The Water Economy of a Low Flush Toilet in a Water Deficient Region

by

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Contract No. A-004-VI
Research Period 3/77 to 9/78
A project completion report.

July 1979

The work upon which this report is based was supported by funds provided by the United States Department of the Interior, Office of Water Research and Technology as authorized under the Water Resources Act of 1964, P.L. 88-379.

Technical Report No. 3
Water Resources Research Center
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ABSTRACT

Water use at a public restroom facility was substantially reduced after installation of low-flush toilets. Water in the region is scarce, demand is high, and water is expensive. The first year of operation of the low-flush toilets saved 36,500 gallons and reduced the true cost of water used at the facility, predominately desalted water, from $757 to $210. The research demonstrated the practical value of a conservation technique that, if widely used in the Territory, could substantially reduce costs for government water and energy production.

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INTRODUCTION AND OVERVIEW

The Territory of the U.S. Virgin Islands is composed of three main islands: St. Croix (84 sq. mi.), St. Thomas (28 sq. mi.), and St. John (20 sq. mi.), and more than 60 smaller islands and cays. The islands as a group receive an average of 40 inches of rainfall annually; however, about 90 percent of that rainfall is lost to evapotranspiration and the group of tropical, oceanic islands is classified as being semi-arid. The water resources, therefore, are scarce and generally of poor quality. Because of the limited scale of each island, there is no hinterland from which to draw additional resources.

Approximately 100,000 people live on the land area of 135 square miles. Most of the population relies directly on roof catchment and cistern storage of the inconstant rainfall for household water supplies.

The Territory experienced a period of phenomenal economic growth and population expansion during the 1960's and 1970's. The government invested heavily in sea water desalting plants in an attempt to relieve the chronic short supply of potable water created by the demands of a booming tourism-based economy. Temporarily successful in fulfilling the needs for potable water, by the mid-70's operational failures of the desalting equipment in combination with a continual reliance on inefficient and obsolete distribution systems and the meteorically rising price of energy made it impossible for the government to meet daily potable water needs, and a six-hour per day rationing schedule was imposed on public water supplies.

At peak production, the desalting plants are capable of supplying approximately 75% of the estimated peak daily demand of 5.5 million gallons of potable water for the Territory. Present cost for desalting sea water is assumed to be at least $15 per thousand gallons; the true cost of production for the V.I. Water and Power Authority is not known. The water is distributed to the public by the Virgin Islands government (Public Works Department) and consumers are charged a rate of $4 per thousand gallons, making it necessary for the government to substantially subsidize Territorial water supply programs.

Conservation of water has therefore been identified as one of the ways the Virgin Islands government can reduce the strain of the present fiscal squeeze.

The Virgin Islands Water Resources Research Center, through a grant from the U.S. Department of Interior, Office of Water Research and Technology, installed several low-flush toilets in a heavily trafficked public restroom facility on St. Thomas and monitored the performance of those units for a period of seventeen (17) months. The project served a practical use for the residents and visitors of the Territory and demonstrated the conservation and cost-saving potential of such equipment to the public agencies that operate and service the public restroom facility.

OBJECTIVES

The project was intended to measure a reduction in water usage at a public restroom facility after installation of low-flush toilets, monitor maintenance and operational problems, and evaluate the net effects that wide-scale use of low-flush equipment could have on the present level of demand for government water production and distribution.

SCOPE

The installation of low-flush toilets in combination with a monitoring program provided the opportunity to evaluate the effects of reducing the amount of water required for sanitary flushing on: a) the daily water needs for operating a specific restroom facility, b) Territory-wide water needs by projecting a reduction of demand, and c) reducing the cost of water for an average household in the U.S. Virgin Islands.

APPROACH AND METHODS

Five (5) conventional toilets in a public restroom facility at Red Hook Ferry Dock, St. Thomas were replaced with low-flush units at a total cost of $3580. The facility is operated by the V.I. Ports Authority and was selected as the project site because it serves the needs of the many residents of St. John and St. Thomas as well as tourists who regularly use the St. Thomas-St. John ferries.

Water for the facility is supplied without cost to the Ports Authority by the Public Works Department. Water is trucked as needed from the public standpipe in Sub-base, about twelve miles away, and is stored at the site in a 1,000 gallon steel tank. It is then pumped to the restroom for use in the lavoratories and for sanitary flushing.

The low-flush units that were installed were Microphor LF-310 stainless steel toilets. The system requires 50-70 PSI of compressed air and a small amount of water from gravity flow or, as in this project,

at 1-60 PSI. A push button mounted on the toilet activates a flow of water into the bowl and opens a valve in the base of the toilet. The valve is then closed automatically and a charge of compressed air ejects waste materials into a discharge line.

The Microphor unit is designed to operate on two (2) quarts of water per flush. All parts of the unit are corrosion resistant, a beneficial feature because of the high level of chlorides present in most of the water delivered to the facility.

A water meter was installed in the feed line between the storage tank and the restroom.

The newly-completed installation was tested on February 24, 1977. From 7:30 a.m. until 3:15 p.m. there was a total of 60 flushes of the units and 30 gallons of water was used. A conventional toilet would have required more than 300 gallons for the identical use.

Operation of the facility was monitored for a period of seventeen (17) months, from February 24, 1977 to June 22, 1978. Water delivery records were submitted for analysis by the Public Works Department for the period January 1, 1976 to June 30, 1979.

RESULTS AND DISCUSSION

The theoretical reduction of the water used for sanitary flushing at the Red Hook facility is a factor of at least 10:1. The 10:1 reduction is the result of replacing the conventional flush toilets which require five (5) gallons (or more) per flush with units that require only two (2) quarts (or, 0.5 gallons) of water per flush.

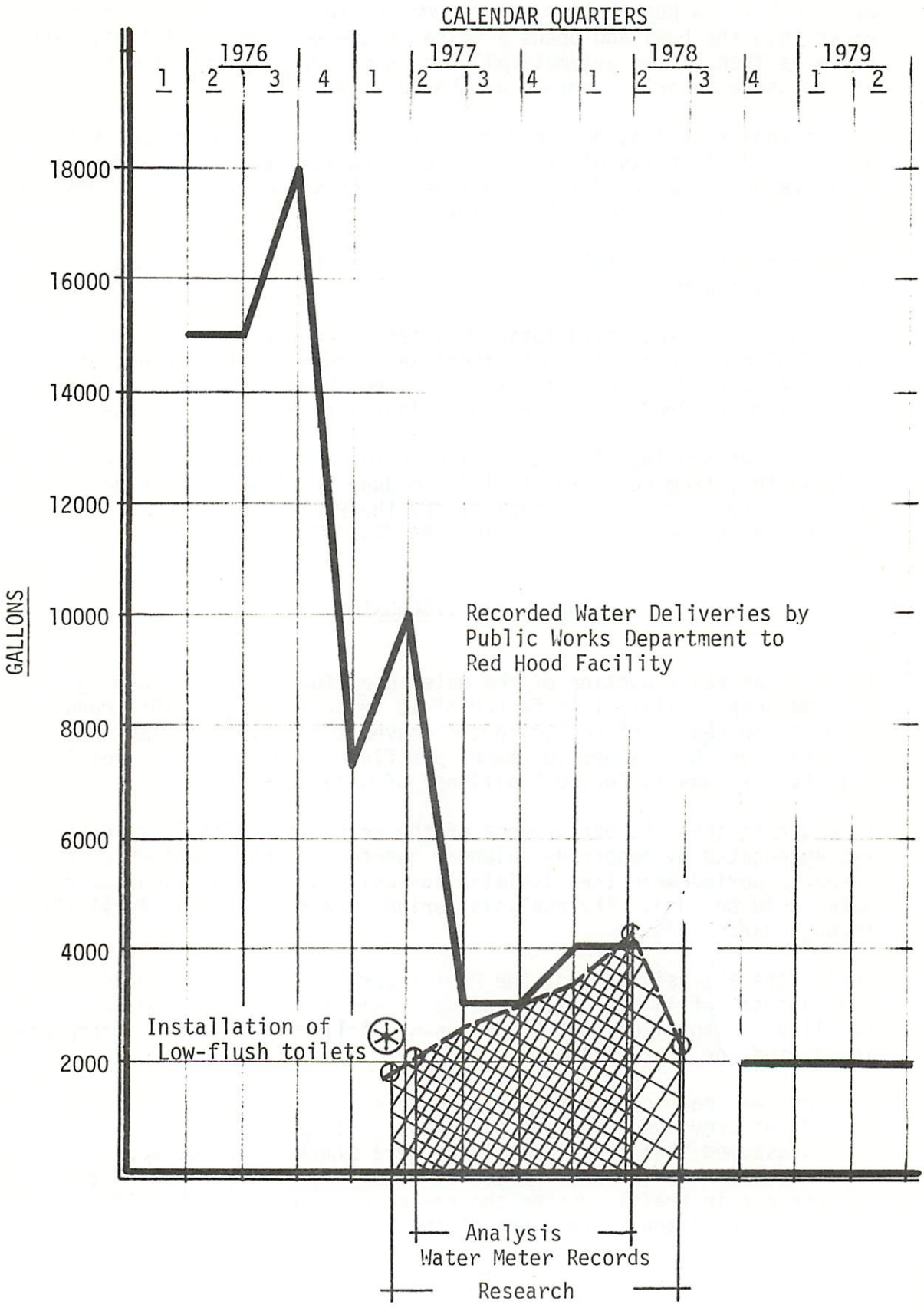
In order to test the performance of the retrofitted facility, data was aggregated by reporting calendar quarters. Four quarters of the research period were then isolated for which good comparisons of the data could be made. The analysis period selected was from April 1977 through March 1978.

During the analysis period, the Public Works Department records show that a total of 14,000 gallons of water was delivered to the Red Hook facility: a total of 50,500 gallons was delivered for the corresponding period one year earlier.

No count was made of the number of people using the facility and no records of previous levels of use exist. For purposes of this study, it was assumed that traffic patterns were similar for the years 1976-1978. (Note: Maintenance personnel noted that there appeared to be an increase in traffic during the research period, and that it was probably due to the improvement of the facility.)

FIG. 1 Record of Water Use at Red Hook

PROJECT NO. A-004-VI The Water Economy of a Low-flush Toilet



WRRC/ap/79

The actual reduction of water use recorded by the government for the analysis period was a ratio of 3.6:1--representing a savings of 36,500 gallons of water. At $4 per thousand gallons, the cost of providing water to the Red Hook facility was reduced from $202 to $56, a savings of $156 in one year. If the water savings is computed at the assumed true cost of water for the Virgin Islands government--$15 per thousand gallons--the reduction was $757.50 to $210.00, or a true savings of $547.50.

The measurements of the performance of the low-flush toilets by records from water meter readings also reflect the significant savings during the research period. Discrepancies between sets of data is assumed to be caused by the paucity of reliable means for government to measure and monitor deliveries of water in the Territory.

Analysis of the water meter records reveals that a total of 12,660 gallons of water was used at the facility for the analysis period (April 1977 - March 1978). The facility used an average of 30.4 gallons per day for the analysis period, and 32.7 gallons per day for the duration of the project (2/24/77 - 6/22/78). This computes to an average use of 60-65 flushes per day with the Microphor units. A conventional flush toilet (5 gallons/flush, or more) would require 300-325 gallons of water per day for that level of use.

During the course of the project, electrical problems were experienced with the compressor unit. It was found that it was a deficiency in the facility wiring and was corrected by the Ports Authority. One mechanical breakdown occurred with a toilet unit. Replacement of a malfunctioning valve cost $70, the total expenditure for maintenance and repair during the research period.

A simple calculation to compute the rate of amortization of the investment in the low-flush toilets would be:

$$\frac{\text{Annual cost of operating conventional toilets} - \text{Annual cost of operating low-flush toilets}}{\text{Annual Savings}} = \frac{\text{Total Investment}}{\text{Annual Savings}} = \text{Rate of Amortization (in number of years)}$$

A computation for the Red Hook facility based on a water price of $4 per thousand gallons is:

Conventional Unit (5 gal/flush)

65 flushes/day x 5 gallons x 365 x $4/1000 = $475.50

Low-Flush Unit (0.5 gal/flush)

65 flushes/day x 0.5 gal x 365 x $4/1000 = 47.45

Gross Annual Savings: $427.05

Gross Annual Savings	$427.05
Less adjustment for annual maintenance & repair	50.00*
Adjusted Gross Annual Savings:	$377.05

*Note: It is assumed that the amount of electricity required to operate the compressor balances the amount normally required to operate the water pump--in fact, the energy demand should be lessened because the low-flush units require less water to be pumped for the same level of use.

The total cost for the installation of low-flush toilets at the Red Hook facility was $3580. Based on the present level of use, and at a price for water at $4 per thousand gallons, it will take 9.5 years to amortize the investment.

A computation for the Red Hook facility based on the assumed true cost of water ($15/1000) in the Virgin Islands is:

Conventional Unit

65 x 5 x 365 x $15/1000	=	$1779.38

Low-Flush Unit

65 x 0.5 x 365 x $15/1000	=	177.94
Gross Annual Savings		$1601.44
Less Adjustment		50.00
Adjusted Gross Annual Savings		$1551.44

Based on the true cost of water to the government, it will actually take only 2.3 years to amortize the Red Hook investment.

The experience of the installation and use of low-flush toilets in St. Thomas demonstrates the level of conservation of water that can be attained by the practical applications of such devices. It has also demonstrated that low-flush toilets, though more expensive to purchase than is a conventional toilet, can quickly pay for itself in the savings that can be realized where water is scarce and expensive.

Clearly, there are many immediate applications in the U.S. Virgin Islands for conserving water and saving money by installing low-flush toilets, particularly with the true cost of water as high as $15 per thousand gallons. With very few assumptions and several general calculations, some of the more obvious applications for

low-flush toilets with maximum benefit to the government of the Virgin Islands can easily be identified.

First, the assumptions:

a) The peak daily demand in the U.S. Virgin Islands is 5.5 million gallons of potable water; the true cost (production, storage, debt service, distribution, administration, etc.) to the government is $15 per thousand gallons; therefore, water costs each resident of the Territory 82.5¢ per day, or, a total of $30.1 million annually for the government.

b) Typically, 45% of all residential and commercial water (not including industrial) is used for sanitary flushing (Note: This is an accepted standard.); for reasons peculiar to water-scarce areas such as the Virgin Islands, this amount may be less; say, an average of 35% for flushing.

and c) The Microphor low-flush toilets theoretically save 90% of the water which would be used by a conventional toilet; there are various low-flush toilets available commercially, and if in use, will save various amounts of water; say, an average savings of 50%.

Therefore, if 35% of the peak daily demand for potable water is used for sanitary flushing, it costs the residents of the Territory $10.5 million per year to flush toilets. However, if all toilets were water savers, it would cut the cost in half: assuming the average price for a low-flush toilet is $300, the money saved by the government would purchase more than 17,000 toilets each year!

The fact is, no one is really sure how much water is used or needed in the Territory. No one knows how much money, public or private, is invested in water annually. What is clear is that water saved is also energy and money saved. Reducing the amount of water used correspondingly reduces the energy required to desalt sea water, operate pumps in our homes as well as the public distribution system, distribute water by trucks on congested streets and highways, and to collect and treat waste water.

Where can low-flush toilets be installed most easily to maximize the impact on water demands in the Territory?

Public School Use:

The present school population is estimated to be 26,000. Assuming each student flushes a conventional toilet 1.5 times a day (5 gal/flush), the water used is 195,000 gallons/day. At a true cost of $15/1000 gallons, the water costs $2925. Assuming the school year is 180 days, water used simply for sanitary flushing in schools costs the government $526,500 each year. Assuming low-flush toilets were

installed throughout the school system and 50% of the flushing water was saved, 877 low-flush toilets could be paid for with public funds that now go down the drain in one year.

Overnight Accomodations Use: (Hotels, Guesthouses, etc.)

There are presently 4300 units in the U.S. Virgin Islands. Assuming an occupancy rate of 2.5 people per unit and each guest uses 100 gallons/day--45% of which is for sanitary flushing--a total of 483,750 gallons of water is used each day for flushing. Assuming an annual occupancy rate of 30%, 53 million gallons of water are required by overnight visitors to the islands for sanitary flushing each year. If half of the water is saved by using low-flush toilets, approximately 1324 toilets could be purchased by money saved the first year.

(Note: A recent installation of low-flush toilets at a beach hotel on St. Thomas reduced overall consumption of water from over 100 gpcd to 80 gpcd.)

Government Office Use:

It is estimated that there is a total employment of 40,000 and that 25% (or 10,000) of those jobs are part of the local (Territorial) government sector. Assuming that each employee flushes a conventional toilet twice a day, the water used for flushing totals 100,000 gallons and costs the government $1500/day.

In one year, assuming each employee works 200 days, water for sanitary flushing costs the government $300,000. If half of the water was saved by installing low-flush toilets in all government offices, 500 toilets could be paid for in the first year of operation.

Public Housing Use:

The V.I. Housing Authority owns about 15% of the housing stock in the Territory and shelters approximately 18% (or 18,000) of the population. Assuming that water use is 35 gallons per person per day and that 25% of that total is used for sanitary flushing, approximately 57.5 million gallons is required annually for flushing toilets (or, 157,500 gallons per day). The true cost of that water is $862,500. If low-flush toilets were installed throughout the public housing units, 1437 toilets could be paid for with the first year's savings on water purchases.

Residential Use:

Most households in the Virgin Islands depend almost exclusively on roof catchment and cistern storage of rainfall for water supply. It has been estimated that the true cost of cistern water (i.e. capital investment in cistern, amortization, operation of pumps, maintenance, etc.) is $20 per thousand gallons. It is assumed that water use in households on cisterns averages 50 gallons per capita per day. A family of four would therefore use about 73,000 gallons per year.

Assuming each resident flushes a conventional toilet twice a day, 14,600 gallons (or, 20%) of the cistern supply is used for sanitary flushing purposes at a cost of approximately $290/year. If a $400 low-flush toilet was installed, it would take slightly less than three years to amortize the investment.

Since most households in the Territory are not serviced by central sewer service, and since most of the soils throughout the Territory are poorly drained, an additional benefit derived from decreasing the amount of water used for sanitary flushing is that ground waters would be less effected by contamination from poorly operating household septic systems.

And finally, decreasing all sources of wastewater by decreasing the amount of water used for sanitary flushing will help protect the marine environments surrounding these islands--a resource that is immeasurably important to the well-being of the inhabitants of the Virgin Islands.

RECOMMENDATIONS

1) The Government of the Virgin Islands should pass legislation prohibiting the importation and sale of toilets which use more than 3.6 gallons of water per flush after January 1, 1980.

2) The Government of the Virgin Islands should immediately embark on an investment program to replace existing conventional toilet fixtures in public housing, public schools, and government offices with low-flush toilets.

3) The Government of the Virgin Islands should develop and implement a public relations campaign which would stress the cost effectiveness of conserving water for private individuals and commercial enterprises in the Territory, and should encourage the use of water saving devices such as low-flush toilets.

4) The Government of the Virgin Islands should study the cost effectiveness of offering tax incentives to private individuals and commercial enterprises for retrofitting existing plumbing fixtures with water saving equipment, especially low-flush toilets.

ACKNOWLEDGEMENTS

The daily efforts of Margaret Blyden at Red Hook are sincerely appreciated.

The advice of Leonard Brown was invaluable.

The assistance and concern of Frank Kay is gratefully acknowledged.

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Table 1

Water Center Water Meter Records

PROJECT NO. A-004-VI The Water Economy of a Low-flush Toilet

Date	Meter	Gallons	No. Flushes	Gal/Day	Quarterly Totals For Analysis
2/24/77	250.8				
/25	270.6	19.8	39	19.8	
/26	329.9	59.3	118	59.3	
/27	359.7	29.8	59	29.8	
/28	419.2	59.5	119	59.5	
3/1	443.3	24.1	48	24.1	
/2	471.8	28.5	57	28.5	
/3	526.7	54.9	109	54.9	
/4	560.4	33.7	67	33.7	
/5	601.3	40.9	81	40.9	
/6	631.9	30.6	61	30.6	
/7	673.0	41.1	82	41.1	
/8	708.5	35.5	71	35.5	
/9	734.9	26.4	52	26.4	
/10	790.0	55.1	110	55.1	
/17	1052.7	262.7	535	37.5*	
/22	1283.5	230.8	461	52.5*	
/24	1390.2	106.7	213	53.4*	Incomplete
4/13	2123	733	1466	36.7*	
5/9	2725	602	1204	23.2*	
5/16	2965	239	478	34.2*	
6/1	3461	496	992	31.0*	
6/13	3746	285	570	23.8*	First 2355 gallons
7/13	4707	961	1922	32.0*	
8/15	5600	893	1786	27.1*	
8/25	5904	304	608	30.4*	
9/26	6742	838	1676	26.2*	Second 2996 gallons
10/17	7258	516	1032	16.6*	
12/15	9944	2686	5372	45.5*	Third 3202 gallons
1/13/78	10856	912	1824	31.4*	
3/1	12620	1764	3528	37.5*	
4/13	13961	1341	2682	31.2*	Fourth 4017 gallons
6/22/78	16050	2089	4178	29.8*	Incomplete
		15,789.4 gal		32.7*gal/day	

ANALYSIS

*Average

Table 2

Comparison of Water Use Records for the Red Hook Facility
(By calendar quarters)

PROJECT NO. A-004-VI The Water Economy of a Low-flush Toilet

Reporting Quarter	Department of Public Works	Water Center Records
First 1976	15,000 gallons	
Second 1976	15,000	
Third 1976	18,000	
Fourth 1976	7,500	
First 1977	10,000	1,140* gallons
Second 1977	3,000	2,355
Third 1977	3,000	2,996
Fourth 1977	4,000	3,202
First 1978	4,000	4,017
Second 1978	7,000	2,089*
Third 1978	2,000	
Fourth 1978	2,000	
First 1979	2,000	
Second 1979	2,000	

ANALYSIS

*Incomplete record

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Table 3

Installation Costs of Low-flush Toilets at Red Hook, St. Thomas

PROJECT NO. A-004-VI The Water Economy of a Low-flush Toilet

5	Microphor toilets (LF-310) @ $385	$ 1925
1	Compressor (30 Gal)	485
1	Water meter	70
	Plumbing Materials	100
	Sub-total (equipment & materials)	2580
Installation		1000
	Total cost for installation	$ 3580

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Table 4

Water Distributed From The Government Standpipe To Red Hook From January 1976 To December 1976.

1976				
January	5, 750	Gals	23	Tons
February	3, 500	"	14	"
March	5, 750	"	23	"
April	5, 000	"	20	"
May	5, 000	"	20	"
June	5, 000	"	20	"
July	6,000	"	24	"
August	5, 000	"	20	"
September	7, 000	"	28	"
October	4, 000	"	16	"
November	500	"	2	"
December	3, 000	"	12	"
	55, 500	Gals	222	Tons

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Table 5

Water Distributed From The Government Standpipe To Red Hook From January 1977 To December 1977.

1977				
January	4, 500	Gals	18	Tons
February	3, 000	"	12	"
March	2, 500	"	10	"
April	1, 000	"	4	"
May	1, 000	"	4	"
June	1, 000	"	4	"
July	1, 000	"	4	"
August	1, 000	"	4	"
September	1, 000	"	4	"
October	1, 000	"	4	"
November	1, 000	"	4	"
December	2, 000		8	"
	20, 000	Gals	80	Tons

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Table 6

Water Distributed From The Government Standpipe To Red Hook From January 1978 To September 1978

1978				
January	1, 000	Gals	4	Tons
February	2, 000	"	8	"
March	1, 000	"	4	"
April	2, 000	"	8	"
May	3, 000	"	12	"
June	2, 000	"	8	"
July	None	"	None	
August	1, 000	"	4	"
September	1, 000	"	4	"
	13, 000	Gals	52	Tons

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Table 7

Water Distributed From The Government Standpipe To Red Hook From October 1978 To May 1979.

1978		
October	1,000 Gals	4 Tons
November	1,000 "	4 "
December	None	None
1979		
January	1,000 "	4 "
February	1,000 "	4 "
March	None	None
April	2,000 "	8 "
May	None	None
	6,000 Gals	24 Tons

LF-310

Stainless Steel Toilet With Push Button Convenience

Our LF-310 is constructed of rugged stainless steel. All parts are corrosion resistant. It's easy to install and simple to operate.

The system requires 50-70 PSI of compressed air and a small amount of water from gravity flow or 1-60 PSI. The push button activates a flow of water into the bowl and opens a valve in the toilet. The valve automatically closes and a charge of air ejects waste material into the discharge line. All Low-Flush toilets can be used with any type of sewage treatment system.

Microphor systems provide reliable waste handling, treatment and environmental protection.

Flush Cycle:	**12-18 seconds**
Water Usage:	**2 quarts per flush**
Warranty:	**One year — all parts**
Air Use:	**1 cubic foot free air at 60 psi**
Discharge Line:	**1½ inch pipe size**

We're Getting Around

Some of the organizations that have installed Microphor Low-Flush toilets include — ■ California Department of Parks and Recreation ■ California Department of Transportation ■ U.S. Environmental Protection Agency ■ U.S. Department of Interior, National Park Service ■ Seismograph Corporation ■ Dodge Ridge Ski Resort ■ U.S. Bureau of Land Management ■ California Department of Conservation ■ Golden Gate Bridge, Highway & Transportation District ■ Jackson (California) Pre-School Facility ■ Ranchers Supply House of Nevada ■ Idaho Department of Transportation ■ New Mexico Highway Department ■ More than 65 leading railroad companies in the U.S.

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