company (Murray, 1973). Their objective was to evaluate ways in which current and advanced aerospace technology could be applied to develop practical solutions to existing and emerging water supply and waste disposal problems.

The studies presented an overview of water resource factors affecting community planning and residential waste treatment systems. They contained surveys of available household equipment for water conservation, quality control, and wastewater treatment. Systems capable of serving a community were developed and priced.

Finally, Booz, Allen and Hamilton, Inc. has conducted a comprehensive study of water management alternatives on Long Island under the sponsorship of the U.S. Army Corps of Engineers and several citizen groups (Hershaft *et al.*, 1974).

The study seeks to define the full range of feasible alternative approaches to water supply, usage, and disposal, in order to conserve Long Island's limited groundwater resources. These approaches are then discussed in terms of their technical, economic, environmental, social, and institutional impacts on the community.

Flow Reduction

Reduction of residential wastewater flow can be achieved through the installation of flow reduction and recycling equipment, as well as the introduction of conservation practices within the home.

FLOW REDUCTION DEVICES

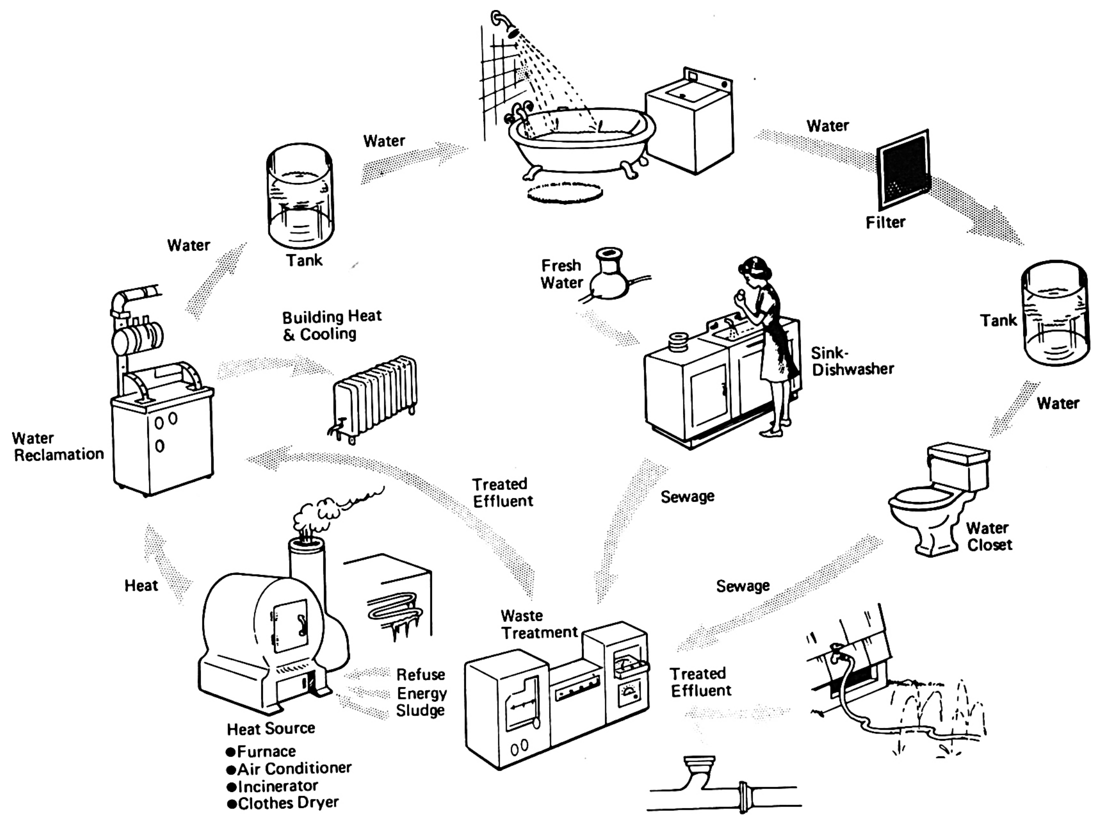
A number of devices that reduce household water supply flow have been put on the market during the past few years. Many of these are rather inexpensive and can be easily installed by the homeowner. Most save both cold and hot water, and thus provide additional savings in fuel for water heating. Nevertheless, this equipment has not found wide acceptance, because there has been little incentive for its use. The type, operation, effectiveness, cost, and manufacturer of the more common devices are listed in Table 2 (Bailey, *et al.*, 1969; Wenk, 1971; Renman *et al.*, 1972; Murawczyk and Ihria, 1973; Murray, 1973; WSSC, 1972).

A parallel approach to the curtailment of quantitative residential water requirements is through in-house recycling of used water for a less exacting use, on the assumption that water quantity need only be sufficient for the intended purpose. The concept of an integrated household recycling system dealing with solid waste and energy, as well as wastewater, is illustrated in Figure 1. One simple method of in-house recycling is the use of laundry and bath wastewater for flushing toilets and watering lawns. Such an installation requires only a storage tank, a pump, and some piping and valves. In certain cases, treatment for foam, suspended solids, and other contaminants may be required.

Inasmuch as toilet flushing represents the largest single use of residential water, the introduction of water saving toilets appears as a promising approach to the reduction of residential water requirements. Indeed a number of such toilets, providing various degrees of water savings, up to 100 per cent, have been designed and marketed. The nature, operation, effectiveness, cost, and manufacturer of the most common designs are described in Table 3 and one of these is illustrated in Figure 2. The last five designs provide further for a separate treatment and disposal of toilet waste (black water) and which eases the load on the waste treatment system. (Bailey *et al.*, 1969; Renman *et al.*, 1972; WSSC 1973.)

Table 2. Flow Reduction Devices

Device	*Operation*	*Remarks*	*Water Saving (gpcd)*	*Installed cost ($)*	*Homeowner Acceptance (%)*	*Manufacturer*
Pressure reducing valve	Normally mounted on main supply line inside the house. Adjusts water pressure down to 50 psi, to reduce flow	Reduces maintenance requirements on valves, washers, hoses, etc.				B & G Valves Taco Valves Withins Valve
Flow reduction valve	Mounted on shower heads, or lavatory or sink faucet. Reduces flow to 2.5-3 gpm	Not very effective on faucets	0.5-6	50-70	87	American Standard Dole Ecological Water Products Kohler Company Speakman Company
Thermostatic mixing valve	Mounted on shower head or lavatory or sink faucet. Maintains constant temperature, once the initial mixture of hot and cold water has been set. Permits bather to turn off shower while soaping.	Provides also safety and convenience				
Faucet aerator	Mounted on faucet. Increases volume of fluid by mixing in air, thus decreasing required water flow	Also reduces splashing	0.5	1	Very good	Ecological Water Products
Water closet insert	Dams a portion of the water in the tanks, thus preventing it from being flushed, yet doesn't lower head	Similar to the operation of the better known "bricks in the tank"		3-6	Good	Aqua Guard Metropol. Water-saving Company Mini-Dam Water Saver Company Saveit of Washington
Special ballcock assembly	Provides quick, sure shut-off of water closet valve, and makes noticeable noise when tank ball is defective			6	Very good	Fail Safe, Ltd. Fluidmaster, Inc.
Front-loading washing machine	Washer tub rotates on a horizontal axis, and requires only half as much water as top-loading model			Same as equivalent conventional model	Fair	General Electric Norge Kenmore (Sears) Westinghouse Whirlpool
Suds-saver washing machine	Stores wash water containing suds in a utility tank and reuses it during second wash cycle	Also saves detergent. Similar feature could be provided for rinse water			Poor	


Water
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Treated
Effluent
Water
Tank
Water
Building Heat
& Cooling
Water
Reclamation
Heat
Refuse
Energy
Sludge
Heat Source
●Furnace
●Air Conditioner
●Incinerator
●Clothes Dryer

Figure 1.

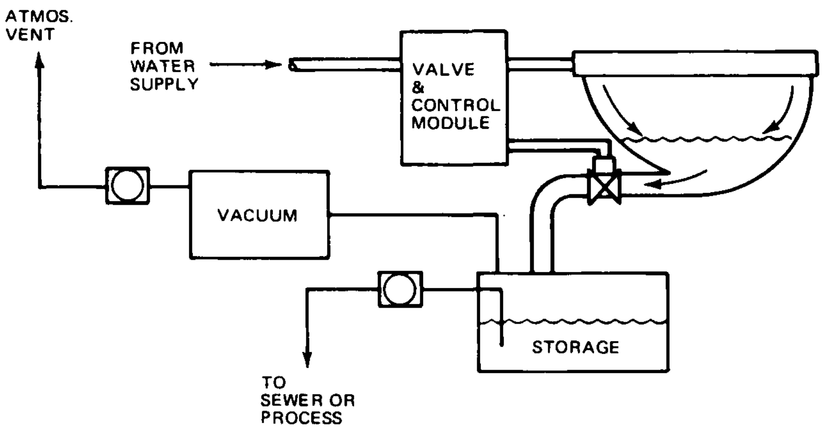

Figure 2. Diagram of a vacuum toilet (Renman et al., 1972).

FLOW REDUCTION PRACTICES

Suggestions for flow reduction practices in the home have been listed by the Washington Suburban Sanitary Commission in a booklet distributed to its customers (see Figure 3) (WSSC, 1972). Some of the more salient ideas are as follows:

- Cooking

  Pond water in the sink for general cleaning, rather than letting the spigot run

  Add salt or vinegar to wash water to reduce amount needed for washing dishes or vegetables

  Curtail use of garbage grinder

  Cool drinking water in the refrigerator, rather than by letting the spigot run

- Bathing

  Take a bath (25 gallons) or a fast shower, rather than a 10-minute shower (50-100 gallons)

  Share a bath or shower with another family member

  Turn water off while soaping up (this is where a thermostatic shower valve helps)

- Toilet Flushing

  Lower water level in the tank by adjusting float, or place a brick or plastic container in the tank

  Flush only when necessary

  Do not use toilet for refuse disposal

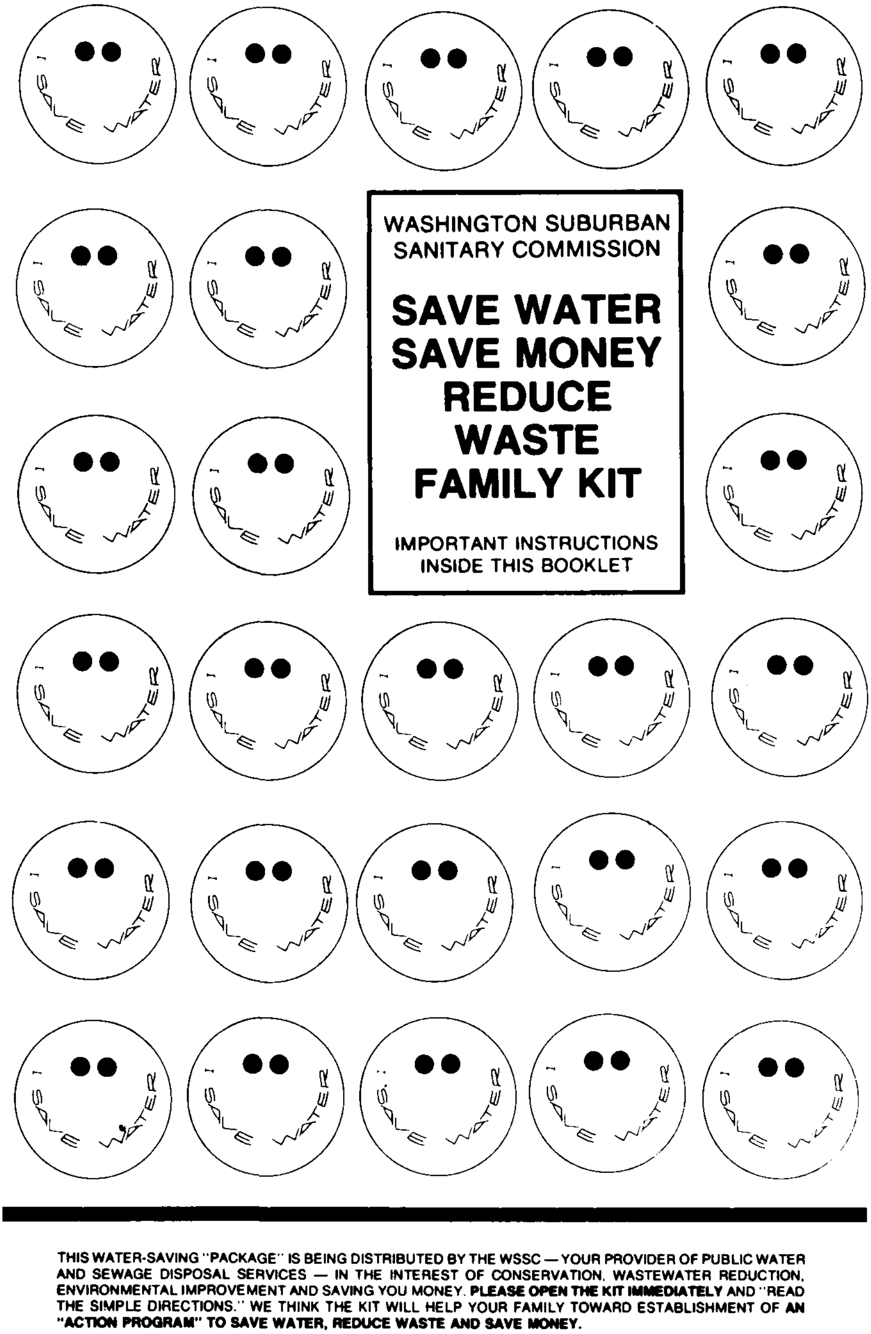
WASHINGTON SUBURBAN
SANITARY COMMISSION
SAVE WATER
SAVE MONEY
REDUCE
WASTE
FAMILY KIT
IMPORTANT INSTRUCTIONS
INSIDE THIS BOOKLET
THIS WATER-SAVING "PACKAGE" IS BEING DISTRIBUTED BY THE WSSC — YOUR PROVIDER OF PUBLIC WATER AND SEWAGE DISPOSAL SERVICES — IN THE INTEREST OF CONSERVATION, WASTEWATER REDUCTION, ENVIRONMENTAL IMPROVEMENT AND SAVING YOU MONEY. PLEASE OPEN THE KIT IMMEDIATELY AND "READ THE SIMPLE DIRECTIONS." WE THINK THE KIT WILL HELP YOUR FAMILY TOWARD ESTABLISHMENT OF AN "ACTION PROGRAM" TO SAVE WATER, REDUCE WASTE AND SAVE MONEY.

Figure 3.

IT IS WORTH SAVING!

WHY SAVE WATER.

A year ago, The Washington Suburban Sanitary Commission distributed the water-saving handbook — "It's Up to You" — to more than 300,000 families in suburban Maryland. This "Package" is a logical followup to the handbook, which, in its introduction, recited "Three Good Reasons" for public water conservation and waste-reduction. THEY ARE:

1. **WATER RESOURCES ARE LIMITED** — Although Americans — for centuries — assumed the nation's water resources were virtually without limit, the varied demands — essential and non-essential, material and aesthetic — placed on available water resources now have erased this assumption of limitless abundance. The time obviously has arrived when all of us must place the **"HANDLE WITH CARE"** label on water resources. Public water conservation is good housekeeping!

2. **WATER (AND SEWER) COSTS ARE RISING** — Historically, Americans have paid a low price for public water service and for disposal of the wastewater (sewage) they have sent down the drain. Today, as basic costs for processing a quality water product and treating wastewater rise rapidly, the customer rates are increasing, too. The WSSC's general move in the direction of advanced (tertiary) treatment — including the retro-fitting of existing disposal capacity — is adding to the cost cf service and pushing the Sewer Rate to higher and higher levels. Water and sewer services are no longer cheap. Water-saving — cutting the metered consumption on which water and sewer bills are based — emerges as an important factor in protection of the family pocketbook.

3. **WHEN WATER IS SAVED, WASTE LOADS ARE REDUCED** — When public water is consumed, the customer generates a like amount of "used" water, which goes down the drain as sewage and is transported through pipelines to a wastewater treatment plant for careful processing. Since "sewage" is more than 90 per cent water, the reduction of water use in the home or business can greatly decrease the volume loading of sewage-handling facilities. By broad customer acceptance of water conservation as a family-household responsibility, the per capita demand on pollution control systems will diminish and both public health and the environment will benefit.

NOW, as the Handbook* urged some months ago, "let's get on with it! **LET'S SAVE SOME WATER!**" —

*Copies of the Handbook are still available from the WSSC Public Information Office, 4017 Hamilton Street, Hyattsville, Md., 20781.

Table 3.

Toilet Type	Operation	Remarks	Water Consumption (Gal/Flush)	Water Saving (gpcd)	Installed Cost ($)	Homeowner Acceptance (%)	Trade Name	Manufacturer
Shallow-trap	Features more efficient trap design		3.5	7-8	110			American Standard
Mechanical trap	Mechanically actuated side valve replaces the conventional water trap in insulating the toilet from the sewer line		1/4	20-25				Crane Company Eljet Plumbingware Kohler Company Monogram Ind.
Batch-type valve	Delivers preset amount of water directly from supply line	Requires large-diameter water pipes	0.5-4	7-15	105-160	92		
Urinals	Uses batch-type valve	Applicable for commercial installations	1-1/2	7	175	37		
Dual-cycle	Provided separate, reduced flushes for urine and feces. Can be used with either conventional or batch-type valve toilet	Conversion kits for conventional toilets are available	1-1/4, 2-1/2	11-17	130	79	Econoflush	Utah Marine Compan Company Water Save, Inc.
Vacuum	Flushes wastes into a receiving tank by a mixture or air and water. Requires a vacuum pump	Applicable to housing developments or office buildings	1/2	20-22	300 per unit		Air-Lav	A. B. Electrolux (Sweden) Kohler-Dayton Div. Liljendahl (Sweden)
							Sanivac	National Homes Corp.
Recirculating	Holding tank is charged with 1.5-4 gallons of water and sterilizing and deodorizing chemicals. After each flushing, the wastewater is filtered to remove solids, and the liquid fraction is treated with chemicals, and reused for 35-80 flushes	Used extensively in aircraft and marine applications	1/20	25	325	46	Monomatic	Monogram Industries Thetford Corp. Sherwood Products

Recirculating *(non-aqueous)*	Mineral oil replaces water and permits gravity separation due to density differential. Additional separation is achieved by means of screening and periodic addition of a coalescent chemical		0	25	Aqua-Sans	Chrysler Corp.
Incinerator	Wastes are deposited directly into a firebox or a holding pan lined with paper. After use, waste is incinerated with the aid of electricity, gas or oil into a sterile ash	Used in marine and remote site applications. Some odor problem persists	0	25	Destroilet Ecology Toilet Incinolet Incinomode Thermox	La Mere Industries Tekmar Corp. Research Prods. Mfg. Company Incinomode Sales Co. N-Con Systems Co.
Composting	Wastes drop into an inclined chamber, where they are mixed with food scraps and controlled amounts of wastewater and air to promote composting		0	25	Bio-Flow Mullbank Multrum	Sani-Flow Systems A. S. Andstor & Co. A. B. Clivus

- Other Uses

  Observe minimal requirements in lawn watering
  Wash car from bucket, rather than by hose

- Leaks

  Check all faucets and toilet tank periodically
  Check water meter with faucets turned off to detect hidden leaks
  Turn off cut-off valves when away from home for prolonged periods

- Pressure Reduction

  Turn down main cut-off valve to lower water pressure to a minimum satisfactory level, and consequently to reduce flow rate.

Flow reduction practices would be particularly effective in decreasing required water and wastewater treatment plant capacity, if they could shift water consumption to off-peak hours.

DEMONSTRATION PROGRAMS

Programs to demonstrate the effectiveness and operational characteristics of flow reduction devices have been conducted by the General Dynamics Company and by the Washington Suburban Sanitary Commission. The General Dynamics program was conducted under sponsorship of the Federal Water Quality Administration as a follow-on to the survey by Bailey *et al.* (1969) that was cited earlier. Several devices were installed in some 20 homes in the New London, Connecticut, area, and the results proved difficult to interpret. (Bostian *et al.*, 1974.)

Between 1972 and 1973, the Washington Suburban Sanitary Commission conducted an investigation of the effectiveness of flow reducing devices, such as pressure reducing valves, shower head flow reduction valves, and toilet inserts. The devices were installed in 2400 dwelling units, and the test was complemented by an extensive educational effort. The savings in water consumption ranged from 12 per cent for apartments to 20 per cent for single family houses. There were no major maintenance problems and the general reaction was favorable. (WSSC, 1973.)

Benefits and Costs

The major benefits of household wastewater flow reduction accrue from decreased demand for water treatment, wastewater treatment, sewer capacity, and energy generation. The costs are incurred in the promotion, acquisition, installation, and operation of the flow reduction equipment, as well as in the potential loss of some conveniences and freedom of action.

MONETARY BENEFITS

The principal monetary benefits of wastewater flow reduction lie in the lowered demand for water and wastewater treatment and sewer capacity and the concomitant reduction in the demand for energy. This is measured in terms of both capital costs for new capacity and operation and maintenance costs of existing and new facilities.

That portion of construction costs contributed by a local municipality is obtained through the sale of bonds. For water supply systems, the capital costs are usually covered by bonds and the operating costs by usage charges. The interest and amortization (debt service) of bonds for the treatment plant alone usually cost more than the operation and maintenance of the plant. For sewers, the debt service accounts for nearly all of the annual cost.

The variables that affect the annual cost of finance are the years to bond maturity (at which time the bond is redeemed) and the interest rate. Both of these factors are governed by the bond market, credit rating of the municipality, and the type of bond. The bond market is determined by prime interest rates and the quantity of bonds in circulation at the time.

Construction costs have been rising steadily since the mid 1930's. The rate of increase has varied with time and geographical area, and is somewhat different for various types of construction. The Environmental Protection Agency's Municipal Construction Division generates a monthly cost index for both sewers and sewage treatment plant construction. The index is maintained for each of 20 cities throughout the country with the national index as an average of the city indices. The cost index is a convenient tool for converting current costs to future projections and permits the calculation of life cycle costs of water and wastewater treatment capacity.

A complicating aspect of reduction in water and wastewater treatment plant capacity, which was alluded to earlier, is the need to scale capacity to peak, rather than average, or total, consumption. The presence of storage tanks and impoundments helps to distribute the load. However, the water supply industry has not been successful in modifying customer usage patterns to the extent of the telephone and electric utilities.

Operation and maintenance costs consist of both fixed (e.g., debt service, light and heat) and variable (e.g., chemicals, motor energy) costs. A reduction in residential water requirements will result in a lowering of both fixed and variable costs of new facilities, but of only the variable costs of existing ones.

MONETARY COSTS

The monetary costs of achieving the desired wastewater flow reduction comprise the costs of promoting, acquiring, installing, and operating the flow reduction devices, as well as the costs of promoting and implementing the flow reduction practices described in the preceding section.

Acquisition and installation costs and effectiveness ratings for flow reduction devices have been compiled by Bailey *et al.* (1969), Murawczyk and Ihria (1973), Murray (1973), Renman *et al.* (1972), and WSSC (1973) (see Table 4). For most devices, the cost is obviously lower in new construction than in a retrofit situation. Reliable operating costs are generally not available, because of the sparse use, but can be estimated on the basis of a critical analysis of the information furnished by the manufacturer. Many devices, of course, do not incur operating costs.

Bailey *et al.* (1969) has evaluated the various devices on the basis of relative costs for a family of four and reached the following conclusions:

- Reduction of water usage appears to be the most economically feasible means of reducing waste flow from the home
- Flow control faucets are of marginal value when replacing workable faucets but are definitely warranted for new homes and for necessary replacements
- Flow control showers are an inexpensive means of economically saving considerable quantities of water
- The use of pressure flush valves to reduce water flow does not appear as advantageous as the redesign of the toilet bowl to allow adequate flushing with less water
- The vacuum flush toilet for the individual home is too expensive because of the high cost of the associated equipment
- Development of a suitable, lower cost disinfectant could make the use of recycle toilets much more practical
- Incinerator toilets are excessively costly to operate and maintain for family use
- The treatment and the quality standards required for flushing water are minimal and the costs of reusing wash water for this purpose are thus relatively low in comparison to those for any other reuse
- The additional treatment of wastewater by distillation, reverse osmosis, or a multifilter system for reuse for all purposes, except drinking, does not now appear economically feasible.

Wenk (1971) has compiled the annual cost savings, based on Bailey's data, for different costs of fresh water and several soil types (in conjunction with disposal through subsurface systems). His results are presented in Table 5.

ENVIRONMENTAL AND SOCIAL CONSIDERATIONS

The major potential environmental and social benefits of household wastewater flow reduction are as follows:

- Preservation of ground water resources (in areas relying on this form of supply) and consequent maintenance of streamflow and its recreational uses

Table 4. Cost of Flow Reduction Devices (Bailey *et al.*, 1969)

	Water Savings	*Estimated Installation Costs*			*Water-Savings Cost-Effectiveness*
Hardware Device	*gpcd*	*Matl.* *$*	*Labor* *$*	*Total* *$*	*Total* *$/gpcd*
1. Aerator for Lavatory and Kitchen Sink	0.5	2	0	2	4
2. Dual Cycle Water Closet	17.5	100	30	130	7.4
3. Limiting Flow Valves for Shower	6	35	15	50	8.3
4. Batch-type Flush Valves (2) for Water Closet	15.5	120	38	158	10.2
5. Vacuum Flush Toilet (for 100 homes)	22.5	–	–	295	13.1
6. Recycle Toilets	24.7	300	25	325	13.2
7. Batch-Type Flush Valves (2) for Water Closet	7.5	75	30	105	14
8. Shallow Trap Water Closet	7.5	80	30	110	14.7
9. Urinal with Batch-Type Flush Valve	7	150	25	175	25
10. Washing Machine with Level Control Control	1.2	35	0	35	29.2
11. Vacuum Flush Toilet (for Single Homes)	22.5	–	–	1520	67
12. Limiting Flow Valves for Lavatory	0.5	45	23	68	136

Table 5. Annual Cost Savings for Alternate Flow Reduction Systems (Wenk, 1971)

	Sewers			*Septic Tank/Soil Absorption*		
	Fresh Water Costs			*Soils*		
	Low	*Avg.*	*High*	*Good*	*Fair*	*Poor*
Rank -	[a]15.30(C)	[a]20.50(C)	[a]39.10(C)	[a]21.20(C)	[a]26.10(C)	[a]43.70(C)
1	3.00(ES)	4.40(ES)	9.70(ES)	4.30(ES)	5.50(ES)	10.00(ES)
2	2.00(EST)	3.10(EST)	7.10(EST)	3.00(EST)	3.90(EST)	7.40(RWW)
3	1.00(FCS)	1.40(FCS)	6.50(RWW)	1.40(FCS)	1.80(FCS)	7.30(EST)
4	0.50(STT)	1.10(STT)	4.00(AFT)	1.10(STT)	1.60(AFT)	3.70(AFT)
5	0.13(FA)	0.80(AFT)	3.60(STT)	0.80(AFT)	1.60(STT)	3.70(STT)
6	0.05(AFV)	0.55(AFV)	3.10(FCS)	0.55(AFV)	1.05(AFV)	3.30(FCS)
7	0.00(AFT)	0.11(FA)	2.65(AFD)	0.13(FA)	0.50(RWW)	3.15(AFV)
8	− 0.20(FCF)	− 0.10(FCF)	0.50(FCF)	0.10(FCF)	0.13(FA)	0.50(FCF)
9	− 3.30(RWW)	− 1.20(RWW)	0.33(FA)	− 1.30(RWW)	0.00(FCF)	0.33(FA)
10	− 17.40(IT)	− 15.20(IT)	− 6.90(CFA)	− 15.30(IT)	− 12.30(AT)	0.30(AT)
11	− 20.20(RT)	− 17.90(CFA)	− 7.20(IT)	− 16.50(AT)	− 13.50(IT)	− 6.30(CFA)
12	− 21.00(CFA)	− 18.10(RT)	−10.60(RT)	− 18.20(CFA)	− 15.60(CFA)	− 6.60(IT)
13	− 23.00(AT)	− 20.90(M)	−10.90(M)	− 18.30(RT)	− 16.60(RT)	−10.20(RT)
14	− 25.00(M)	− 23.00(AT)	−18.20(CSF)	− 22.20(M)	− 18.60(M)	−10.30(M)
15	− 28.40(CSF)	− 26.20(CSF)	−23.00(AT)	− 26.30(CSF)	− 24.50(CSF)	−18.40(CSF)

16	- 34.40(VFT)	- 32.60(VFT)	-23.80(BT)	- 32.70(VFT)	- 31.20(VFT)	-23.20(BT)
17	- 44.00(BT)	- 39.60(BT)	-25.90(VFT)	- 40.00(BT)	- 36.30(VT)	-25.40(VFT)
18	- 45.10(ET)	- 45.10(ET)	-45.10(ET)	- 44.60(ET)	- 40.90(ET)	-27.70(ET)
19	- 67.00(CSFA)	- 62.60(CSFA)	-46.80(CSFA)	- 63.00(CSFA)	- 59.30(CSFA)	-45.80(CSFA)
20	- 71.00(CN)	- 67.90(DN)	-56.90(DN)	- 68.20(DN)	- 65.60(DN)	-56.30(DN)
21	- 87.00(DR)	- 82.60(DR)	-66.80(DR)	- 83.00(DR)	- 79.80(DR)	-65.80(DR)
22	-109.00(RO)	-105.90(RO)	-94.90(RO)	-106.20(RO)	-103.60(RO)	-94.30(RO)

[a] Costs for conventional systems against which savings may be compared.

CODE	
AFT	Automatic Flush Toilets
AFV	Automatic Flush Valve Toilets
AT	Aerobic Treatment
BT	Biological Treatment (reuse except for drinking)
CFA	Carbon Filtration and Adsorption of nonsanitary wastes (reuse except for drinking)
CSF	Coagulation, Sedimentation and Filtration (all wastes, reuse for toilet flush)
CSFA	Coagulation, Sedimentation, Filtration and Adsorption (reuse except for drinking)
DN	Distillation (all nonsanitary wastes)
DR	Distillation (all wastes, reuse except drinking)
ES	English Style (dual flush)
EST	English Style Toilets
ET	Electrolytic Treatment (in place of septic tank)
FA	Faucet Aerators
FCF	Flow Control Faucet (kitchen or lavatory)
FCS	Flow Control Showers
IT	Incinerator Toilets
M	Multifiltration (all nonsanitary wastes)
RO	Reverse Osmosis
RT	Recycle Toilets
RWW	Reuse of Washwater, for Toilet Flushing
STT	Shallow-Trap Toilets
VFT	Vacuum Flush Toilets, Single House

- Reduction in the requirements for dewatering of wastewater in sewage treatment
- Curtailment of waterway pollution by sewage overflows of overtaxed wastewater treatment plants
- Curtailment of pollution by wastewater treatment plant effluent and sludge (in the case of incinerating toilets)
- Conservation of scarce treatment chemicals, such as chlorine
- Diminution of the disruption caused by construction of treatment plants and installation of vast sewer networks
- Reduction in pollution by power facilities
- Gain in employment in the equipment manufacturing and installation industries.

The corresponding costs include:

- Social adaptation to new practices entailing some loss of personal freedom of action
- Disruption caused by retrofitting the flow reduction equipment in existing construction
- Public time consumed in debating and implementing the new practices
- Loss in employment in the water and wastewater treatment plant construction and operation industries.

Institutional Considerations

Despite the generally favorable public reaction to water conservation, very few people are likely to install flow reduction equipment or implement flow reduction practices without substantial government incentives that are able to overcome the strong institutional resistance to this type of innovation.

INSTITUTIONAL RESTRAINTS

All public decisions are the composite result of many complex forces, incentives, and fears, felt by and expressed through a number of individuals, groups, and institutions within the community. The balance between self interest and public good is delicate and highly subjective. Most frequently, these personal conflicts are resolved in the economic and political arenas. Moreover, the participation of Federal, interstate state, regional, and local agencies in planning, construction, and operation of water facilities produces extremely intricate patterns of jurisdiction and responsibility. Each agency acts according to the desires of some constituency. Where conflicts of interest exist between these constituencies, the result may be inaction.

Specific institutional resistance to widespread adoption of flow reduction devices and practices hinges on the following constraints:

- There is a widespread resistance of public health officials, who exercise a veto power over the choice, to systems with a potential of failing or not operating properly, without the care of trained personnel
- Local sanitary regulations and standards are generally written in terms of engineering specifications tied to existing equipment and processes
- There has been insufficient effort devoted to demonstrating the high reliability, stable performance, and minimal operating requirements of new devices.

A survey of homeowners, architects-engineers, plumbers, and plumbing equipment manufacturers, which was conducted by Bailey *et al.*, (1969), brings a note of optimism to this picture. All of the groups were favorably disposed toward the use of many flow reduction devices, and most of the objections seemed to stem from aesthetic, rather than functional, or economic, considerations.

EDUCATIONAL PROGRAMS

The nature and effectiveness of educational programs can perhaps best be illustrated by the experience of the Washington Suburban Sanitary Commission (WSSC). The program has attracted widespread interest from more than 40 states and several foreign countries.

Since 1970, the WSSC has been gathering information on the feasibility of reducing sewage loads by promotion of water conservation practices. During this period, the WSSC has developed basic publicity materials aimed at encouraging voluntary customer participation in this effort. The following specific activities were instituted:

- Preparation of a booklet for general mailing to all customers on ways to conserve water in the home (see Figure 3)
- A customer contest for new ideas in water saving
- Distribution of cards for the kitchen and bathroom carrying water-saving suggestions
- Presentation of speakers before community groups.

The Commission concluded that most people in its suburban Maryland service area, which includes over 1.1 million customers, are sincerely interested in the protection and improvement of their water environment and are apparently willing to sacrifice some convenience in a voluntary effort to conserve water and reduce waste.

FINANCIAL INCENTIVES

Financial incentives for the adoption of flow reduction devices and practices may take the form of rate modification, or government subsidies and tax incentives. In fact, the true cost of water to the homeowner is seldom reflected in his water bill, since the capital investment in the supply facilities and equipment and a portion of the operating cost are usually financed from general tax revenues.

The more common water rate structures are as follows:

- Block, or flat, rate—a fixed charge, regardless of the amount used
- Declining block rate—minimum charge for an initial amount and progressively lower charges for additional amounts
- Incremental block rate—minimum charge for an initial amount and progressively higher charges for additional amounts
- Constant rate—a fixed charge for each incremental amount
- Summer differential rate—a higher rate for lawn watering.

A survey by the American Water Works Association (AWWA, 1965) found that nearly all of the 807 responding water utilities used the declining block rate.

The effectiveness of introducing an incremental block or other rate structure designed to discourage water use is determined by the elasticity of demand for water, which is likely to vary with the homeowner's financial status, climate, and local custom (e.g., lawn watering, backyard pools). Typically, rate increases have resulted in reduced consumption, followed by a gradual recovery to a point somewhat below the original level. A 1966 survey in Nassau County found that the per capita consumption in Levittown was 20 per cent higher than in neighboring East Meadow and attributed the difference to the lack of water meters (block rate) in the former water district (Cornelius and Dawson, 1966). Finally, any rate changes designed to reduce water consumption are likely to be more effective if accompanied by a well-orchestrated educational campaign.

REGULATION OF WATER USE

Regulation of water use may be exercised through direct allocation of water, or through modification of plumbing codes to encourage introduction of flow reduction devices. Water allocation has not been practiced in the United States, although some local jurisdictions have regulated the watering of lawns and washing of cars in times of draught.

Modification of plumbing codes will ultimately require rewriting the Federal Specification WW-P-541D, which spells out general and detailed requirements for plumbing fixtures. In the meantime, however, local jurisdictions can exercise their powers to make their local plumbing codes more receptive to the use of flow reduction devices. The WSSC has issued the following requirements for certain new construction within its jurisdiction:

- Tank type toilets for new residential and commercial buildings must provide a maximum flush not to exceed 3-1/2 gallons

- Water-saving shower heads must be installed, limiting flow to a maximum of 3-1/2 gallons per minute
- Aerators, which reduce flow to approximately four gallons per minute are required in all kitchen sinks and lavatories
- Pressure on incoming service must be adjusted to under 60 psi
- Cellar floor drains may not be connected to the sanitary sewage system but must discharge to an approved storm drain, and all buildings in areas known to have a water table above the basement floor are required to have foundation drains around the outside of the building with a satisfactory point of discharge.

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