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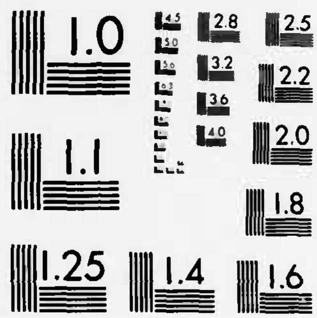

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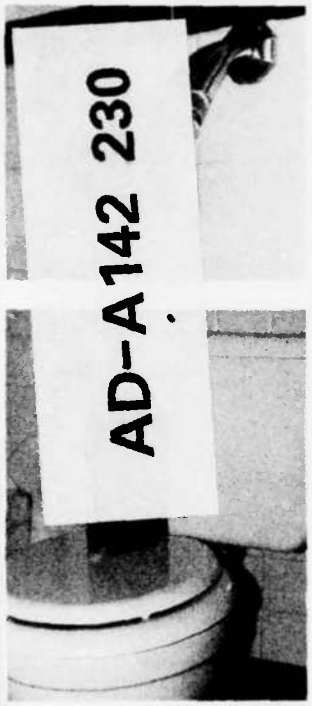

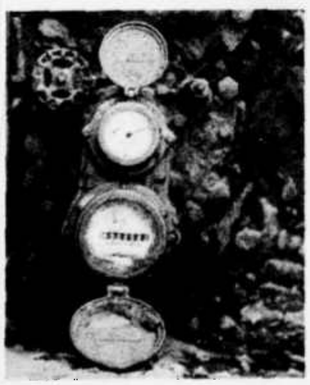

TECHNICAL REPORT EL-84-3

ALGORITHM FOR DETERMINING THE EFFECTIVENESS OF WATER CONSERVATION MEASURES

by

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March 1984

Final Report

Approved For Public Release; Distribution Unlimited

Prepared for Office, Chief of Engineers, U. S. Army
Washington, D. C. 20314

Under Contract No. DACW39-82-C-0060

Monitored by Environmental Laboratory
U. S. Army Engineer Waterways Experiment Station
P. O. Box 631, Vicksburg, Miss. 39180

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER Technical Report EL-84-3	2. GOVT ACCESSION NO. AD-A142230	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) ALGORITHM FOR DETERMINING THE EFFECTIVENESS OF WATER CONSERVATION MEASURES		5. TYPE OF REPORT & PERIOD COVERED Final report 6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) William G. Richards Deborah J. McCall Arun K. Deb		8. CONTRACT OR GRANT NUMBER(s) Contract No. DACW39-82-C-0060
9. PERFORMING ORGANIZATION NAME AND ADDRESS Roy F. Weston, Inc. Weston Way West Chester, Pa. 19380		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS Office, Chief of Engineers, U. S. Army Washington, D. C. 20314		12. REPORT DATE March 1984 13. NUMBER OF PAGES 118
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office) U. S. Army Engineer Waterways Experiment Station Environmental Laboratory P. O. Box 631, Vicksburg, Miss. 39180		15. SECURITY CLASS. (of this report) Unclassified 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

Available from National Technical Information Service, 5285 Port Royal Road, Springfield, Va. 22161.

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Algorithms. (LC)
Conservation of natural resources--Research. (LC)
Water conservation--Mathematical models. (LC)
Water consumption--Research. (LC)

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

An algorithm has been developed to determine the effectiveness in reducing water use by the implementation of a variety of water conservation measures. The algorithm developed may be used to estimate water use reductions resulting from the implementation of a large number of conservation measures and combinations of measures, and is designed so that it may be easily programmed as a new module within the Methodology for Areawide Planning Studies (MAPS) computer program. The effectiveness of any water conservation program is dependent

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Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

20. ABSTRACT (Continued).

upon site-specific conditions, so caution should be used in applying the numerical values for reduction, coverage, and interaction factors presented in this report. To serve this purpose, detailed references are given so that the user can utilize the sources of data to ensure that the values selected are appropriate.

PREFACE

This work was funded under the Water Supply System Design (CWIS 31733) work unit of the Water Supply and Conservation Program. The work was performed by Roy F. Weston, Inc., under Contract No. DACW39-82-C-0060. The study team at Weston consisted of Mr. William G. Richards, Ms. Deborah J. McCall, and Dr. Arun K. Deb.

The contract was monitored by Dr. Thomas M. Walski of the Water Resources Engineering Group (WREG), Environmental Engineering Division (EED), Environmental Laboratory (EL), U. S. Army Engineer Waterways Experiment Station, Vicksburg, Miss. Dr. Walski was assisted by Dr. Joe Miller Morgan and Ms. Janet S. Condra, also of the WREG.

The study was conducted under the direct supervision of Mr. Michael R. Palermo, Chief, WREG, and under the general supervision of Mr. Andrew J. Green, Chief, EED, and Dr. John Harrison, Chief, EL.

Commander and Director of WES was COL Tilford C. Creel, CE. Technical Director was Mr. F. R. Brown.

This report should be cited as follows:

Richards, W. G., McCall, D. J., and Deb, A. K. 1984. "Algorithm for Determining the Effectiveness of Water Conservation Measures," Technical Report EL-84-3, prepared by Roy F. Weston, Inc., West Chester, Pa., for the U. S. Army Engineer Waterways Experiment Station, CE, Vicksburg, Miss.

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CONVERSION FACTORS, U.S. CUSTOMARY TO METRIC (SI) UNITS OF MEASUREMENT

U. S. customary units of measurement used in this report can be converted to metric (SI) units as follows:

Multiply	By	To Obtain
Gallons per minute	3.785412	Cubic decimeters per minute
Gallons (U.S. liquid)	3.785412	Cubic decimeters

ALGORITHM FOR DETERMINING THE EFFECTIVENSS OF WATER CONSERVATION MEASURES

1.0 INTRODUCTION

1.1 Background

In the past, water utilities have generally emphasized conservation only on an emergency basis such as during prolonged droughts or when key facilities have been disabled. However, there is now increasing recognition that full time water conservation programs may be economically attractive since capital expenditures may be avoided or postponed if water demands, and hence design flow rates, can be significantly reduced. Thus, a concentrated effort is under way to make water conservation an integral part of many water supply planning programs.

The United States Army Corps of Engineers (CE) has initiated a major research and development effort in water supply. Two elements of this program are the Water Supply System Design and Methodology for Areawide Planning Studies (MAPS) work units being conducted at the CE Waterways Experiment Station in Vicksburg, Mississippi. Specifically, these work units have as their objectives improving the capability of CE personnel to plan, design, and operate water supply facilities. As part of this work, a versatile and comprehensive computer program (called MAPS) that may be used in planning, evaluating, and designing water supply projects has been developed, tested, and verified.

MAPS is quite large (about 18,000 cards), but is modular in nature and is designed so that the user need have no previous experience in computer programming. These features, coupled with the conversational, interactive operating mode employed, make MAPS very easy to use. Presently, the program may be used to design and estimate costs for a variety of water supply facilities, simulate and analyze water distribution networks, and estimate costs associated with implementation of several water conservation measures.

1.2 Purpose

The purpose of the work reported herein was to develop an easy to use algorithm, or procedure, for estimating reductions in water use that may be expected when conservation measures are implemented. The algorithm developed conforms fully to the general procedures already adopted by the Corps of Engineers (IWR CR 80-1; Source #169 in Part 7), may be used to estimate water use reductions resulting from implementation of a large number of conservation measures and combinations of measures, and is designed so that it may be easily programmed as a new MAPS module. Once the algorithm is incorporated into MAPS, users will be able to rapidly consider a wide variety of design alternatives and determine the impacts that various levels of water conservation will have on the sizes of costs of specific water supply facilities.

1.3 Overview

The development and description of the water use reduction algorithm are documented in this report. Part 2 presents an overview of the technical approach utilized and a discussion of the appropriate use of the procedure in specific circumstances. The terminology used, input data required, specific methodologies employed, options available, and the output that can be obtained are described in Part 3. In addition, each water conservation measure included in the algorithm is discussed in detail. In Part 4, a detailed rationale is presented for each component of the algorithm. The verification of the algorithm is discussed in Part 5, and illustrative examples are presented in Part 6. A bibliography of the pertinent literature is surveyed in Part 7.

1.4 Caveat

The effectiveness of any water conservation program is somewhat dependent on site-specific conditions. Therefore, the user of the report should exercise considerable caution in applying the numerical values for reduction, coverage, and interaction factors presented in this report to a specific water supply study. It is strongly recommended that the user first try to locate data on conservation effectiveness relevant to the particular study area. If such data are not available, the user should then carefully examine and consider the information presented in this report. Only those values developed for circumstances and conditions similar to those existing in the study area should be used. Unfortunately, in many cases, literature values vary over a considerable range. Therefore, it is imperative that the user be able to present a sound rationale justifying whatever numerical values are used to calculate conservation effectiveness. It is not sufficient to simply state that "typical" values were used.

To serve this purpose, detailed references are given so that the user can go to the source of the data to ensure that the values selected are appropriate. For this reason, all reduction, coverage, and interaction factors found in the literature are presented in this report, not just "average" or "typical" values. The user may also, for example, wish to be conservative in using those reduction, coverage, or interaction values based on theoretical considerations since values generated by this means are sometimes overly optimistic.

2.0 TECHNICAL APPROACH

The water conservation effectiveness module developed by this effort provides a methodology which can be used as a "planning tool" to calculate the effect of various water conservation measures on the otherwise unrestricted water use by a community or utility. The optimal use of this module would be for the user to provide site-specific data on the reductions to be achieved and coverage to be applied in the application being studied. It must be emphasized that there is no substitute for using the most appropriate information available that is pertinent to the specific circumstances being evaluated. Every effort to develop site-specific data should always be pursued.

The work effort to develop an algorithm for determining the effectiveness of water conservation measures consisted of five elements. (1) The first element was the data collection phase, which consisted of an extensive literature search and telephone survey to obtain as much pertinent and up-to-date information as possible. (2) Then the available data and case studies were synthesized and prioritized in terms of their usefulness in developing the specific water conservation factors for reduction, coverage, and interactions between conservation measures. (These terms are defined in the description of the conservation effectiveness methodology in Part 3.) (3) The values of these factors (or functions to determine these factors) which are used in the algorithm were determined and organized into matrices from which they could be accessed either by the MAPS system, or manually if the algorithm is being applied by hand. (4) A step-by-step algorithm was developed for ensuring that the user can access the data and properly determine the effectiveness of the desired conservation measures. (5) Finally, illustrative examples and verification of the methodology were presented to demonstrate its accuracy and applicability.

The development of factors for the determination of the effectiveness of conservation measures depended upon the ability to prudently evaluate appropriate studies from the existing literature, supplemented by follow-up and additional case studies obtained by direct contacts. By use of rapid information retrieval systems, approximately 500 abstracts of reports and articles related to water conservation were obtained. From these initial abstracts a data base of 126 complete reports and articles was obtained, and served as the primary source of information. These references are provided in the bibliography in Part 7. In addition, there were frequent telephone contacts with authors, water utility officials, and researchers concerned with conservation measures to follow up on the primary sources or discuss additional test cases.

The multitude of sources and the extreme variance of the techniques used in the literature to describe results obtained by conservation measures required that greater emphasis be placed upon data developed by more documentable methods. Thus, the information sources were checked and compiled in accordance with priorities developed to identify the most appropriate data. Studies that provided comparisons of water use "with and without" conservation measures were preferred over surveys relying upon evaluations "before and after" the enactment of measures as the former is a direct comparison of the effect of a measure while the latter involves the possible development of interferences through variations of indirect factors over time. Another factor that was given priority in evaluating the importance of data sources was the preference for studies considering the actual implementation of conservation measures over theoretical derivations. Practical and field determinations of water use and device reductions were emphasized in preference to laboratory testing. A priority ranking system, described in Part 4.2, was developed to incorporate these preferences into a systematic system giving greater weight to more appropriate data.

From the prioritized data sources the values or variables for the reduction, coverage, and interaction values were determined. These were arranged into matrices that allow the conservation effectiveness methodology to properly access the required factors by the conservation measure, water use type, and flow dimension required. Although all values determined were examined for their reasonableness, the need to emphasize the preference for site-specific data in any application must always be considered.

A step-by-step methodology for determining the effectiveness of the conservation method was developed and is described in Part 3 and illustrated in Figure 3-1. This procedure ensures the proper input of the required data by the user; the proper accessing of the values or variables within the reduction, coverage, and interaction matrices; and the correct computation of effectiveness for the desired conditions.

For illustration, the methodology as described in Part 3 has been provided in terms of a manual computation by the user with indications of required input data at the time of describing the calculation or step for which the data will be used. It should be noted that in the conservation effectiveness module all input data will be provided by the user initially and then the algorithm will be executed in the order indicated.

Finally, illustrative examples of the use of the methodology were developed to show its feasibility in practical situations. Specific test cases to illustrate all aspects of the algorithm were developed. These were supplemented by including specific actual conservation cases to provide a direct comparison of the calculated result using the algorithm with actual water conservation data.

3.0 WATER CONSERVATION EFFECTIVENESS

3.1 Introduction

The MAPS water conservation effectiveness module calculates the reduction in unrestricted water use as a result of the implementation of individual water conservation measures or a water conservation program including several conservation measures. The user must indicate the measures to be considered and such items as the time period to be evaluated, the flow dimension and water use sectors to be considered, and the level of a conservation program that will be carried out. (Coverage factors for modest, moderate, and maximum programs are provided or the user may override these with other data.) In addition, more specific information, such as rationing goals, price ratios, elasticity, and rate of new construction may be required for specific conservation measures.

3.2 Definitions

3.2.1 Effectiveness, EFF_{ijkt}

The effectiveness of a water conservation measure i, for water use sector j, and dimension k, at time t is the reduction in water use or loss resulting from the implementation of that measure. Similarly, the effectiveness of a conservation program combining several conservation measures would be the total reduction in water use and loss for a dimension for all water uses resulting from the combined action of all measures.

The mathematical definition of effectiveness may be given by:

$$EFF_{ijkt} = FLOW_{jkt} * RFACT_{ijkt} * COVER_{ijkt} \qquad \text{(Eq.3-1)}$$

where:

EFF = effectiveness;
FLOW = the predicted unrestricted water use for use sector j, dimension k, at time t (The units of flow in the conservation effectiveness module are in MGD although any volumetric flow units can be used as long as they remain consistent for all input.);

RFACT = the fractional reduction in water use or loss expected to result from measure i for use sector j and dimension k at time t; and

COVER = the coverage of measure i in use sector j for dimension k at time t.

The combined effectiveness of a number of measures is not necessarily equal to the sum of their individual effects. The combined effectiveness of two measures whose individual effectiveness are given by:

$$EFF_1 = FLOW * RFACT_1 * COVER_1 \quad \text{(Eq. 3-2)}$$

$$EFF_2 = FLOW * RFACT_2 * COVER_2 \quad \text{(Eq. 3-3)}$$

where $EFF_1 > EFF_2$, can be expressed as:

$$EFF_{12} = EFF_1 + ACT_{12} * EFF_2 \quad \text{(Eq. 3-4)}$$

Here ACT_{12} is the interaction factor for measure 2 added to measure 1. FLOW, RFACT, COVER, and ACT are further defined in this section.

The percent effectiveness is the effectiveness determined for a water use sector or dimension as a percent of the unrestricted flow for that sector or dimension.

3.2.2 Unrestricted Water Use, $FLOW_{jkt}$

This is the water use predicted in the absence of any conservation measures. Its knowledge and disaggregation with respect to the water use sectors are prerequisites to the estimation of effectiveness.

3.2.3 Water Use Sector

All water use, either unrestricted or with conservation, may be disaggregated into certain classifications, called water use sectors. For the purposes of the MAPS conservation effectiveness module, six water use sectors have been defined which, when all are used in an analysis, equal the total water use for a community under study. These six water use sectors include interior residential, exterior residential, commercial, industrial, public, and unaccounted-for water uses.

3.2.4 Dimension

A dimension of water use is a flow rate corresponding to a specific condition. For example, the flow rate that corresponds to the average quantity of water supplied to a community over a twenty-four hour period is the average daily flow dimension. The MAPS conservation effectiveness module allows consideration of three dimensions: average daily flow, peak daily flow, and peak hourly flow.

3.2.5 Fractional Water Use Reduction, $RFACT_{ijkt}$

The fractional reduction in water use is the ratio of the reduction in water use resulting from the institution of a conservation measure i, in water use sector j, for dimension k, at time t, to the unrestricted water use in the same sector, dimension, and time. Values for RFACT are given in Tables 3-1 and 3-2 of section 3.6 for all conservation measures, for all water use categories, and for average and peak flow dimensions.

3.2.6 Coverage of Conservation Measure, $COVER_{ijkt}$

Coverage is defined as the fraction of water use that is actually subject to reduction because of some conservation activity. The coverage of a conservation measure i, in water use sector j, for dimension k, at time t, is that fraction of the water use that is affected by that measure.

Coverage factors vary because some measures apply only to a portion of the water use within a sector, some measures may be adopted by only a fraction of users within a sector, and some measures will be implemented gradually over time or their effectiveness may change over time. The upper limit of a coverage factor is always 1.0.

Variations in the effectiveness of conservation measures over time are accounted for by allowing the coverage factor to vary from the initial coverage (COVERG) by an annual ratio of change in coverage factor (AROC). Thus, for any year (KYEAR) after the initiation of a measure, the coverage factor would be equal to the initial coverage times the annual ratio of change of coverage raised to the power of the years since initiating the measure minus one. It is mathematically expressed as:

COVER = COVERG * AROC ** (KYEAR - 1.0) (Eq. 3-5) where:

- COVER = coverage
- COVERG = initial coverage
- AROC = annual ratio of change factor
- KYEAR = year since initiation of measure

Estimates of AROC have been provided for each conservation measure. In addition, initial coverage values, COVERG, have been estimated for three levels of a conservation program, modest, moderate, or maximum efforts, for each of the six water use sectors.

3.2.7 Interactions Between Conservation Measures, ACT

When two or more conservation measures are in effect at the same time, there may be an interaction between them that causes the effectiveness of the combined measures to be different than both measures considered separately. The interaction factor is that number which accounts for the interactions between two or more conservation measures implemented simultaneously. From equation 3-4, the interaction factor can be defined mathematically as:

$$ACT_{12} = \frac{EFF_{12} - EFF_{1}}{EFF_{2}} \qquad \text{(Eq. 3-6)}$$

In most cases, the interaction factor will either be equal to one (no interaction) or to zero (one measure wholly incorporated into another measure). At times, however, the combined effect of two or more measures is different from the sum of their individual effects, even accounting for wholly incorporated measures. Values of interaction factors were determined whenever data were available to justify such a calculation. When two conservation measures were similar in nature and an interaction factor could be determined from collected data for one measure with a third measure, but not the second measure with the third, the determined interaction was considered to apply in both cases. For instance, when an interaction factor was determined between toilet dams and public education, and no data were available to determine an interaction between displacement devices and public education, the former interaction factor was considered applicable in the latter case as well.

3.3 Input Required

Time data

The first and last year of the study period.

The year of initiating each conservation measure.

For certain measures the year of ending a measure is optional.

Flow data

The minimum data that needs to be specified is the average unrestricted daily flow dimension for six water use categories for the first and last years of the study period.

The maximum data that can be specified are three flow dimensions, six water use categories, for five years of output, including the first and last years of the study period.

Dimensions
- Unrestricted average daily flow
- Unrestricted peak daily flow
- Unrestricted peak hourly flow

Water Use Sectors
- Interior residential
- Exterior residential
- Commercial
- Industrial
- Public
- Unaccounted-for water

Conservation measures (select from)
- Low flow showerheads
- Shower flow restrictors
- Toilet dams
- Displacement devices
- Flush mechanisms
- Shallow trap toilets
- Pressure toilets
- Dual-flush toilets
- Faucet aerators
- Faucet flow restrictors
- Pressure reducing valves
- Service line restrictors
- Toilet leak and repair
- Reuse/recycle
- Metering

Pipeline leak repair

Conservation ordinances (also requires annual rate of new construction)

Restricted water uses

Rationing (also requires goal established for rationing program)

Pricing policies (also requires average price ratio - new to old - for each dimension and use sector, price elasticity)

Public education

Coverage

Initial coverage value or choice of modest, moderate, or maximum program

Annual ratio of change in coverage factor

Other

An option exists for reducing peak hourly flow by regulating use of exterior residential and public uses to non-peak time. If this option is used, then the percent of exterior residential and/or public peak hourly flow to be reduced must be input.

Another option allows the identification of consumptive use and nonconsumptive use for each use sector and any or all dimensions. If this option is used, then the percent of consumptive use for each water use sector before conservation is input for all desired flow dimensions.

3.4 Output

Flow data

- Flow with conservation for specified dimensions and water use sectors in desired years for each measure and/or all measures combined.
- Dimensions (as required)
  - Average daily flow
  - Peak daily flow
  - Peak hourly flow
- Water use sectors (as required)
  - Interior residential
  - Exterior residential
  - Commercial
  - Industrial
  - Public
  - Unaccounted-for water

Effectiveness

Effective water savings and the percent effectiveness for each dimension, water use sector, and/or for all sectors combined.

3.5 Conservation Effectiveness Methodology

The methodology for determining the effectiveness of selected conservation measures and the corresponding reduction in flow from the unrestricted water use is presented in Figure 3-1. Each of the steps required in this procedure will be discussed in order.

3.5.(1) First, the required unrestricted flow rates for each water use sector are provided by the user. There are several options available to the user to provide this unrestricted flow data in the form most suitable to his application.

The minimum data required are the unrestricted average daily flows for each use category projected for the first and last years of the study period. Under this option, the peak flow dimensions will then be derived from this input assuming peak daily flow as 1.8 times average daily flow and peak hourly flow as 3.0 times average daily flow. In addition, the flow data for intermediate years for which output is desired will be determined by interpolation. This interpolation will be accomplished by the following equation:

$$FLOW_N = FLOW_1 + [FLOW_2 - FLOW_1] * [(KYEAR_N - KYEAR_1) \div (KYEAR_2 - KYEAR_1)] ** EXPNT \qquad \text{(Eq. 3-7)}$$

where:

$FLOW_N$ = flow for desired year

$FLOW_1$ = flow in first year of study period

$FLOW_2$ = flow in last year of study period

$KYEAR_N$ = desired year

$KYEAR_1$ = first year of study period

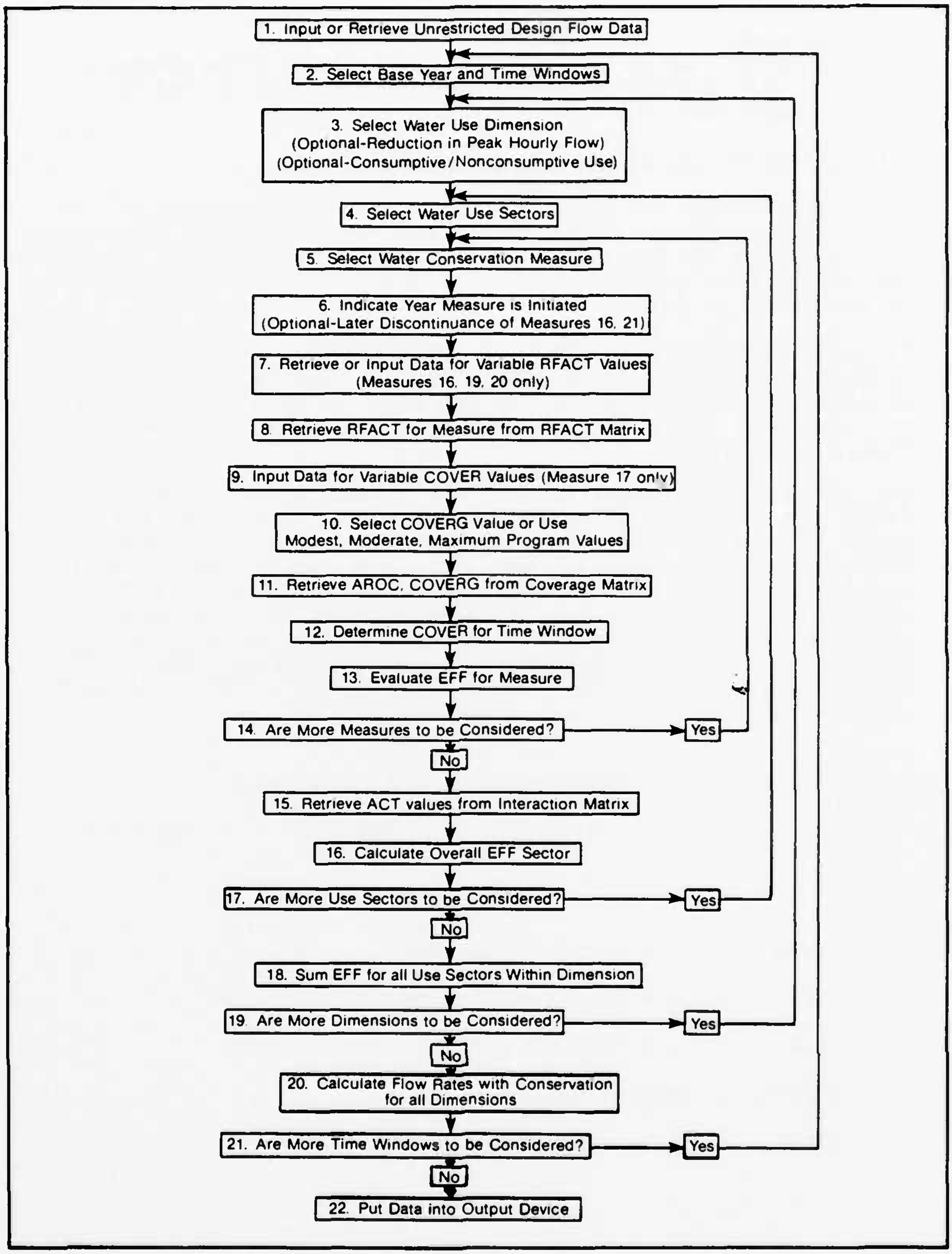

FIGURE 3-1 WATER CONSERVATION EFFECTIVENESS PROCEDURES

$KYEAR_2$ = last year of study period

EXPNT = interpolation exponent

If the user provides no other input, EXPNT will be assumed to be 1.0 and the interpolation will be linear. However, the user may specify a value for EXPNT in order to describe the curve for projected flow between the first and last years. For assistance in selecting values of EXPNT, Figure 3-2 shows how flow will vary with time for selected values of EXPNT.

A second option for the user to input unrestricted flow data would be to specify the average daily flow for as many as three additional years in addition to the first and last years of the study period. Should determinations be required for any additional years other than those specified under this option, unrestricted flow will be determined by linear interpolation. Peak flow dimensions will be derived from average daily flow as described above.

The third and fourth options for inputting unrestricted flow are variations of the two options described above; however, all three dimensions of flow are specified by the user. Thus, the third option would involve specifying average, peak daily, and peak hourly flow for the base and design year and selecting the exponent for interpolation between these two times. The fourth option would consist of specifying average, peak daily, and peak hourly flow for the first and last years and up to three additional years. If other flows are required, they will be determined by linear interpolation.

3.5.(2) The user next inputs the first year and all future years for which he desires to have the conservation effectiveness evaluation conducted, up to a maximum of five. These future years for which output will be developed are designated as time "windows" and will generally include the end of the study period being considered by the user as well as any intermediate periods of interest. The first year would generally be the same year as the initial implementation of any conservation program. The last year would be the final year under consideration and would frequently be the basis for design of some important component under design by the user. After designation, the conservation effectiveness module will proceed to evaluate the earliest future time window.

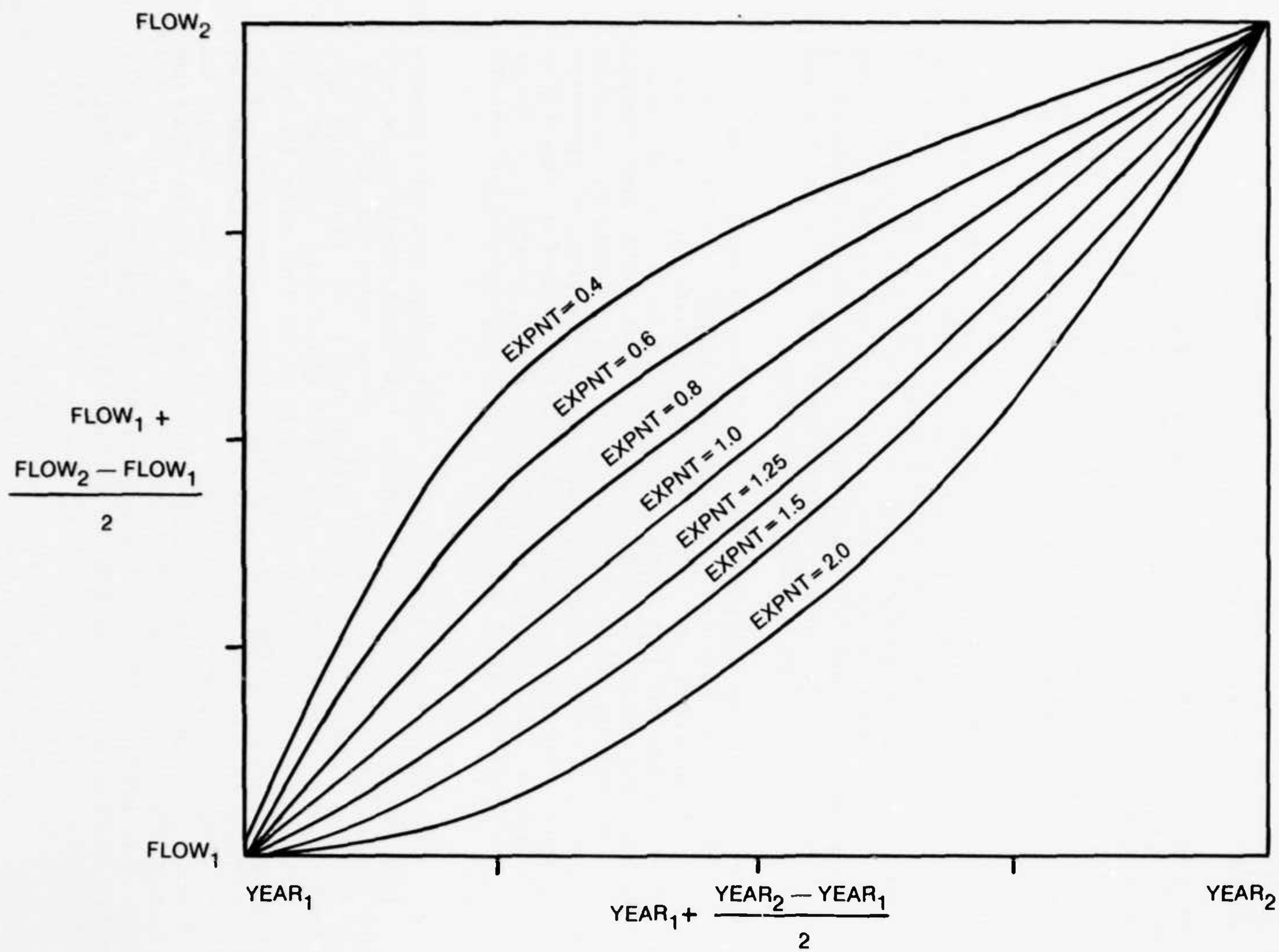

FIGURE 3-2 DETERMINATION OF UNRESTRICTED FLOW BETWEEN BASE (1) AND DESIGN (2) YEARS

3.5.(3) The user indicates the dimension (average daily flow, peak daily flow, or peak hourly flow) to be considered. If peak hourly flow is considered, the user can choose to implement an option that simulates a community reducing its peak hourly flow by regulating the time of day that lawn watering and/or municipal use can occur. When implemented, the user would input a percentage of the exterior residential and public use categories by which the peak hourly flow would be reduced as a result of regulating the time of their use. This percentage would then be removed from the peak hourly flow for those use categories before subsequent determinations. Thus, the peak hourly flow considering this reduction but before accounting for any other conservation measures will be equal to:

$$PHF = PHF_{(T)} - \frac{\%(ER)}{100} PHF_{(ER)} - \frac{\%(M)}{100} PHF_{(M)} \qquad \text{(Eq. 3-8)}$$

where

PHF = unrestricted peak hourly flow
%(j) = percent peak hourly flow reduction in use sector j
T = total use
ER = exterior residential use sector
M = municipal use sector

If the user desires to differentiate consumptive use from non-consumptive use, he may input the percent consumptive use before conservation for each of the six water use sectors for each dimension of concern. All conservation measures, except recycle/reuse, will act proportionally on consumptive and non-consumptive use within a water use sector. For reuse/recycle, all of the reduced volume of water will come from the non-consumptive category.

3.5.(4) The user selects which of the six water use sectors (interior residential, exterior residential, commercial, industrial, public, or unaccounted for) is to be evaluated or whether all sectors are to be evaluated.

3.5.(5) The user next selects the specific conservation measure to be evaluated.

3.5.(6) The year for which the conservation measure is to be initiated must be provided as input for any measure. If no information is provided, the first year will be assumed. For the conservation measures of public education and/or pipeline leak repair, it is also possible to consider discontinuing the measures after having them implemented for a period of time. This can be used to simulate the effect of not renewing the funding for a public education program, as a gradual loss of effectiveness after the discontinuance of this measure has been included in the methodology. This is accomplished by changing the annual ratio of change factor, AROC, (described in Section 3.2.6) after the year of discontinuing the measure. If this option is to be exercised for these measures, both the year of initiation and the year the program is ended must be designated. For pipeline leak repair, the percent of unaccounted-for water use will gradually increase from the level existing when the measure was discontinued to the original unrestricted unaccounted-for water use projections.

3.5.(7) Conservation measures for pipeline leak repair, rationing, and pricing policy require additional input to determine the appropriate RFACT. The RFACT for pipeline leak repair is applied only to the unaccounted-for water use category and is determined from the users description of how effective such a program is expected to be in reducing unaccounted-for water use and how long it will take to achieve these reductions. The user provides the percent unaccounted-for water expected to be achieved by the leak detection program and the year in which this goal will be met. For intermediate years between the enactment of the pipeline leak repair measure and the achievement of the percent unaccounted-for goal, an intermediate percent unaccounted-for will be determined by linear interpolation, and the RFACT required to achieve that will be calculated. For the year when the percent unaccounted-for goal is achieved, and all subsequent years for which the pipeline leak repair measure is in effect, the RFACT calculated will be that necessary to maintain the percent unaccounted-for goal.

For the rationing conservation measure, the actual reduction achieved is very dependent upon the goal that is to be accomplished by the measure. Because rationing is generally instituted as a last resort in emergency conditions, it is usually expected to accomplish an immediate and considerable reduction in water use. For goals between 25-50% reduction, the actual reduction achieved as reported in the literature has generally been close to the goal that was established. When utilizing the rationing conservation measure, the user will be required to input directly the reduction factor to be achieved by the rationing measure (a uniform goal for all water use categories except unaccounted-for water use, which is unaffected, may be provided or different goals may be indicated for different use sectors).

For the pricing policy measure, the fractional reduction of water use for the four use sectors subject to pricing (interior residential, exterior residential, commercial, and industrial) is found by the following expression:

$$RFACT_{(PP)} = 1.0 - [PRRATE] ** ELAST \quad \text{(Eq. 3-9)}$$

where:

$RFACT_{(PP)}$ = reduction for pricing policy for water use and dimension

PRRATE = price ratio of new to old prices faced by users in use sector and dimension

ELAST = price elasticity of demand for use sector and dimension

This expression has been used in "The Evaluation of Water Conservation for Municipal and Industrial Water Supply," Volume II prepared for the U.S. Army Corps of Engineers, Institute for Water Resources, February 1981. (Source number 171 in Bibliography, Part 7.0)

The user would then be required to input the average values of PRRATE faced by users in each use sector for the dimension under consideration as well as the estimated price elasticity. No default value is provided for elasticity, so the user is required to input a value if he chooses to use this option.

3.5.(8) At this stage, the fractional reduction factor, RFACT, for the conservation measure, dimension, and use sector being evaluated, will be retrieved, either from the matrix of RFACT included within the conservation effectiveness module or from one of the determinations described in (7) above.

3.5.(9) The conservation ordinances measure requires additional input by the user to determine its appropriate coverage factor. This measure reflects the gradual introduction of water saving fixtures into new construction as the result of promulgated ordinances. Thus, the coverage will gradually increase from an initial value of zero with the rate of increase in coverage depending upon the annual rate of new construction. Thus, the user must provide a rate of new construction for the residential, commercial, industrial, and public use sectors. The annual ratio of change in coverage factor AROC will then be determined as 1.0 plus the annual rate of new construction, and the coverage factor for the conservation ordinance for any year after initiation of the measure will be evaluated as:

$$COVER_{(CO)} = 1.0 - \frac{1.0}{(1.0 + CNSTRT) ** (KYEAR - 1.0)} \quad \text{(Eq. 3-10)}$$

where:

$COVER_{(CO)}$ = coverage of conservation ordinance measure
CNSTRT = fractional rate of new construction
KYEAR = year

3.5.(10) For all measures other than conservation ordinances, the initial coverage factor that will be applied will depend upon the level of emphasis that is to be provided for the conservation program instituted. Suggested initial coverage values for each measure are provided for three levels of conservation programs indicated as modest, moderate, or maximum. These values have been selected based upon knowledge of a number of conservation programs and a limited amount of data available in the literature. It is recognized, however, that a continuity of possible levels of emphasis exist, so the user is encouraged to input his own initial coverage value using the values provided for modest, moderate, and maximum conservation programs as a guide.

3.5.(11) At this stage, the annual rate of change of coverage factor, AROC, for the measure under consideration will be retrieved from the coverage matrix. If the user selected a modest, moderate, or maximum program in step (10), then the initial coverage value (COVERG) appropriate for that program, and the measure and water sector under evaluation will also be retrieved from the coverage matrix.

3.5.(12) The coverage factor for the time window being evaluated will then be determined. The coverage factor for any year after the initiation of a measure will be determined by equation 3-5 for all measures except conservation ordinances, which will be calculated by equation 3-10. The maximum value of a coverage value that will be used in the algorithm is 1.0.

3.5.(13) The effectiveness (EFF) of the measure for the water use sector, dimension, and time period being evaluated will be calculated by equation 3-1.

3.5.(14) If additional measures are to be considered within the same use sector, the user will input the next measure and return to step (5).

3.5.(15) When all measures within a use sector have been considered, appropriate interactions between measures will be determined from the interaction matrix.

3.5.(16) The overall effectiveness of all measures within the water use sector will be determined based upon the interactions obtained in (15). For two measures, 1 and 2, where $EFF_1 > EFF_2$, the overall effectiveness will be determined as by equation 3-4. For three measures, 1, 2, and 3, where $EFF_1 > EFF_2 > EFF_3$, the overall effectiveness will be determined as:

$$EFF_{123} = EFF_1 + ACT_{12} * EFF_2 + ACT_{13} * ACT_{23} * EFF_3 \qquad \text{(Eq. 3-11)}$$

Similar determinations are made for greater than three measures.

3.5.(17) If additional water use sectors are to be considered within the same dimension, the user will have to input the next use sector and return to step (4).

3.5.(18) When all water use sectors desired within a dimension have been considered, the total reduction obtained in all sectors will be summed to determine the reduction in the dimension.

3.5.(19) If additional dimensions are to be evaluated during the same time window, the user will input the next dimension and return to step (3).

3.5.(20) When all dimensions desired during a time window have been evaluated, the flow rates with conservation for each dimension will be calculated.

3.5.(21) If additional time windows are to be considered, the conservation effectiveness module will return to step (3).

3.5.(22) When all desired time windows have been evaluated, all data will be placed in the appropriate output device.

3.6 Conservation Measures

Low Flow Showerheads refer to showerheads designed to operate instead of a conventional showerhead and that will limit flowrates to 3 gpm* or less. The method utilized to reduce flow is not a consideration in this definition and this measure can be part of new construction or retrofitting. Reductions from low flow showerheads occur only in the interior residential and public water use categories.

Shower Flow Restrictors are devices which are inserted between the existing conventional showerhead and the showerhead arm. They are an addition to the shower apparatus and are generally only retrofitted to existing systems. Reductions from shower flow restrictors occur only in the interior residential and public water use categories.

Toilet Dams are devices inserted into toilet tanks in order to hold back a portion of the water normally used for flushing. Reductions from toilet dams are considered as occurring only in the interior residential water use and commercial categories. Although there would be some unknown reduction in industrial use sectors from the use of toilet dams (or any toilet-related device), it is believed that this would be a very small portion of that sectors' total use. It is certain that the emphasis of toilet-related conservation measures is directed almost exclusively towards residential, commercial, and public use.

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* A table of factors for converting U.S. customary units of measurement to metric (SI) is presented on page vi.

Displacement Devices are space-occupying objects such as bricks or plastic bottles which reduce the volume of water normally used for flushing by displacement rather than damming. Reductions from displacement devices occur only in the interior residential, commercial, and public water use categories.

Flush Mechanisms include the wide variety of devices which change the mechanical operation of the conventional toilet in some manner so as to reduce the volume of water used in flushing. These would not include dual flush devices or other mechanisms which require the user to change his habits but only those devices which would operate automatically. Reductions from flush mechanisms occur only in the interior residential, commercial, and public water use categories.

Shallow Trap Toilets are toilets specifically designed to function similarly to conventional toilets but which utilize 3.5 gallons or less of water per flush. They do not require any modifications of user habits or use a flushing mechanism other than water. Reductions from shallow trap toilets occur only in the interior residential, commercial, and public water use categories.

Pressure Toilets use compressed air to assist in the flushing action and generally restrict water use to less than 1 gallon per flush. They may or may not be designed to operate similarly to conventional toilets and may involve modification of user habits. Reductions from pressure toilets occur only in the interior residential, commercial, and public water use categories.

Dual Flush Toilets have been designed to deliver two different quantities of water for liquid waste flushing and for solid wate flushing. They can be designed to appear similar to conventional toilets but require user habit modifications for the flushing mechanism to be effective. Reductions from dual flush toilets occur only in the interior residential, commercial, and public water use categories.

Faucet Aerators are water-saving devices which reduce flow rates to less than 3 gpm that are designed to replace conventional aerators. They can be used in either new construction or retrofit situations. Reductions from faucet aerators occur only in the interior residential, commercial, and public water use categories.

Faucet Flow Restrictors are devices which are inserted into the faucet to restrict the flow of water. They are an addition to the faucet structure and are generally only retrofitted to existing systems. Reductions from faucet flow restrictors occur only in the interior residential, commercial, and public water use categories.

Pressure Reducing Valves are devices which are inserted into service pipes that can be adjusted to reduce water pressure below the pressure delivered by the water utility. They then result in reduced flow rates through water faucets and appurtenances. Reductions from pressure reducing valves occur in the interior residential, exterior residential, commercial, industrial, and public water use categories.

Service Line Flow Restrictors would include any restrictors inserted into water pipes or appurtenances other than those used in showers and faucets. Reductions from service line flow restrictors occur in the interior residential, commercial, industrial, and public water use sectors.

Toilet Leak Repair would include all concerted activities directed toward discovering and eliminating leakage in toilets. The most common techniques are the use of dye tablets or food coloring. The toilet leak repair conservation measure would consider reduction as the result of a management measure advertising, publicizing, or distributing the use of tablets, etc., and not the normal leak repair that could be expected without any action being taken by a management agency. Reductions from toilet leak repair occur only in the interior residential, commercial, and public use sectors.

Commercial/Industrial Reuse and Recycle refers to actions taken by industries and commercial establishments to recycle water or reuse water in their processes. Reductions from reuse and recycle measures occur in the commercial and industrial water use sectors.

Water Metering consists of the monitoring and charging for water based upon the volume used by the customer. The practice can only be considered a conservation measure when it is enacted for the first time in an area or is being extended to a new water use category that had not been previously metered. In this study, first time metering programs will be evaluated without considering the accompanying pricing policies. Pricing policies are evaluated separately for utilities which have been metered for some time. Reductions from water metering occur for those use sectors subject to metering and payment of fees as a result of metering. This would generally include interior residential, exterior residential, commercial, and industrial use sectors.

Pipeline Leak Repair considers the detection and elimination of leaks within water utility distribution and transmission lines. Reduction from pipeline leak repair occurs only in the unaccounted-for water use sector. The impact of discontinuing a pipeline leak repair program after its implementation for a period of time can be simulated by indicating both the year of implementation and the year of discontinuance.

Conservation Ordinances refer to the enactment of ordinances to bring about permanent changes in either new or existing structures through mandated use of devices. They are generally accomplished through modifications to plumbing and building codes that must be accomodated whenever new construction permits are requested. This measure differs from the rationing and restricted limited water use measures in that it does not include ordinances of a temporary nature in response to an emergency. Reductions from conservation ordinances occur in interior residential, commercial, industrial, and public use sectors.

Restricted/Limited Water Uses are enacted in response to a temporary water emergency and may come about through either water utility decrees, legislative action, or government pronouncement. In this study, only mandatory, and not voluntary, enactments are considered. Reductions from restricted water uses occur in exterior residential, commercial, industrial, and public water use categories.

Rationing refers to the specific temporary restriction of water use by consumers to a specific amount. It differs from restricted/limited water uses in that it restricts total use without any indication as to how the user is to accomplish the reduction. Rationing usually is accomplished by some enforcement action such as the levying of fines for noncompliance. Reductions from rationing apply to all water use sectors except for the unaccounted-for use sector.

Pricing Policy Revisions include the reductions obtained by any change in water price that results in water savings. This would include any change in price structure, as well as changes in rates. This measure applies only to previously metered communities. Reductions from pricing policy occur in the interior residential, exterior residential, commercial, and industrial water use sectors.

Public Education may consist of several methods to alert the public of the need or advantage to conserving water. It may include direct mail campaigns providing information or water saving kits mailed to customers. News media campaigns including the use of television, radio, or newspapers to convey educational messages on conservation are also included. Special events such as lectures to civic organizations or school assemblies would also be part of the public education program. It was originally intended that mail campaigns distributing water saving kits be kept as a separate measure; however, the available data did not indicate any difference in reductions between such programs and other public education programs not distributing kits. Reductions from public education occur in all water use sectors except the unaccounted-for water use sector. The impact of discontinuing a public education program after its implementation for a period of time can be simulated by indicating both the year of implementation and the year of discontinuance.

Two additional conservation measures, metering faucets and tax incentives, were originally included among the water conservation measures to be evaluated. However, a thorough literature survey and telephone contacts with conservation-oriented agencies did not determine any definitive reduction data for either of these measures. For this reason, they have not been included in the water conservation effectiveness module.

3.7 Reduction, Coverage, and Interaction Factor Matrices

This section presents the matrices for reduction, coverage, and interaction factors for use in estimating water conservation effectiveness. The reduction matrix includes two tables: Table 3-1 for the average daily flow dimension and Table 3-2 for the peak flow dimensions. These two tables list the reduction factor for each measure for each of the six water categories. The coverage matrix (Tables 3-3, 3-4, and 3-5) lists the annual ratio of change in coverage factor, as well as suggested initial coverage factors for modest, moderate, and maximum conservation programs, for each measure in all six water use sectors. The interaction matrix (Table 3-6) includes all interaction factors between conservation measures.

The coverage factors that are used for toilet measures in the commercial and public use categories are based upon a primarily office-oriented commercial and public water use base. If the user is considering an application where the commercial and/or public water use is basically oriented to nonhuman uses such as car washing, laundering, street cleaning, etc., he may want to reduce the coverage factors used for commercial and public use. An application totally oriented to nonhuman use would have coverage factors of zero so the user could choose appropriate intermediate values depending on the orientation of commercial and public use in his application.

TABLE 3-1

REDUCTION FACTORS FOR AVERAGE DAILY FLOW DIMENSION

CONSERVATION MEASURE	WATER USE SECTORS IR	ER	COM	IND	PUB	UF
1 Low Flow Showerheads	.139	--	--	--	.139	--
2 Shower Flow Restrictors	.112	--	--	--	.115	--
3 Toilet Dams	.102	--	.102	--	.102	--
4 Displacement Devices	.129	--	.129	--	.129	--
5 Flush Mechanisms	.142	--	.142	--	.142	--
6 Shallow-Trap Toilets	.124	--	.124	--	.124	--
7 Pressure Toilets	.336	--	.336	--	.336	--
8 Dual-Flush Toilets	.190	--	.190	--	.190	--
9 Faucet Aerators	.014	--	.014	--	.014	--
10 Faucet Flow Restrictors	.014	--	.014	--	.014	--
11 Pressure Reducing Valves	.138	.138	.138	.138	.138	--
12 Service Line Restrictors	.008		.008	.008	.008	--
13 Toilet Leak Repair	.140	--	.140	--	.140	--
14 Recycle/Reuse	--	--	.444	.444	--	--
15 Metering	.180	.477	.373	.373	--	--
16 Pipeline Leak Repair*	--	--	--	--	--	--
17 Conservation Ordinances	.136	--	.136	.136	.136	--
18 Restricted Water Uses	--	.221	.221	.221	.221	--
19 Rationing**	--	--	--	--	--	--
20 Pricing Policy	-----$[1-(P_2/P_1)^e]$---					
21 Public Education	.089	.089	.089	.089	.089	--

* User inputs percent unaccounted for goal to be achieved and year to be accomplished.

** User inputs reduction factor directly.

TABLE 3-2

REDUCTION FACTORS FOR PEAK FLOW DIMENSIONS

CONSERVATION MEASURE	WATER USE SECTORS					
	IR	ER	COM	IND	PUB	UF
1 Low Flow Showerheads	.139	--	--	--	.139	--
2 Shower Flow Restrictors	.112	--	--	--	.112	--
3 Toilet Dams	.102	--	.102	--	.102	--
4 Displacement Devices	.129	--	.129	--	.129	--
5 Flush Mechanisms	.142	--	.142	--	.142	--
6 Shallow-Trap Toilets	.124	--	.124	--	.124	--
7 Pressure Toilets	.336	--	.336	--	.336	--
8 Dual-Flush Toilets	.190	--	.190	--	.190	--
9 Faucet Aerators	.014	--	.014	--	.014	--
10 Faucet Flow Restrictors	.014	--	.014	--	.014	--
11 Pressure Reducing Valves	.138	.138	.138	.138	.138	--
12 Service Line Restrictors	.008		.008	.008	.008	--
13 Toilet Leak Repair	.140	--	.140	--	.140	--
14 Recycle/Reuse	--	--	.444	.444	--	--
15 Metering	.306	.358	.373	.373	--	--
16 Pipeline Leak Repair*	--	--	--	--	--	--
17 Conservation Ordinances	.136	--	.136	.136	.136	--
18 Restricted Water Uses	--	.309	.309	.309	.309	--
19 Rationing**	--	--	--	--	--	--
20 Pricing Policy	------ $[1 - (P_2/P_1)^e]$ --					
21 Public Education	.089	.089	.089	.089	.089	--

* User inputs percent unaccounted for goal and year to be achieved.

** User inputs reduction factor directly.

TABLE 3-3

ANNUAL RATIO OF CHANGE IN COVERAGE FACTORS (AROC) AND INITIAL COVERAGE FOR INTERIOR AND EXTERIOR RESIDENTIAL USE SECTORS

CONSERVATION MEASURE	AROC	COVERG, INTERIOR RESIDENTIAL			COVERG, EXTERIOR RESIDENTIAL		
		MODEST	MODERATE	MAXIMUM	MODEST	MODERATE	MAXIMUM
1 Low Flow Showerheads	1.0	0.20	0.40	0.70	—	—	—
2 Shower Flow Restrictors	0.9	0.25	0.40	0.95	—	—	—
3 Toilet Dams	0.9	0.25	0.50	0.90	—	—	—
4 Displacement Devices	0.9	0.25	0.50	0.90	—	—	—
5 Flush Mechanisms	0.9	0.10	0.25	0.50	—	—	—
6 Shallow-Trap Toilets	1.0	0.02	0.05	0.10	—	—	—
7 Pressure Toilets	1.0	0.01	0.02	0.05	—	—	—
8 Dual Flush Toilets	0.9	0.02	0.05	0.10	—	—	—
9 Faucet Aerators	0.9	0.25	0.50	0.90	—	—	—
10 Faucet Flow Restrictors	0.9	0.25	0.50	0.90	—	—	—
11 Pressure Reducing Valves	1.0	0.10	0.25	0.50	.10	.25	.50
12 Service Line Restrictors	1.0	0.20	0.45	0.70	—	—	—
13 Toilet Leak Repair	0.9	0.02	0.05	0.10	—	—	—
14 Recycle/Reuse	1.0	—	—	—	—	—	—
15 Metering	0.95	1.0	1.0	1.0	1.0	1.0	1.0
16 Pipeline Leak Repair	1.0	—	—	—	—	—	—
17 Conservation Ordinances	*	0.0	0.0	0.0	—	—	—
18 Restricted Water Uses	1.0	—	—	—	0.50	0.75	1.0
19 Rationing	1.0	1.0	1.0	1.0	1.0	1.0	1.0
20 Pricing Policy	1.0	1.0	1.0	1.0	1.0	1.0	1.0
21 Public Education**	1.1/0.8	0.50	0.75	0.90	0.25	0.50	0.90

* 1.0 Plus the annual rate of new construction.
** First value is before discontinuance of measure, second value is after discontinuance of measure.

TABLE 3-4

INITIAL COVERAGE FOR COMMERCIAL AND INDUSTRIAL USE SECTORS

CONSERVATION MEASURE	COVERG, COMMERCIAL			COVERG, INDUSTRIAL		
	MODEST	MODERATE	MAXIMUM	MODEST	MODERATE	MAXIMUM
1 Low Flow Showerheads	—	—	—	—	—	—
2 Shower Flow Restrictors	—	—	—	—	—	—
3 Toilet Dams	0.25	0.50	0.90	—	—	—
4 Displacement Devices	0.25	0.50	0.90	—	—	—
5 Flush Mechanisms	0.10	0.25	0.50	—	—	—
6 Shallow-Trap Toilets	0.02	0.05	0.10	—	—	—
7 Pressure Toilets	0.01	0.02	0.05	—	—	—
8 Dual Flush Toilets	0.02	0.05	0.10	—	—	—
9 Faucet Aerators	0.25	0.50	0.90	—	—	—
10 Faucet Flow Restrictors	0.25	0.50	0.90	—	—	—
11 Pressure Reducing Valves	0.10	0.25	0.50	0.10	0.25	0.50
12 Service Line Restrictors	0.20	0.45	0.70	0.20	0.45	0.70
13 Toilet Leak Repair	0.02	0.05	0.10	—	—	—
14 Recycle/Reuse	0.10	0.33	0.60	0.10	0.33	0.60
15 Metering	1.0	1.0	1.0	0.0	1.0	1.0
16 Pipeline Leak Repair	—	—	—	—	—	—
17 Conservation Ordinances	0.0	0.0	0.0	0.0	0.0	0.0
18 Restricted Water Uses	0.5	0.75	1.0	0.50	0.75	1.0
19 Rationing	1.0	1.0	1.0	1.0	1.0	1.0
20 Pricing Policy	1.0	1.0	1.0	1.0	1.0	1.0
21 Public Education	0.25	0.50	0.75	0.25	0.50	0.75

TABLE 3-5

INITIAL COVERAGE FOR PUBLIC AND UNACCOUNTED-FOR USE SECTORS

CONSERVATION MEASURE	COVERG, PUBLIC			COVERG, UNACCOUNTED-FOR		
	MODEST	MODERATE	MAXIMUM	MODEST	MODERATE	MAXIMUM
1 Low Flow Showerheads	0.10	0.20	0.33	—	—	—
2 Shower Flow Restrictors	0.10	0.20	0.33	—	—	—
3 Toilet Dams	0.25	0.50	0.90	—	—	—
4 Displacement Devices	0.25	0.50	0.90	—	—	—
5 Flush Mechanisms	0.10	0.25	0.50	—	—	—
6 Shallow-Trap Toilets	0.02	0.05	0.10	—	—	—
7 Pressure Toilets	0.01	0.02	0.05	—	—	—
8 Dual Flush Toilets	0.02	0.05	0.10	—	—	—
9 Faucet Aerators	0.25	0.50	0.90	—	—	—
10 Faucet Flow Restrictors	0.25	0.50	0.90	—	—	—
11 Pressure Reducing Valves	0.25	0.50	0.75	—	—	—
12 Service Line Restrictors	0.20	0.45	0.70	—	—	—
13 Toilet Leak Repair	0.02	0.05	0.10	—	—	—
14 Recycle/Reuse	—	—	—	—	—	—
15 Metering	—	—	—	—	—	—
16 Pipeline Leak Repair	—	—	—	0.33	0.75	1.0
17 Conservation Ordinances	0.0	0.0	0.0	—	—	—
18 Restricted Water Uses	1.0	1.0	1.0	—	—	—
19 Rationing	1.0	1.0	1.0	—	—	—
20 Pricing Policy	—	—	—	—	—	—
21 Public Education	0.50	0.75	1.0	—	—	—

TABLE 3-6

INTERACTION FACTORS MATRIX

(Added to Conservation Measure)

	INTERACTION FOR CONSERVATION MEASURES		2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1	Low Flow Showerheads	—	0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	.789
2	Shower Flow Restrictors	1.0	—	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	.789
3	Toilet Dams	1.0	1.0	—	0	0	0	0	0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	.789
4	Displacement Devices	1.0	1.0	0	—	0	0	0	0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	.789
5	Flush Mechanisms	1.0	1.0	0	0	—	0	0	0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	.789
6	Shallow Trap Toilets	1.0	1.0	0	0	0	—	0	0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0	1.0	1.0	1.0	1.0
7	Pressure Toilets	1.0	1.0	0	0	0	0	—	0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0	1.0	1.0	1.0	1.0
8	Dual Flush Toilets	1.0	1.0	0	0	0	0	0	—	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0	1.0	1.0	1.0	1.0
9	Faucet Aerators	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	—	0	1.0	1.0	1.0	1.0	1.0	1.0	0	1.0	1.0	1.0	.789
10	Faucet Flow Restrictors	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0	—	1.0	0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	.789
11	Pressure Reducing Valves	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	—	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.	1.0	1.0
12	Service Line Restrictors	0	0	1.0	1.0	1.0	1.0	1.0	1.0	0	0	1.0	—	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	.789
13	Toilet Leak Repair	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	—	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
14	Recycle/Reuse	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	—	1.0	1.0	1.0	1.0	1.0	1.0	1.0
15	Metering	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	—	1.0	1.0	1.0	0	1.0	1.0
16	Pipeline Leak Repair	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	—	1.0	1.0	1.0	1.0	1.0
17	Conservation Ordinances	0	1.0	1.0	1.0	1.0	0	0	0	0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	—	1.0	1.0	1.0	1.0
18	Restricted Uses	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	—	.55	1.0	.934
19	Rationing	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	.47	—	1.0	.580
20	Pricing Policy	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0	1.0	1.0	1.0	1.0	—	1.0
21	Public Education	.917	.917	.917	.917	.917	1.0	1.0	1.0	.917	.917	1.0	.917	1.0	1.0	1.0	1.0	1.0	.952	.180	1.0	—

4.0 DOCUMENTATION

4.1 Introduction

This section is supplemental to the presentation of reduction (RFACT), coverage (COVER), and interaction (ACT) factors in Part 3.0. The details of the determination of RFACT, COVER, and ACT factors are documented in Parts 4.2 through 4.7. Part 4.2 describes the ranking system used to weight the various reduction values; Part 4.3 gives the basis by which all reported reduction values were equated to a common basis; Part 4.4 is the actual description and tabulation of reduction values, sources of information, and their ranks; Part 4.5 documents coverage factors; the basis for interaction factors is presented in Part 4.6; and determination of the reduction factors for peak dimensions is documented in Part 4.7.

4.2 Priority System for Ranking Data Sources

In order to help evaluate and determine the emphasis to be given to the different sources of information, a priority ranking system was established. This priority system establishes various weights depending upon the type of study that provided the conservation reduction information (actual implementation vs. laboratory, etc.), the comparison method used to determine reductions (with/without vs. before/after), how specific the values are, how recent the values are, the size of the tested population, and an evaluation of the accuracy of the data. The priority rank has been used to indicate the most preferred data sources when more than one information source is available. The details of this ranking system evaluation method are presented in Table 4-1.

The system was developed for this study such that greater emphasis and detail would be placed on the more important rank components such as the nature of the reduction value, comparison method, study type, and accuracy of data. Less critical to the value of the final rank are population and time of study which both have a more generalized range of ranking weights. As a general rule, a data source with a rank of 4.0 or greater is considered to be a reliable source.

4.3 Common Basis for Reduction Factors

The major effort required in developing the reduction factors is equating the reductions reported by information

TABLE 4-1

PRIORITY SYSTEM FOR RANKING DATA SOURCES

DATA SOURCE RANK = (RV) (P) (T) (CM) (ST) (A)

RV = Nature of Specified Reduction Values
= 1.5 when numerical values are available for specific conservation measures
= 1.25 when numerical values are available for combinations of conservation measures
= 1.0 when subjective indications are available for conservation measures
= 0.5 when measures are only described and no indication is given of reduction

P = Approximate Population Considered in Study
= 1.2 for population greater than 10,000
= 1.1 for population between 1,000-10,000
= 1.0 when unknown, not appropriate, or less than 1,000

T = Time of Conduct or Completion of Study
= 1.25 for post-1977
= 1.125 for 1973-1977
= 1.0 for 1972 and prior

CM = Comparison Methods used to Determine Impact of Conservation Methods
= 1.5 for with/without comparison
= 1.4 for before/after comparison
= 1.2 for unknown technique, subjective comparison
= 1.0 for no comparison

ST = Study Type
= 1.5 for actual implementation
= 1.4 for laboratory testing
= 1.2 for theoretical determination
= 1.0 for subjective determination or discussion

A = Accuracy of Data
= 2.0 when data source is extremely precise and accurate
= 1.5 for good data source
= 1.25 for adequate data source
= 1.0 for unknown data source
= 0.5 for questionable data source

sources to a common basis. That basis is, by definition, the reduction achieved within an individual water use category. Data were found to be reported in three ways. First, data were reported as a percent reduction for the specific volume of water impacted by a conservation measure. For example, a low flow showerhead reduced the shower use by 40 percent. Secondly, data could be reported as a percent reduction of a total water use category, such as a low flow showerhead reducing interior residential demand by 12 percent. And third, data could indicate a specific volume reduced in a period of time. For example, a low flow showerhead reduced the volume of water used by a household by 20 gallons per day.

All data provided by the data sources were converted to a single basis for reduction determinations. When specific water use information was not provided in a study, the water use disaggregation scheme shown in Tables 4-2 and 4-3 (which were determined from 37 separate surveys or reports) were used. For example, if a 50% reduction in shower flow was reported in a certain data source, the appropriate RFACT would be equal to 0.50 times 0.30 (30 percent of interior residential water use which is attributable to bathing) or 0.15. Reductions reported as a percent of a total use category are already in the desired form. The third example case is exemplified by a situation where a savings of 5 gal/capita/day (gpcd) is reported. For this case, the reduction factor for the interior residential water use category would be 5 gpcd divided by 60 gpcd or 0.083. This methodology is inherent where appropriate in the documentation of reduction factors provided in Part 4.4.

4.4 Reduction Factors

This section presents water use reduction values and final rank-weighted reduction factors for each of the 21 water conservation measures considered in this study. The values refer to reductions in average daily demand. The peak day and peak hour water use dimensions are discussed in Part 4.7. The source numbers identified are identical to the Bibliography, Part 7.

4.4.1 Low-Flow Showerhead

Several sources of data were available for developing the reduction factor for this conservation measure. As shown in Table 4-4, reduction values range from 0.08 to 0.26, except

TABLE 4-2

URBAN WATER DEMANDS AS A PERCENTAGE OF AVERAGE DAILY USE

Reference Number and Source	CATEGORY OF USE					
	Res.	Com.	Indus.	Public	Unacc. for	Total Flow gpcd
96 McPherson (1976)	33	12	33	7	15	
28 California Dept. of Water Resources (1976)	68	10	18	(-----4------)		
63 Haney & Hamann (1964)	43	19	25	(----13------)		
177 U.S. Public Health Service (1967)	41	18	24	(----17------)		
88 Linaweaver, Geyer, & Wolff (1966)	50					160
47 Fair, Geyer, & Okun (1968)	33	(---43----)		7	17	150
14 Bostian: EPA (1974)	46	17	25	12	--	
71 Hirshleifer, DeHaven, Milliman (1960)	45	18	32	5	--	
111 Murray & Reeves, USGS (1972)	38	(---32----)		(----30------)		166
123 Omaha District (1976) (1968)	46	18	23	(----13------)		157
51 Frey, Gamble, and Sauerlender: NE US (1975)	49	12	21	(----18------)		166
1 American Water Works Association (1970)	42	18	22	(----18------)		179
187 Weston National Water Utility Survey (1977)	52	17	15	7	9	153
127 Pennsylvania Water Utility Survey (1975)	39	12	31	5	13	162
171 Atlanta	45	26	6	4	18	
171 Tuscon	67	19	4	--	9	
181 Warren	58	11	11	9	11	
AVERAGE	43	16	22	5	15	160

TABLE 4-3

INTERIOR RESIDENTIAL WATER USAGE COMPARISON AS A PERCENTAGE OF AVERAGE DAILY USE

Reference Number and Source	CATEGORY OF USE						
	Toilet Flush	Bath	Laund	Dish wash	Drink & Cook	Misc	Total Flow gpcd
96 McPherson (1976)	42	27	(----17---)		8	6	
28 California Dept. of Water Resources (1976)	42	32	14	(---12-----)			
45 Energy Resources Company (1975)	39	34	14	6	5	2	64
79 Laak (1975)	47*	21*	18*	(----9*---)			41*
110 Murawczyk & Ihrig (1973)							62
86 Ligman (1972)	41*	26*	19*	(---10*---)			45*
179 Wallman (1972)	27-45*	18-36*	18*	(---13*---)			30-50*
72 Howe, et al (1971)	45	30	(----20---)		5		
5 Baily & Wallman (1971)	39	34	14	(---11----)		2	64
43 U.S. Geological Survey (1964)	41	37	4	(---11----)		7	
63 Haney & Hamann (1965)	39	32	14	(---11----)		4	61.5
7 Bennett (1975)	33*	24*	27*	(---16----)			44.5*
158 Siegrist, Witt & Boyle (1976)	22*	23*	25*	(---11*---)		19*	
184 Water Encyclopedia (1970)	42	38	7	(---11----)		2	
14 Bostian: EPA (1973)	27-45	22-36	18	(---13----)			
177 U.S. Public Health Service (1967)	30	35	20	(---15----)			
35 Chanlett (1973)	43	38	7	(---11----)			
190 Univ. of Wis. (1973)	40	30	15	(---10----)		5	50
3 Bailey, et al (1969)	49*	32*	4*	(---12*---)		3*	
113 Nelson (1977)	44	30	14	6	6		
6 Baker, et al (1975)	39	31	14	6	5	5	
72 Howe, et al (1971)	45	30	14	6	5		
125 Palmini & Shelton (1982)	39	31	16	4	3	7	
154 Sharpe & Tsong	39	31	15	6	5	5	
AVERAGE	40	30	15	6	5	4	60

* Rural Figures

for one value of 0.01. The reduction of 0.01 was observed in a demonstration study by Cohen and Wallman (37) which included installation of either a 3.5 gpm or 2.5 gpm showerhead in eight single-family homes. This single low reduction value may be attributed to the fact that the participants of the study showed below average frequency of bathing as well as a preference for tub baths over showers. The authors reported that only 11.6% of home water use was for bathing, which is much lower than the generally accepted average value of 30%. The ranks used in weighting the reduction values ranged from 2.5 to 8.1 with an average value of 4.5. The final rank-weighted average reduction in interior residential water use due to low-flow showerheads is 0.139. A sample calculation of the rank-weighted average reduction follows:

$$\text{RFACT} = \frac{\begin{array}{l}0.081(4.2)+0.12(4.3)+0.12(5.3)+0.01(1.8)+\\ 0.143(2.5)+0.26(3.5)+0.135(2.5)+0.228(3.9)+\\ 0.15(5.7)+0.15(4.9)+0.183(4.9)+0.094(7.9)+\\ 0.112(3.5)+0.18(1.4)+0.12(3.5)\end{array}}{59.8}$$

$$= 0.139 \qquad \text{(Eq. 4-1)}$$

4.4.2 Shower Flow Restrictors

As for showerheads, the data available for determining the reduction due to shower flow restrictors were plentiful. Fourteen sources, shown in Table 4-5, provided values ranging from .08 to 0.20 with ranks varying between 2.8 and 5.7. In addition, two very low reduction values were reported. First, an actual increase of 4.5% in water use was reported in a Gaithersburg, Maryland (10), demonstration study. This result is viewed with some skepticism, however, since it reflects the study findings after only three months and occurred during the 1974 summer season when the highest consumption records in that area were set (as of the time of the writing, 1975). The second low value was predicted as part of the overall water conservation program in the Washington Suburban Sanitary Commission (44). The method used to arrive at the estimated 1.2-2.0% reduction in interior residential use was not available from the source. The value is somewhat questionable since the WSSC program involves several interacting conservation measures and separating out the effectiveness of one measure is quite judgmental in light of such interactions as well as variables such as time and climate. The final, rank-weighted average reduction factor for the average daily consumption dimension of interior residential water use is 0.112.

TABLE 4-4

REDUCTION VALUES FOR LOW-FLOW SHOWERHEADS

SOURCE NUMBER	TYPE OF STUDY	REDUCTION REPORTED	REDUCTION FACTOR, R_{IR}*	RANK WEIGHTING FACTORS** RV	P	T	CM	ST	A	RANK
125	Demo-E.Brunswick, NJ	19.5 gal/family	0.081	1.5	1.0	1.25	1.5	1.2	1.25	4.2
113	Estimate (Nelson '77)	12% of IR	0.12	1.5	1.0	1.125	1.4	1.2	1.4	4.3
37	Homes (Cohen & Wallman '74)	1% of IR	0.01	1.5	1.0	1.125	1.4	1.5	0.5	1.8
10	Demo - Cabin John	12% of IR	0.12	1.5	1.0	1.125	1.4	1.5	1.5	5.3
186	Estimate	47.5% of flow	0.143	1.5	1.0	1.125	1.0	1.2	1.25	2.5
6	Estimate	87.5% of flow	0.26	1.5	1.0	1.125	1.4	1.2	1.25	3.5
154	Estimate	30-60% of flow	0.135	1.5	1.0	1.125	1.5	1.0	1.0	2.5
148	Estimates	76% of flow	0.228	1.5	1.0	1.25	1.4	1.2	1.25	3.9
145	One demo - Dormitory	40-60% of flow	0.15	1.5	1.0	1.125	1.5	1.5	1.5	5.7
143	Demo- Apartment building	15% of IR	0.15	1.5	1.0	1.25	1.4	1.5	1.25	4.9
85	Demo - Apartment complex	18.3% of IR	0.183	1.5	1.1	1.125	1.4	1.5	1.25	4.9
20	Fixture Use Survey-So CA	5.0 - 6.3 gcd	0.094	1.5	1.0	1.25	1.4	1.5	2.0	7.9
20	Previous Literature (p.2-2)	6.7 gcd	0.112	1.5	1.0	1.125	1.4	1.2	1.25	3.5
146	General Statement	50-70% of flow	0.18	1.0	1.0	1.125	1.2	1.0	1.0	1.4
97	Estimate Santa Clara Co.	7.5 gcd (12%)	0.12	1.5	1.0	1.125	1.2	1.5	1.25	3.5

RANK-WEIGHTED AVERAGE REDUCTION FACTOR = 0.139

* Reduction in interior residential water use.
** See Part 4.2 for definition of terms.

TABLE 4-5

REDUCTION VALUES FOR SHOWER FLOW RESTRICTORS

SOURCE NUMBER	TYPE OF STUDY	REDUCTION REPORTED	REDUCTION FACTOR, R_{IR}*	RANK WEIGHTING FACTORS** RV	P	T	CM	ST	A	RANK
4	Estimate	6 gcd	0.10	1.5	1.0	1.125	1.4	1.2	1.5	4.3
125	Demo - E. Brunswick, NJ	19.5 gal/family	0.081	1.5	1.0	1.25	1.5	1.2	1.25	4.2
10	Demo - Gaithersburg, MD	4.5% incr. in total use	0.00	1.5	1.0	1.125	1.4	1.5	0.5	1.8
113	Estimate (p.32,197,204,213)	7.5 gcd	0.125	1.5	1.0	1.125	1.4	1.2	1.5	4.3
113	Manufacturers' Est. (p.105)	67.8 % of shower	0.203	1.5	1.0	1.125	1.4	1.2	1.25	3.5
97	Estimate Santa Clara County	6 gcd - 9%; 12% of IR	0.105	1.5	1.0	1.125	1.4	1.2	1.25	3.5
54	Estimate	6.8 gcd	0.11	1.5	1.0	1.125	1.4	1.2	1.0	2.8
48	Estimate	18-20% of IR	0.19	1.5	1.0	1.125	1.4	1.2	1.25	3.5
161	Estimate	0-12% of IR	0.06	1.5	1.0	1.250	1.4	1.2	1.25	3.9
44	WSSC	1.2-2.0% of IR	0.018	1.5	1.0	1.125	1.4	1.5	1.00	3.5
27	Estimate	9-12% of IR	0.105	1.5	1.0	1.125	1.4	1.2	1.25	3.5
75	Estimate	12% of IR	0.12	1.5	1.0	1.125	1.4	1.2	1.00	2.8
148	Estimate	1.5-3.0 gpm flow	0.203	1.5	1.0	1.250	1.4	1.2	1.25	3.9
114	Estimate	6.8 gcd; 69.3 gcd IR	0.098	1.5	1.0	1.250	1.4	1.2	1.50	4.7

RANK-WEIGHTED AVERAGE REDUCTION FACTOR = 0.112

* Reduction in interior residential water use.
** See Part 4.2 for definition of terms.

4.4.3 Toilet Dams

Eleven sources of information, mostly theoretical estimates, were available for determining the water use reduction due to toilet dam inserts. Such estimates are common for volume devices where simple mathematical calculations can provide the maximum possible savings, barring installation and/or maintenance problems. The reduction values for this measure vary by more than one order of magnitude, as seen in Table 4-6. They range from 0.018 to 0.20 plus two actual increases (reduction = 0) reported during the conduct of a demonstration study in the WSSC area (10). These increases are attributed to malfunctioning or actual removal of the devices which when properly maintained were shown to be effective. The value of 0.018 (125) is also uncommonly low with 0.083 being the next highest value. Some error could be incorporated into this value in the translation from the reported 4.3 gal savings to the derived factor. In the absence of actual data, the factor of 0.018 was determined as 4.3 gal/4 people per dwelling unit/60 gpcd. Should the actual figures be different, there would be only a slight modification of the ultimate reduction factor. The overall rank-weighted reduction due to toilet dams was found to be 0.120 of interior residential water use.

4.4.4 Displacement Devices

This water-saving device category includes plastic bottles, plastic bags, or any object which will displace its own volume of water. The eleven sources of available information provided reduction values ranging from 0.039 to 0.19 with ranks of 2.4 to 5.7, as shown in Table 4-7. Most of the values are theoretical estimates based on maximum possible volume reduction. Exceptions are the Cabin John Study (182), and the estimate from source #28 which was based on field tests. The overall rank-weighted average reduction due to displacement devices is 0.129, slightly higher than the factor determined for toilet dams.

4.4.5 Flush Mechanisms

Documentation of the effectiveness of flush mechanisms such as toilet-tank balls and valves was not as abundant as for dams and displacement devices. Only seven separate sources of data were available. The reduction values ranged from 0.125 to 0.156, indicating consistency in the various estimates. This is not suprising since all sources reported es-

TABLE 4-6

REDUCTION VALUES FOR TOILET DAMS

SOURCE NUMBER	TYPE OF STUDY	REDUCTION		RANK WEIGHTING FACTORS**						RANK
		REPORTED	FACTOR, R_{IR}*	RV	P	T	CM	ST	A	
28	Estimate (p. 1)	18% of IR	0.18	1.5	1.0	1.125	1.4	1.2	1.25	3.5
125	Demo - E. Brunswick, NJ	4.3 gal	0.018	1.5	1.0	1.25	1.5	1.2	1.25	4.2
113	Estimate (p. 39, 213)	1 gal/flush= 5 gcd	0.083	1.5	1.0	1.125	1.4	1.2	1.5	4.3
113	Manufacturer's Est. (p.131)	36% of flush	0.144	1.5	1.0	1.125	1.4	1.2	1.25	3.5
52	Estimate-Elmhurst, Ill.	30-40% of flush	0.14	1.5	1.0	1.25	1.4	1.2	1.0	3.9
95	Estimate	40% of flushing	0.16	1.5	1.0	1.125	1.4	1.2	1.0	2.8
129	Estimate	50% of flushing	0.20	1.5	1.0	1.125	1.2	1.4	1.00	2.8
85	Estimate - Hamilton, NJ	1.2 of 7.8 mgd capacity	0.154	1.5	1.2	1.125	1.4	1.2	1.25	3.8
147	Lab Testing	29.8% of flushing	0.12	1.5	1.0	1.25	1.4	1.4	1.5	5.5
13	Estimate - Elmhurst, IL	1-2 gal/flush;9%	0.09	1.5	1.2	1.125	1.4	1.2	1.25	4.3
10	Demo-Columbia/White Oak,CA	3% incr. in 3 months	0.00	1.5	1.0	1.125	1.4	1.5	0.5	1.8
10	Demo-Columbia/White Oak,CA	10% in 5 months	0.10	1.5	1.0	1.125	1.4	1.5	1.25	4.4
10	Demo-Columbia/White Oak,CA	2.3% over year	0.023	1.5	1.0	1.125	1.4	1.5	1.5	5.3
10	Demo-Columbia/White Oak,CA	8% increase in 2 months	0.00	1.5	1.0	1.125	1.4	1.5	0.5	1.8

<u>RANK-WEIGHTED AVERAGE REDUCTION FACTOR</u> = 0.120

* Reduction in interior residential water use.
** See Part 4.2 for definition of terms.

TABLE 4-7

REDUCTION VALUES FOR DISPLACEMENT DEVICES

SOURCE NUMBER	TYPE OF STUDY	REDUCTION		RANK WEIGHTING FACTORS**						RANK
		REPORTED	FACTOR, R_{IR}*	RV	P	T	CM	ST	A	
182	Demo - Cabin John	12% of IR (apts.)	0.12	1.5	1.0	1.125	1.4	1.5	1.25	4.5
182	Demo - Cabin John	18-20% (homes)	0.19	1.5	1.0	1.125	1.4	1.5	1.25	4.5
97	Estimate - Santa Clara Co.	12-20% of IR	0.16	1.5	1.0	1.125	1.4	1.2	1.25	3.5
27m	Estimate	10-18% of IR	0.14	1.5	1.2	1.125	1.4	1.2	1.0	3.4
24	Estimate	5-30% of IR	0.175	1.5	1.0	1.125	1.2	1.2	1.0	2.4
75	Estimate	18% of IR	0.18	1.5	1.2	1.125	1.4	1.2	1.25	4.3
28	Estimate - Field Tests	10-18% of IR	0.14	1.5	1.2	1.125	1.4	1.4	1.25	4.9
113	Estimate - (Nelson '77)	2.5 gcd; 64 gcd IR	0.039	1.5	1.0	1.125	1.4	1.2	1.25	3.5
147	Lab Testing	12% of flush	0.048	1.5	1.0	1.25	1.4	1.4	1.5	5.5
147	Lab Testing	27.8% of flush	0.11	1.5	1.0	1.25	1.4	1.4	1.5	5.5
140	Estimate	1 qt., 4 flushes/day	0.167	1.5	1.0	1.125	1.4	1.2	1.0	3.2

RANK-WEIGHTED AVERAGE REDUCTION FACTOR = 0.129

* Reduction in interior residential water use.
** See Part 4.2 for definition of terms.

timates based on ideal conditions with no data from actual implementation studies available. Table 4-8 lists the data sources for this measure with their ranks, ranging from 2.8 to 5.5. The rank-weighted average reduction due to toilet flush mechanisms was calculated as 0.142 of interior residential demand.

4.4.6 Shallow Trap Toilets

Nine separate information sources were available for this measure, also called low-flush toilets. The reduction values ranged from 0.069 to 0.167 with ranks of 2.4 to 7.9, as shown in Table 4-9. No specific explanation was available for the low value of 0.069 reported for the actual demonstration study by Cohen and Wallman (37), but the next lowest value, 0.112, is more than 1.5 times larger. The only other nontheoretical data (reported in source 20 for a fixture use survey) was 0.122, nearly double the lowest value. The overall rank-weighted average reduction for shallow trap toilets is 0.124 of residential interior water use.

4.4.7 Pressure Toilets

Ten estimates of water use reductions due to pressure toilets were available. They ranged from 0.22 to 0.417 with ranks of 2.8 to 4.3 as shown in Table 4-10. The narrow range and low ranks can be expected since all the values are theoretical estimates. Installation of pressure toilets as a method of reducing flush volumes is not as common as insert devices or low-flush toilets and, thus, reduction estimates based on actual data are scarce. The calculated rank-weighted reduction value for pressure toilets was 0.336.

4.4.8 Dual Flush Toilets

As for pressure toilets, the estimate of reduction due to dual flush toilets is based largely on theoretical estimates. The seven estimates available for determining the reduction factor for this measure ranged from 0.033 to 0.36 as shown in Table 4-11. The low end of this range reflects an actual demonstration study by Cohen and Wallman (37) where the reported reductions are notably less than those that are theoretical values. The importance of the rank is well exemplified: the demonstration study values are ranked at 5.3 while the theoretical estimates range from 2.4 to a maximum of only 4.3. The final rank-weighted average reduction due to dual flush toilets was calculated to be 0.190 of interior residential water use.

TABLE 4-8

REDUCTION VALUES FOR FLUSH MECHANISMS

SOURCE NUMBER	TYPE OF STUDY	REDUCTION REPORTED	REDUCTION FACTOR, R_{IR}*	RANK WEIGHTING FACTORS** RV	P	T	CM	ST	A	RANK
4	Estimate (Bailey '75)	7.5 gcd	0.125	1.5	1.0	1.125	1.4	1.2	1.5	4.3
4	Estimate (Bailey '75)	7.0 gcd	0.117	1.5	1.0	1.125	1.4	1.2	1.5	4.3
113	Estimate (Nelson '77)	7.5 gcd	0.125	1.5	1.0	1.125	1.4	1.2	1.5	4.3
113	Manufacturers' Estimate(p.131)	39% of flush	0.156	1.5	1.0	1.125	1.4	1.2	1.25	3.5
97	Estimate - Santa Clara Co.	7.5 gcd	0.125	1.5	1.0	1.125	1.4	1.2	1.25	3.5
95	Estimate	50% of flush	0.20	1.5	1.0	1.125	1.4	1.2	1.0	2.8
147	Lab Testing	40% of flush	0.16	1.5	1.0	1.125	1.4	1.4	1.5	5.5

RANK-WEIGHTED AVERAGE REDUCTION FACTOR = 0.142

* Reduction in interior residential water use.
** See Part 4.2 for definition of terms.

TABLE 4-9

REDUCTION VALUES FOR SHALLOW TRAP TOILETS

SOURCE NUMBER	TYPE OF STUDY	REDUCTION REPORTED	REDUCTION FACTOR, R_{IR}*	RANK WEIGHTING FACTORS** RV	P	T	CM	ST	A	RANK
113	Estimate (p.193,213)	7.5 gcd	0.125	1.5	1.0	1.125	1.4	1.2	1.5	4.3
113	Manufacturers' Est (p.119)	45% of flush	0.18	1.0	1.0	1.125	1.2	1.2	1.5	2.4
78	Estimate	30% of flush; Flush is 45% OF IR	0.135	1.5	1.0	1.125	1.2	1.2	1.5	3.6
4	Estimate (Bailey '75)	7.5 gcd	0.125	1.5	1.0	1.125	1.4	1.2	1.5	4.3
37	Homes(Cohen & Wallman'74)	3.9 gcd;56.6gcd IR	0.069	1.5	1.0	1.125	1.4	1.5	1.5	5.3
148	Manufacturers' Estimate	1-1.8 gal/flush; 5 gal conventional	0.112	1.5	1.0	1.25	1.4	1.2	1.5	4.7
114	Estimate	9 gcd; 69.3 gcd IR	0.13	1.5	1.0	1.25	1.4	1.2	1.5	4.7
20	Fixture use survey-So.CA	7.3 gcd	0.122	1.5	1.0	1.25	1.4	1.5	2.0	7.9
20	Previous Lit. (p. 2-2)	10 gcd	0.167	1.5	1.0	1.125	1.4	1.2	1.25	3.5

RANK-WEIGHTED AVERAGE REDUCTION FACTOR = 0.124

* Reduction in interior residential water use.

** See Part 4.2 for definition of terms.

TABLE 4-10

REDUCTION VALUES FOR PRESSURE TOILETS

SOURCE NUMBER	TYPE OF STUDY	REDUCTION REPORTED	REDUCTION FACTOR, R_{IR}*	RANK WEIGHTING FACTORS** RV	P	T	CM	ST	A	RANK
28	Estimate (p. 34)	90% of flush	0.36	1.5	1.0	1.125	1.4	1.2	1.25	3.5
116	Estimate	50-60% of flush	0.22	1.5	1.0	1.2	1.4	1.2	1.25	3.8
113	Manufacturers' Est. (p. 125)	95% of flush	0.38	1.5	1.0	1.125	1.4	1.2	1.125	3.5
4	Estimate (Bailey '75)	22.5 gcd	0.375	1.5	1.0	1.125	1.4	1.2	1.5	4.3
113	Estimate (Nelson '77)	22.5 gcd	0.375	1.5	1.0	1.125	1.4	1.2	1.5	4.3
113	Estimate (Nelson '77)	25 gcd	0.417	1.5	1.0	1.125	1.4	1.2	1.5	4.3
48	Manufact. Est. (Press. Tank)	50-60% of flush	0.22	1.5	1.0	1.125	1.4	1.2	1.25	3.5
48	Manufact. Est. (Press. Flush)	90% of flush	0.36	1.5	1.0	1.125	1.4	1.2	1.25	3.5
24	Estimate (Press. Tank)	55% of flush	0.22	1.5	1.0	1.125	1.40	1.2	1.0	2.8
24	Estimate (Press. Flush)	100% of flush	0.40	1.5	1.0	1.125	1.4	1.2	1.0	2.8

RANK-WEIGHTED AVERAGE REDUCTION FACTOR= 0.336

* Reduction in interior residential water use.
** See Part 4.2 for definition of terms.

4.4.9 Faucet Aerators

Data available for determining water use reduction due to faucet aerators were generally abundant and consistent. As shown in Table 4-12, the 13 reduction values ranged from 0.008 to 0.025. The two reduction values that came from actual data were both 0.020 (6,125). This falls within the range of theoretical estimates but is somewhat higher than the final rank-weighted average reduction factor of 0.014.

4.4.10 Faucet Flow Restrictors

The reduction factor for faucet flow restrictors is based on the 11 reduction estimates shown in Table 4-13. All the values are theoretical and fall within the range of 0.008 to 0.028 and are ranked at 2.8 to 4.7. These values are similar to those found for faucet aerators, as would be expected since both limit the rate of flow to similar levels. When reported, the flow rates for flow restrictors ranged from 1.5 gpm to 2.5 gpm. However, no strong correlation was observed between flow rate and reduction. For example, Source #28 had a flow rate of 1.5 gpm associated with the reported reduction of 0-2% which compares closely with the estimated 0.8% reduction estimate for a higher flow rate of 2.5 gpm reported in Source #113. Thus, no justification existed for determining the reduction factor as a function of flow rate. The final rank-weighted average reduction value of 0.014 compares closely with but is slightly greater than the value determined for aerators (0.014).

4.4.11 Pressure Reducing Valves

The water use reduction attainable by using pressure reducing valves in service lines shown in Table 4-14 varies widely. Values ranging from 0.05 to 0.30 are not unexpected since the percent reduction is, in effect, a function of the pressure before installation of the valve. Thus, this initial pressure is the source of the variability in the measure. Unfortunately, the relationship between initial pressure and reduction could not be determined because the former was generally not reported. For the five documented sources, the final rank-weighted average value of the reduction factor is 0.138. This factor applies to four of the six water use categories, i.e., interior residential, commercial, industrial, and public.

TABLE 4-11

REDUCTION VALUE FOR DUAL FLUSH TOILETS

NUMBER	TYPE OF STUDY	REDUCTION		RANK WEIGHTING FACTORS**						RANK
		REPORTED	FACTOR, R_{IR}*	RV	P	T	CM	ST	A	
28	Manufacturers' Est.(p.33)	75% of flush	0.30	1.5	1.0	1.125	1.4	1.2	1.25	3.5
6	Estimate	4.5 gal; 5 gal/flush	0.36	1.5	1.0	1.125	1.4	1.2	1.25	3.5
4	Estimate (Bailey '75)	17.5 gcd	0.292	1.5	1.0	1.125	1.4	1.2	1.5	4.3
37	Homes (Cohen & Wallman '74)	5.4 gcd; 62.8gcd IR	0.086	1.5	1.0	1.125	1.4	1.5	1.5	5.3
37	Homes (Cohen & Wallman '74)	3.3 gcd;100 gcd IR	0.033	1.5	1.0	1.125	1.4	1.5	1.5	5.3
97	Estimate	15.5 gcd	0.258	1.5	1.0	1.125	1.4	1.2	1.125	3.5
24	Estimate	20% of flush	0.08	1.5	1.0	1.125	1.2	1.2	1.0	2.4

<u>RANK-WEIGHTED AVERAGE REDUCTION FACTOR</u> = 0.190

* Reduction in interior residential water use.
** See Part 4.2 for definition of terms.

TABLE 4-12

REDUCTION VALUE FOR FAUCET AERATORS

NUMBER	TYPE OF STUDY	REDUCTION REPORTED	REDUCTION FACTOR, R_{IR}*	RV	P	T	CM	ST	A	RANK
				RANK WEIGHTING FACTORS**						
125	Demo-E. Brunswick, NJ	4.9 gal	0.020	1.5	1.0	1.25	1.5	1.2	1.25	4.2
28	Estimate (p. 1)	2% of IR	0.020	1.5	1.0	1.125	1.4	1.2	1.25	3.5
6	Demo-office building	50% of faucet flow	0.020	1.5	1.0	1.0	1.4	1.5	1.25	3.9
113	Manufacturers' Est(p.87)	62% of faucet flow	0.025	1.5	1.0	1.125	1.4	1.2	1.25	3.5
113	Estimate (p. 213)	0.5 gcd	0.0083	1.5	1.0	1.125	1.4	1.2	1.5	4.3
4	Estimate (Bailey'75)	0.5 gcd	0.0083	1.5	1.0	1.125	1.4	1.2	1.5	4.3
97	Estimate	0.5 gcd	0.0083	1.5	1.0	1.125	1.4	1.5	1.25	4.4
54	Estimate	0.8 gcd	0.0133	1.5	1.0	1.125	1.4	1.2	1.0	2.8
156	Estimate	25% of faucet flow	0.01	1.5	1.0	1.125	1.4	1.2	1.0	2.8
161	Estimate	0.5 gcd	0.0083	1.5	1.0	1.25	1.4	1.2	1.25	3.9
75	Estimate	2% of IR	0.02	1.5	1.0	1.125	1.4	1.2	1.0	2.8
115	Estimate	0.8 gcd	0.0133	1.5	1.0	1.25	1.4	1.2	1.25	3.9
53	Estimate (p. 8)	25% of faucet flow	0.01	1.5	1.0	1.125	1.2	1.2	1.25	3.0

RANK-WEIGHTED AVERAGE REDUCTION FACTOR = 0.014

* Reduction in interior residential water use.
** See Part 4.2 for definition of terms.

TABLE 4-13

REDUCTION VALUE FOR FAUCET FLOW RESTRICTORS

NUMBER	TYPE OF STUDY	REDUCTION REPORTED	REDUCTION FACTOR, R_{IR}*	RANK WEIGHTING FACTORS** RV	P	T	CM	ST	A	RANK
125	Demo, E. Brunswick, NJ	4.9 gal	0.0204	1.5	1.0	1.25	1.5	1.2	1.25	4.2
28	Estimate (p. 18)	0-2% of IR	0.01	1.5	1.0	1.125	1.4	1.2	1.25	3.5
113	Manufacturers' Est. (p. 82)	63.8% of faucet flow	0.026	1.5	1.0	1.125	1.4	1.2	1.25	3.5
4	Estimate (Bailey '75)	0.5 gcd	0.008	1.5	1.0	1.25	1.4	1.2	1.5	4.3
113	Estimate (Nelson '77)	0.5 gcd	0.008	1.5	1.0	1.125	1.4	1.2	1.5	4.3
97	Estimate - Santa Clara Co.	0.5 gcd	0.008	1.5	1.0	1.125	1.4	1.2	1.25	3.5
48	Estimate	70% of faucet flow	0.028	1.5	1.0	1.125	1.4	1.2	1.0	3.5
156	Estimate	25% of faucet flow	0.01	1.5	1.0	1.125	1.4	1.2	1.0	2.8
161	Estimate	0-20% of faucet flow	0.004	1.5	1.0	1.125	1.4	1.2	1.25	3.9
150	Estimate	50% of faucet flow	0.020	1.5	1.0	1.125	1.4	1.2	1.25	4.7
114	Estimate	0.8 gcd; 69.3 IR	0.012	1.5	1.0	1.25	1.4	1.2	1.5	4.7

RANK - WEIGHTED AVERAGE REDUCTION FACTOR = 0.014

* Reduction in interior residential water use.
** See Part 4.2 for definition of terms.

TABLE 4-14

REDUCTION VALUES FOR PRESSURE REDUCING VALVES

NUMBER	TYPE OF STUDY	REDUCTION REPORTED	REDUCTION FACTOR, R*	RANK WEIGHTING FACTORS** RV	P	T	CM	ST	A	RANK
28	Estimate (p.1)	5%	0.05	1.5	1.0	1.125	1.4	1.2	1.25	3.5
97	Estimate	20%	0.20	1.5	1.0	1.125	1.4	1.2	1.25	3.5
48	Estimate	30%	0.30	1.5	1.0	1.125	1.4	1.2	1.25	3.5
161	Estimate	0-20%	0.10	1.5	1.0	1.25	1.4	1.2	1.25	3.9
75	Estimate	5%	0.05	1.5	1.2	1.125	1.4	1.2	1.25	4.3

RANK - WEIGHTED AVERAGE REDUCTION FACTOR = 0.138

* Reduction in interior residential, exterior residential, commercial, industrial, & public water use.

** See Part 4.2 for definition of terms.

4.4.12 Service Line Flow Restrictors

Only one information source (161) which gave an estimate of the reduction attainable by this measure was found. A savings of 0.5 gal/day, which translates into a reduction factor of 0.008 of residential interior water use (0.5 gpd divided by 60 gpcd) was estimated. The rank which corresponds to this source is 3.9 (1.5 X 1.0 X 1.25 X 1.4 X 1.2 X 1.25).

In-line flow restrictors may also affect water use in other categories, i.e., commercial, industrial, and public; thus, the value of 0.008 was applied in these categories also.

4.4.13 Toilet Leak Repair

Despite the relative ease and popularity of using dye pills for detecting and repairing toilet leaks, very little data are available which isolate this measure from interactions with other conservation measures. In all the actual cases reviewed, toilet leak repair was implemented in conjunction with another measure(s), e.g., shower flow restrictors and a displacement device in a water conservation kit. Thus, the reduction factor for this measure is based on only one source (171), which is an estimate made for illustrative purposes in a conservation scenario for the city of Atlanta, GA. The reduction factor is 0.14 of interior residential use and the rank of the source is 5.7 (1.5 X 1.2 X 1.25 X 1.4 X 1.2 X 1.5).

4.4.14 Commercial/Industrial Recycle/Reuse

The potential reduction in water use resulting from this measure varies considerably with the industry, process, and method being considered. As shown in Table 4-15, the reduction for various processes ranged from 6.9% to over 98% of water use. The upper end of this range reflects maximum observed reductions and cannot be considered the norm. The ranks of the twelve RFACT values are between 3.5 and 4.9, indicating relatively average quality of data for all values. The final rank-weighted average reduction in industrial water use is calculated as 0.444.

4.4.15 Metering

Determination of the reduction in water use due to implementation of metering was made for all water use categories except public and unaccounted-for water. The data available for this conservation measure are presented in Table 4-16. As shown, the reduction values were reported in three categories: reduction in exterior residential (ER) use, in exterior plus interior residential (R) use, and in all metered uses. The five reduction values for ER gave a rank-weighted average reduction of 0.477. This value was used in conjunction with the seven ER and IR reduction values to determine the IR reduction factor. This was done by weighting the IR and ER reductions by their respective percentages of total residential water use and solving for the IR reduction as follows:

$$RFACT_R = RFACT_{IR}(.85) + RFACT_{ER}(.15)$$

$$RFACT_R = RFACT_{IR}\ (.85) + .477\ (.15) \qquad \text{(Eq. 4-2)}$$

$$RFACT_{IR} = \frac{RFACT_R - 0.0716}{0.85}$$

This method produced a final rank-weighted IR reduction factor of 0.180. The reductions in commercial and industrial uses were assumed equal. The RFACT for commercial (C) and industrial (I) uses was developed from the ten reduction values for metered use (Rm) shown in Table 4-16, in conjunction with the factors previously determined. As for the reduction in IR, each factor was weighted by its respective percentage of total water use. That is,

$$RFACT_M = RFACT_{IR}(0.4512) + RFACT_{ER}(0.0796) + RFACT_{C+I}(0.4691)$$

$$RFACT_{C+I} = \frac{RFACT_M - (0.191)(0.4512) - (0.477)(0.0796)}{0.444}$$

(Eq. 4-3)

$$RFACT_{C+I} = \frac{RFACT_M - 0.1241}{0.4691}$$

The final rank-weighted reduction factor for commercial and industrial use was 0.373.

TABLE 4-15

REDUCTION VALUES FOR COMMERCIAL/INDUSTRIAL RECYCLE/REUSE

NUMBER	TYPE OF STUDY	REDUCTION: REPORTED	REDUCTION: FACTOR, R_{ER}*	RANK WEIGHTING FACTORS**: RV	P	T	CM	ST	A	RANK
28	Metals Process	up to 58,600 gal	0.977	1.5	1.0	1.125	1.4	1.5	1.0	3.5
28	Carbon Block Process	up to 13.75 gal	0.982	1.5	1.0	1.125	1.4	1.5	1.0	3.5
28	Paperboard (Reuse)	26% of Intake	0.26	1.5	1.0	1.125	1.4	1.5	1.25	4.5
28	Animal By-Prod(Recycle)	30% of Intake	0.30	1.5	1.0	1.125	1.4	1.5	1.25	4.5
28	Tomato Process (Reuse)	10-15%	0.125	1.5	1.0	1.125	1.4	1.5	1.25	4.5
116	Aircraft Company (Reuse	30%	0.30	1.5	1.0	1.25	1.4	1.5	1.25	4.9
116	Electroplating	93%	0.93	1.5	1.0	1.25	1.4	1.5	1.0	3.9
53	Papermill	45%	0.45	1.5	1.0	1.25	1.4	1.5	1.25	4.9
53	Fiber Plant (Reuse)	30%	0.30	1.5	1.0	1.25	1.4	1.5	1.25	4.9
53	Tomato Processing	87%	0.87	1.5	1.0	1.125	1.4	1.2	1.25	3.9
26	Chemical Co. (Recycle)	51%	0.51	1.5	1.0	1.125	1.4	1.5	1.25	4.4
26	Oil Refining (Recycle)	6.9%	0.069	1.5	1.0	1.125	1.4	1.5	1.25	4.4
38	Pulp and Paper (Recycle/Reuse)	24,600 to 20,800 gal	0.154	1.25	1.0	1.125	1.4	1.5	1.5	4.4
31	Chicken Processing	32%	0.32	1.25	1.0	1.125	1.4	1.5	1.5	4.4
144	Electronics (Reuse)	50%	0.50	1.0	1.0	1.2	1.4	1.5	1.25	3.2

RANK-WEIGHTED AVERAGE REDUCTION FACTOR = 0.444

* Reduction in industrial water use.
** See Part 4.2 for definition of terms.

TABLE 4-16

REDUCTION VALUES FOR WATER METERING

NUMBER	TYPE OF STUDY	REDUCTION REPORTED	REDUCTION FACTOR, R_{ER}*	RANK WEIGHTING FACTORS** RV	P	T	CM	ST	A	RANK
65	Unspecified (Hanke&Bolard'71)	50% of ER	0.50	1.5	1.2	1.0	1.4	1.5	1.0	3.8
87	Actual (Linaweaver,et al '67)	avg. 60% of ER	0.60	1.5	1.2	1.0	1.5	1.5	1.5	6.1
64	Actual-Boulder(Hanke'69)	50% of ER	0.50	1.5	1.2	1.0	1.5	1.5	1.5	5.1
22	Estimate - Denver(Bryson'73)	47% of ER	0.47	1.5	1.2	1.125	1.2	1.2	1.0	2.9
50	Hypothetical - Denver	31% of ER	0.31	1.5	1.2	1.25	1.4	1.2	1.5	5.7
			FACTOR, $R_{ER} + R_{IR}$							
28	General Stmt - CA	25% of ER and IR	0.25	1.0	1.0	1.125	1.2	1.0	1.0	1.4
53	Actual, w/time-Denver	29% of ER and IR	(0.29) yr 1-10							
53	Actual, w/time-Denver	13-30% of ER and IR	(0.215) yr 5-8							
53	Actual, w/time-Denver	6% of ER and IR	(0.06) yr 9-12							
53	Actual,overall-Denver	25% of ER and IR	0.25	1.5	1.2	1.0	1.5	1.5	1.5	6.1
64	Actual-Boulder(Hanke'69)	36% of ER and IR	0.36	1.5	1.2	1.0	1.5	1.5	1.5	6.1
56	Actual-Denver(Greene'72)	Avg 21% of ER and IR	0.21	1.5	1.2	1.0	1.5	1.5	1.5	6.1
20	Actual-Denver	Overall 15% of ER and IR	0.15	1.5	1.2	1.0	1.5	1.5	2.0	8.1
89	X-Section(Linaweaver et al'67)	0%	0.00	1.0	1.0	1.0	1.2	1.2	1.5	2.2

RANK-WEIGHTED AVERAGE REDUCTION FACTOR $(R_{ER}) = 0.477$
$(R_{IR}) = 0.180$
$(RFACT_{C+I}) = 0.373$

* Reduction in water use as shown: exterior residential (ER), interior residential (IR), all metered (M), industrial (I).
** See Part 4.2 for definition of terms.

TABLE 4-16 (Cont.)

REDUCTION VALUES FOR WATER METERING

NUMBER	TYPE OF STUDY	REDUCTION REPORTED	REDUCTION FACTOR, Rm*	RANK WEIGHTING FACTORS** RV	P	T	CM	ST	A	RANK
66	Estimate - (Hanke'81)	15% of Consumption	0.15	1.5	1.0	1.25	1.4	1.2	1.0	3.2
113	Actual-Central Valley, CA	30% of City Use	0.30	1.0	1.2	1.125	1.5	1.5	1.5	4.6
188	Actual-Kingston, NY	27% of avg use	0.27	1.5	1.2	1.0	1.4	1.5	1.5	5.7
138	Actual-Phila., PA	28% of demand	0.28	1.5	1.2	1.25	1.4	1.5	1.25	5.9
42	28 City survey(Brauer,etal'67)	30% of all metered	0.30	1.5	1.2	1.125	1.5	1.5	1.5	6.8
90	Est-Pueblo, CO(Chiagioji'73)	60% of flat rate use	0.40	1.0	1.2	1.0	1.5	1.5	1.0	2.7
189	General Stmt(Baumann,et al'79)	25-50% of demand	0.375	1.5	1.0	1.25	1.4	1.2	1.25	3.9
29	Actual - CA	20-55% of demand	0.375	1.5	1.2	1.0	1.4	1.5	1.5	5.7
50	Hypothetical-Denver		0.21	1.5	1.2	1.25	1.4	1.2	1.5	5.7
144	Actual, food,steel	67%, 33% of I	0.50	1.0	1.0	1.2	1.4	1.5	1.25	3.2
50	Hypothetical - Denver	21% of Total Demand	0.21	1.5	1.2	1.25	1.4	1.2	1.5	5.7

RANK-WEIGHTED AVERAGE REDUCTION FACTOR $(R_{ER}) = 0.477$
$(R_{IR}) = 0.180$
$(RFACT_{C+I}) = 0.373$

* Reduction in water use as shown: exterior residential (ER), interior residential (IR), all metered (M), industrial (I).
** See Part 4.2 for definition of terms.

4.4.16 Pipeline Leak Repair

Several sources of data were available for reductions attributable to pipeline leak repair programs. The reduction values, ranks, and sources are shown in Table 4-17. The wide range of values (0.092 to 0.60) made it apparent that the reduction due to a leak detection and repair program is a function of many factors including the unaccounted-for water in the system. Thus, an attempt to establish a relationship between these two variables was made, as shown in Figure 4-1. Only six sources of data provided both the estimated reduction and the unaccounted-for water needed to develop the linear relationship. The corresponding function which describes that relationship is:

$$RFACT_{PLP} = 1.33\ UFLOW \qquad \text{(Eq. 4-4)}$$

where:

$RFACT_{PLP}$ = reduction factor for pipeline leak repair

UFLOW = fraction of unacounted for flow to total unrestricted flow

However, the range of data, the small number of sources, and the influence of other factors such as differing techniques for determining unaccounted-for water, or inaccuracies of master meters, prevent this expression from being used directly to determine RFACT. Instead, the conservation effectiveness module will require the user to input the percent unaccounted-for water to be achieved by a pipeline leak repair program and the year such a goal will be accomplished as described in Part 3.5(7).

4.4.17 Conservation Ordinances

The availability of reduction data for this measure is limited. Since the adoption of conservation-oriented plumbing codes has taken place only in recent years, assessment of its effectiveness has not been well documented. Only two sources of data, one theoretical and one actual, were found to be applicable to this measure. The information provided in these sources is shown in Table 4-18. This measure could potentially affect all water use categories except exterior residential and unaccounted-for water.

TABLE 4-17

REDUCTION VALUES FOR PIPELINE LEAK REPAIR

NUMBER	TYPE OF STUDY	REDUCTION REPORTED	REDUCTION FACTOR, R_{UF}*	RANK WEIGHTING FACTORS** RV	P	T	CM	ST	A	RANK
28	Estimate(p.29,Howe etal,'71)	9% of Total	***	1.5	1.0	1.0	1.4	1.2	1.25	3.2
53	Actual - East Bay MUD	1.5% of 9.5% UF	0.158	1.5	1.2	1.125	1.4	1.5	2.0	8.5
28	Actual - East Bay MUD (p. 30)	1.9% (of 9.5% UF)	0.20	1.5	1.0	1.0	1.4	1.2	1.25	3.2
116	Hypothetical (p. 69)	4% of UF	***	1.5	1.0	1.25	1.4	1.2	1.25	3.9
40	Actual - Pittsburgh, PA	24% of total	***	1.5	1.2	1.0	1.4	1.5	1.0	3.8
104	Actual (Mitchell '57)	17% of total	***	1.5	1.0	1.0	1.4	1.5	0.5	1.6
109	Actual - Westchester, NY	45% of 29.5% UF	***	1.5	1.2	1.25	1.4	1.5	1.5	7.1
128	Actual - Gary, IN	5% of 20% UF	0.25	1.5	1.2	1.25	1.4	1.5	2.0	9.5
128	Actual-Wyomingtown	50% of total	***	1.5	1.0	1.0	1.4	1.5	1.0	3.2
128	Actual - Utah City	50% of total	***	1.5	1.0	1.125	1.4	1.5	1.0	3.5
128	Actual - Utah City	20% of total	***	1.5	1.0	1.0	1.4	1.5	1.0	3.2
****	Actual - Phila., PA	9.2% of 30% UF	0.092	1.5	1.2	1.25	1.4	1.5	1.5	7.1
189	Estimate	30% of 10-15% UF	0.30	1.5	1.0	1.25	1.4	1.2	1.25	3.9
189	Estimate	42% of 20% UF	0.42	1.5	1.0	1.25	1.4	1.2	1.25	3.9
189	Estimate	50+% for 25-50% UF	0.50	1.5	1.0	1.25	1.4	1.2	1.25	3.9

RANK-WEIGHTED AVERAGE REDUCTION FACTOR = 1.33 [UF] (See Figure 4.1)

* Reduction is unaccounted-for water.
** See Part 4.2 for definition of terms.
*** % Unaccounted-for water not provided; reduction not calculated.
**** Determined by interview.

Source Number	Data Points	
	X (Unaccounted)	Y (Reduction)
189	0.125	0.30
189	0.20	0.417
189	0.375	0.50+
53	0.095	0.158
128	0.20	0.25
Phila. Water Dept.	0.30	0.092

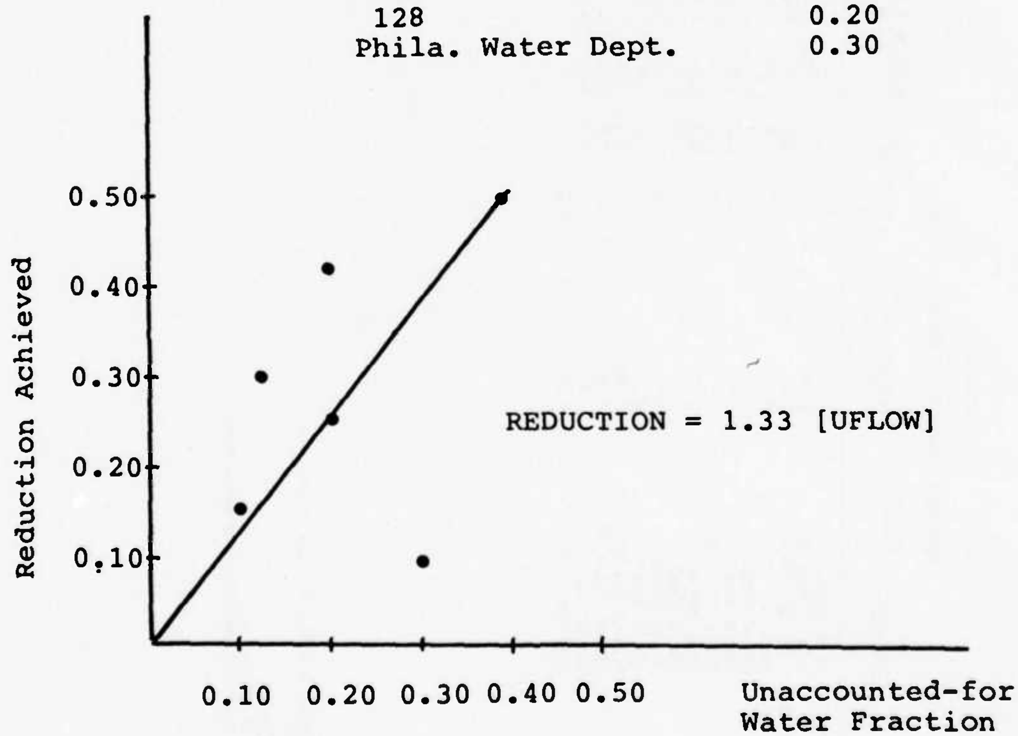

FIGURE 4-1 Relationship Between Unaccounted-for Water and Reduction Due to Pipeline Leak Repair

TABLE 4-18

REDUCTION VALUES FOR CONSERVATION ORDINANCES

		REDUCTION		RANK WEIGHTING FACTORS*						
NUMBER	TYPE OF STUDY	REPORTED	FACTOR, R_{IR}	RV	P	T	CM	ST	A	RANK
28	Estimate - Marin MWD	11% of IR	0.11	1.5	1.2	1.125	1.4	1.2	1.25	4.3
20	Actual Demo - CA	15% of IR	0.15	1.5	1.0	1.25	1.5	1.5	2.0	8.4

<u>RANK-WEIGHTED AVERAGE REDUCTION FACTORS</u> = RFACT = 0.136

* See Part 4.2 for definition of terms.

An 11% reduction in interior residential water use was estimated in source #28 for the Marin Municipal Water District where a conservation-oriented plumbing code has been in effect since 1976. Source #20 provides the most reliable information since it was a study conducted in the "with/without" fashion. Based on sources 28 and 20, the rank-weighted average reduction in interior residential water use was 0.136.

4.4.18 Restricted/Limited Water Uses

The impact of this conservation measure is realized in the industrial, commercial, public, and exterior residential water use categories. For the latter three uses, eleven reduction estimates were available, while only one existed for the industrial use category, as shown in Table 4-19. The range of values for all uses was narrow, ranging only from 0.13 to 0.30, and including actual as well as theoretical values. The ranks corresponding to this range were between 1.9 and 5.7 indicating a variety of data sources. One reduction value of 0.60 was reported (source #33). This is double the highest estimate from other sources. The final rank-weighted reduction factor for all water uses was 0.221.

4.4.19 Rationing

Data on the effectiveness of a rationing program came largely from California communities which were impacted by the 1976-77 drought. Table 4-20 shows seven such communities plus one northeastern United States area which implemented a rationing program. The achieved water use reduction varies as a function of the rationing goal set forth. A notable difference in the achieved reduction as a function of geographic location is also apparent by comparing the California data with that of New Jersey. Whereas the California reduction values range from 0.19 to 0.67, the value from the New Jersey case is only 0.083. This reflects the historical differences in climate and water conservation awareness in the two regions.

Because of the dependence of the reduction due to rationing on the goal set for a community, no reduction factors are included in the conservation effectiveness module. Instead the user should input the RFACT directly for each water use category. The relationship given in Figure 4-2 and the information sources may be used as a guide.

TABLE 4-19

REDUCTION VALUES FOR RESTRICTED USES

NUMBER	TYPE OF STUDY	REDUCTION		RANK WEIGHTING FACTORS**						RANK
		REPORTED	FACTOR*	RV	P	T	CM	ST	A	
121	Actual - Denver (Mand.)	26% of ER,C,P	0.26	1.5	1.2	1.125	1.4	1.5	0.5	2.1
121	Actual - Denver (Vol.)	18-20% of ER,C,P	0.19	1.5	1.2	1.125	1.4	1.5	1.5	5.3
166	Actual - Marin Municipal (p. 18)	25% of ER,C,P	0.25	1.5	1.1	1.125	1.4	1.5	1.5	5.8
29	Actual - Sunnyvale	28% of ER,C,P	0.28	1.5	1.2	1.125	1.4	1.5	1.25	5.3
42	Actual - Denver (p. 46)	21% of ER,C,P	0.21	1.5	1.2	1.125	1.4	1.5	1.25	5.3
42	Actual - Perth (p. 46)	10.6 - 14.3% of ER,C,P	0.125	1.5	1.0	1.25	1.4	1.2	1.25	3.9
33	Survey (Century Research Corporation, '72)	60% of ER,C,P	0.60	1.5	1.0	1.0	1.4	1.2	1.0	2.5
29	Actual - L.A., CA	13% of ER,P,C	0.13	1.5	1.2	1.125	1.4	1.5	1.25	5.3
118	Actual Stanford, CT	10-15% of ER,P,C	0.125	1.5	1.2	1.25	1.4	1.2	0.5	1.9
2	Actual (Anderson, '67)	17% of ER,P,C,I	0.17	1.5	1.2	1.0	1.4	1.5	1.25	4.7

RANK-WEIGHTED AVERAGE REDUCTION FACTORS : RFACT = 0.221

* Reduction in water use category as noted (exterior residential (ER), commercial (C), industrial (I), public (P)).

** See Part 4.2 for definition of terms.

TABLE 4-20

REDUCTION VALUES FOR RATIONING

NUMBER	TYPE OF STUDY	REDUCTION REPORTED	REDUCTION FACTOR*	RANK WEIGHTING FACTORS** RV	P	T	CM	ST	A	RANK
29	Actual - MWD, CA	Goal 57%, R = 53%	0.53	1.5	1.2	1.25	1.4	1.5	1.25	5.3
29	Actual - Alameda Co, CA	Goal 25%; R = 30%	0.30	1.5	1.2	1.125	1.4	1.5.	1.25	5.3
29	Actual - Monterey, CA	Goal N/A; R = 46%	0.46	1.5	1.2	1.15	1.4	1.5	1.25	5.3
29	Actual - MilPitas, CA	Goal 25%; R = 50%	0.50	1.5	1.2	1.125	1.4	1.5	1.25	5.3
82	Actual - East Bay MUD, CA	Goal 135%;R = 38%	0.38	1.5	1.2	1.125	1.4	1.5	1.5	6.4
122	Actual - Metro WD, CA	Goal 10%; R = 19%	0.19	1.5	1.2	1.125	1.4	1.5	1.25	5.3
116	Actual - No. Marin, CA	Goal N/A; R = 67%	0.67	1.5	1.1	1.125	1.4	1.5	1.25	5.3
189	Actual - New Jersey	Goal 25%; R = 8.3%	0.083	1.25	1.2	1.2	1.4	1.5	1.25	4.7

<u>RANK-WEIGHTED AVERAGE REDUCTION FACTOR</u> = User input.

* Reduction in all water uses except unaccounted-for water.
** See Part 4.2 for definition of terms.

Source Number	Data Points	
	X (Goal)	Y (Achieved)
83	0.35	0.38
40	0.57	0.53
107	0.25	0.083
60	0.10	0.19
40	0.25	0.30
40	0.25	0.50

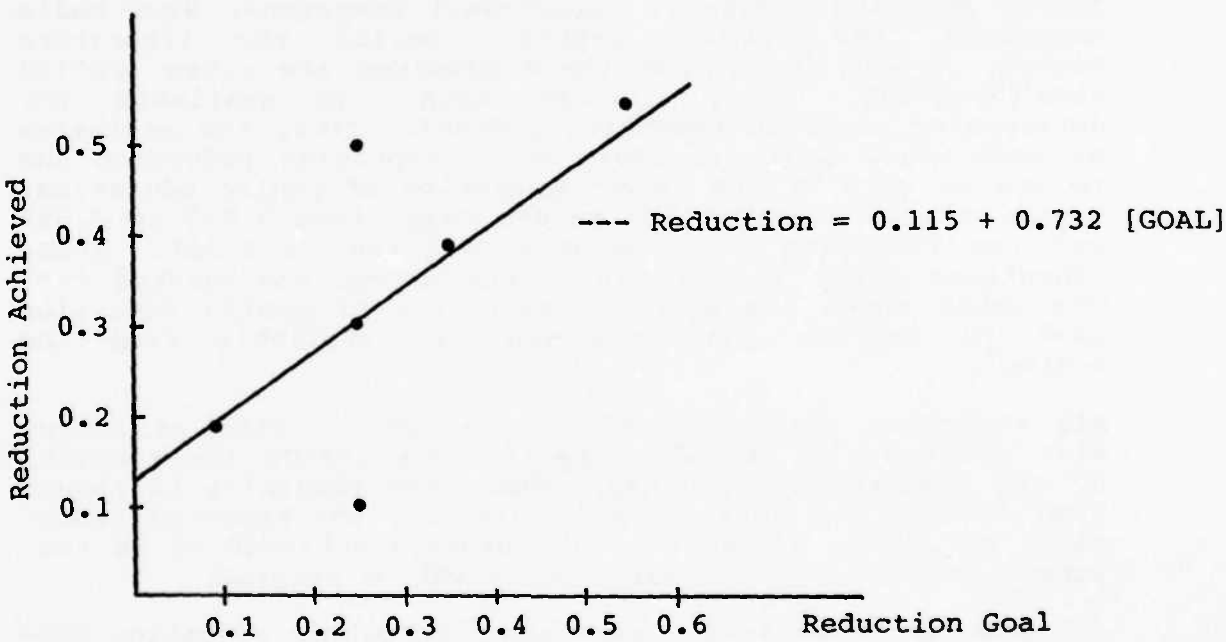

FIGURE 4-2 Relationship Between Reduction Goal and Reduction Achieved by Rationing

4.4.20 Pricing Policy

A total of thirteen data sources, shown in Table 4-21, reported information related to reduction in water use resulting from various pricing policies. Of these, three reported price elasticities and the remaining ten reported reduction factors. These ranged from 0.03 to 0.17 with ranks ranging from 4.3 to 5.9. A variety of pricing policies were reflected. Since limited data were available for any given policy, it was decided that a single methodology would be chosen to arrive at the reduction factor for this measure. Such a methodology was reported in reference 171 and is a function of new price for water (P_2), the old price (P_1), and the price elasticity (e). Thus, the user must know P_2, P_1, and be able to estimate e. Several studies have been conducted to determine the elasticities of demand for water. These are summarized in Table 4-22.

4.4.21 Public Education

This conservation measure was formed to encompass three originally separate measures: Direct-Mail Campaigns, News Media Campaigns, and Special Events. During the literature search, it was found that these measures are often applied simultaneously. Only limited data were available for determining separate reduction factors. Thus, the estimates of reduction, shown in Table 4-23, represent reduction due to one or more of the three categories of public education. Twelve of the 16 reduction values range from 0.023 to 0.092 and the remaining four range from 0.156 to 0.289. These reductions apply to all water uses except unaccounted for. The table shows the specific method(s) of public education used to achieve the reduction (if available from the source).

All reduction estimates except the two reported in Source #107 reflect the overall effectiveness (RFACT times COVER) of the conservation program. Thus, the remaining 14 reduction factors are determined by dividing the reported reductions by .90 to adjust for 90% coverage achieved in an (assumed) maximum coverage water conservation program.

As shown in Table 4-23, there are some public education campaigns with water saving device kits and some without kits. However, calculation of separate RFACT's for the two ver-

TABLE 4-21

REDUCTION VALUES FOR PRICING POLICIES

NUMBER	TYPE OF STUDY	REDUCTION REPORTED	REDUCTION FACTOR*	RANK WEIGHTING FACTORS** RV	P	T	CM	ST	A	RANK
116	70% Price Incr.-Hanover,MA	3-5% in total demand	0.04	1.5	1.2	1.0	1.4	1.5	1.25	4.7
171	Illustrative Ex.-Tuscon, AR		$1 - (P_2-P_1)^e$	1.5	1.2	1.25	1.4	1.2	1.5	5.7
155	Incr. rate - Washington Suburban	1.1-8.7% in total demand	0.049	1.5	1.0	1.25	1.4	1.2	1.5	4.7
163	Inverted rate-Westminster,CO	10% in total demand	0.10	1.5	1.2	1.25	1.4	1.5	1.25	5.9
92	Incr. rate - Washington Suburban	13% of total June 1/4	0.13	1.5	1.2	1.25	1.4	1.5	1.25	5.9
21	X-sect. studies(Bruner'69)	e = -.27	—	1.5	1.2	1.0	1.4	1.2	0.5	1.5
21	Time Series-Phoenix (")	e = -.8	—	1.5	1.0	1.0	1.4	1.2	0.5	1.3
23	Colo. Towns(Burns et al,p.31)	e = -.29(IR) - .4(ER)	—	1.5	1.0	1.125	1.0	1.5	0.5	1.3
30	20% incr.(Casuto&Ryan,'79)	5% in R; e=-.15 to -.3	0.05	1.5	1.0	1.25	1.4	1.2	1.25	4.4
91	Regr. Anal. & Case Study	15% in R; 3 = -.37	0.15	1.5	1.1	1.25	1.4	1.2	1.25	4.3
91	Seasonal rate-Amherst, MA	17% in IR & ER	0.17	1.5	1.2	1.25	1.4	1.2	1.5	5.7
91	Incr. Block-Amherst, MA	10% in IR & ER	0.10	1.5	1.2	1.25	1.4	1.2	1.5	5.7
91	Seasonal Rate-Amherst, MA	5% in total demand	0.05	1.5	1.2	1.25	1.4	1.2	1.5	5.7
91	Incr. block-Amherst, MA	3% in total demand	0.03	1.5	1.2	1.25	1.4	1.2	1.5	5.7

RANK-WEIGHTED AVERAGE REDUCTION FACTOR $= 1 - (P_2/P_1)^e$ (See Section 4.3.20)

* Reduction in all water uses except unaccounted-for water.

** See Part 4.2 for definition of terms.

TABLE 4-22

ESTIMATED ELASTICITIES OF DEMAND FOR WATER

Investigator	Year	Type of Analysis	Price Elasticity
Gottlieb	1952	68 Kansas Cities	-1.02
	1952	19 Kansas Cities	-1.24
	1957	84 Kansas Cities	-0.69
	1957	24 Kansas Cities	-0.68
	1958	24 Kansas Cities	-0.66
	1963	Kansas Cross-Sectional	-0.95(mean)
Seidel and Baumann	1957	American cities Cross-Sectional @.45/1,000 g	-0.12
Renshaw	1958	36 Water service systems, cross-sectional	-0.45
Fourt	1958	34 American cities, cross-sectional	-0.39
Wong et al.	1963	Northeastern Illinois, cross-sectional	-0.31(mean)
Heaver and Winter	1963	Ontario cities	-0.254
Hedges and Moore	1963	Northern California irrigation	-0.19
Howe and Linaweaver	1963-1965	21 Residential domestic	
		Public sewers	-0.23
		Seasonal use	-1.16
Gardner and Schick	1964	42 Northern Utah Water systems, cross-sectional	-0.77
Flack	1965	54 Western cities, cross-sectional @ .45/1,000 g	-0.12
		All Cities @.45/1,000 g	-0.65
Ware and North	1965	634 Georgia residences	-0.67
Bain, Caves, and Margolis	1966	41 Northern California Cities Irrigation	-1.10

TABLE 4-22 (Con't)

ESTIMATED ELASTICITIES OF DEMAND FOR WATER

Investigator	Year	Type of Analysis	Price Elasticity
	1966	41 California cities, cross-sectional	-1.099
Burns, et al.	1970's	Stratified 2 price comparison	-0.20 to -0.38 inhouse -0.27 to 0.53 sprinkling
Young, R. A.	1973	Tuscon time-series 1946-1971	-0.20 (re-analysis)
Pepe et al.	1975	4 South Carolina cities, 2 and 3 year time series	0.00 to -0.51
Grunewald et al.	1975	150 rural Kentucky cross-sectional	-0.92
Hogarty and McCay	1975	Blacksburg, VA 2 year time-series	-0.50 to -1.41
Camp, R. C.	1978	228 Mississippi households; cross-sectional	-0.24 to -0.31
Carver, P. H.	1978	13 Washington, D.C. utilities 6 yr. time series cross-sectional	0.00 to -0.1 (short run)
	1978	Fairfax Co., VA, 4 yr time-series of an innovative price structure	-0.02 to -0.17
Turnovsky	1969	Industrial Massachusetts cross-sectional	-0.47 to -0.17
DeRooy	1974	New Jersey chemical cross-sectional	-0.89 cooling -0.74 processing -0.74 steam generation

TABLE 4-22 (Con't)

ESTIMATED ELASTICITIES OF DEMAND FOR WATER

Investigator	Year	Type of Analysis	Price Elasticity
Lynne et al.	1978	Miami, FL cross-sectional	-1.33 dept. stores -0.89 grocery stores -0.14 to -0.30 hotel eating and drinking: not significantlydifferent from zero
Conley	1967	24 S. California communities, cross-sectional	-0.625 (mean)
Turnovsky	1969	19 MA towns, cross-sectional	-0.225 (mean)
Bruner	1969	Phoenix	-0.03
Grima	1970	91 Observations, cross-sectional	-0.93
	1972	Ontario cities, winter	-0.75
Wong	1970	Chicago,1951-61 time series Four community size groups cross-sectional	-0.15(mean) -0.54(mean
Ridge, R.	1972	Cross-sectional industrial	-0.3 malt liquor -0.6 fluid milk processing
Leone, Ginn		Cross-sectional Industrial	-0.3 to -0.4 paper -0.7 to -0.4 chemical -0.5 to -0.4 petroleum -0.7 to -1.1 steel

Source: Amended from U.S. Army Corps, 1976 (Presented in Source 170, p. 37-39, as documented in this report)

TABLE 4-23

REDUCTION VALUES FOR PUBLIC EDUCATION

NUMBER	TYPE OF STUDY*	REDUCTION REPORTED	REDUCTION FACTOR**	RANK WEIGHTING FACTORS*** RV	P	T	CM	ST	A	RANK
118	Public Ed. Westchester Co.NY	4-5% overall	0.050	1.25	1.2	1.25	1.4	1.5	0.5	5.9
83	Public Ed. East Bay MUD	5% overall	0.055	1.25	1.2	1.125	1.4	1.5	1.2	4.4
108	DM - Stillwater, OK	14-24% overall	0.211	1.5	1.0	1.25	1.5	1.2	1.5	5.0
101	Estimate - Voluntary Prog.	5 gcd	0.092	1.5	1.0	1.125	1.4	1.2	1.25	3.5
28	Public Ed. - Marin MWD	171 to 160 gcd	0.071	1.5	1.2	1.125	1.4	1.5	1.25	5.3
28	Public Ed. - Fresno, CA	26% overall	0.299	1.5	1.2	1.125	1.4	1.5	1.25	5.3
107	Kit Demo w/Regression Anal.	3.37% w/ & in/out	0.034	1.25	1.0	1.125	1.5	1.5	1.5	4.8
107	Kit Demo w/Regression Anal.	4.30% before & after	0.043	1.25	1.0	1.125	1.5	1.4	1.5	4.4
50	DM; Kit - Denver example	4% overall	0.044	1.25	1.2	1.25	1.4	1.2	1.5	4.8
189	NM, SE - Washington Suburban	1.4% overall	0.016	1.5	1.2	1.125	1.4	1.5	1.25	5.3
189	DM; Kits - Washington Suburban	4.42%	0.048	1.25	1.2	1.125	1.4	1.5	1.25	5.3
189	Public Ed - Connecticut	14% in 1 month	0.156	1.5	1.2	1.25	1.4	1.5	0.5	2.4
189	Public Ed - Madison, WI	2.1% overall	0.023	1.5	1.2	1.25	1.4	1.5	1.25	5.9
189	Public Ed. - NY State	7% in 1 month	0.078	1.5	1.2	1.25	1.4	1.5	0.5	2.4
11	NM-U.K.(A.Blackburn '78)	20% overall	0.222	1.25	1.2	1.125	1.4	1.5	1.25	4.4
39	DM; Kits - So. Tahoe	4.2% overall	0.047	1.25	1.01	1.25	1.4	1.5	1.5	4.4

RANK-WEIGHTED AVERAGE REDUCTION FACTOR = .089

* Specified if known; includes Direct Mail Campaigns (DM), News Media Campaigns (NM), and Special Events (SE).

** Reduction in all water use categories except unaccounted-for water; Values (except Source 107) are divided by 0.90 to account for 90% coverage.

*** See Part 4.2 for definition of terms.

sions results in virtually no difference in RFACT's. This is based on fourteen of the sixteen reported values (sources 101 and 11 did not indicate whether they did or did not include kits). The final rank-weighted reduction factor was calculated to be 0.089.

4.5 Coverage Factors

4.5.1 Initial Coverage Values

The values listed in Tables 3-3, 3-4, and 3-5 are suggested initial coverage values considered appropriate for modest, moderate, and maximum conservation programs. The concept of defining the initial coverage as related to the degree of effort placed upon the conservation program was extended to all conservation measures and initial coverage values have been developed for modest, moderate, and maximum programs for all measures. It is realized that programs can be developed to provide coverage other than those suggested so it is emphasized that these initial coverage values be considered a guide and the user be encouraged to consider inputting his own initial coverage when appropriate.

The initial coverage factors provided in Tables 3-3, 3-4, and 3-5 have been selected primarily based upon experience in recent and ongoing conservation programs as well as from the limited available data reported in the literature. When knowledge of initial coverage or literature data was not available, values were chosen for similarity with comparable measures or to remain consistent with the ease or difficulty in implementing a conservation measure. Metering and pricing measures were generally given initial coverage equal to 1.0 with the single exception that a modest metering program might not include industrial customers.

4.5.2 Annual Ratio of Change in Coverage Factor (AROC)

Factors for the annual ratio of change in coverage are listed for each conservation measure in Table 3-4. This factor allows the variability of effectiveness with time to be accounted for in the coverage factor. A common application of this factor would be the normal wear or removal of water conservation devices over time that would reduce the actual coverage achieved by a conservation measure. For instance, an annual ratio of change in coverage factor of 0.9 would correspond to 10% of all conservation devices installed during a year being removed by the user or malfunctioning so as to be ineffective. Another example would be using an annual rate of change factor of 0.95 for toilet leak repair to indicate that about 5% of fixed toilet leaks would have renewed leaks after a year.

In addition to AROC values of conservation measures selected as described above, three special cases in the use of the annual ratio of change were developed: 1)The metering conservation measure has been given an AROC value of 0.95 to approximate the reduced effectiveness over time reported for Denver, CO, in source #53. 2)Conservation ordinances have an AROC value equivalent to 1.0 plus the rate of new construction to account for new construction incorporating water-conserving factors. 3)Source #70 indicated that a continued public education program would reinforce its impact over time. Therefore,that measure was given a value of 1.1 to reflect this. (However, any subsequently determined coverage value has an upper limit of 1.0.) Other measures showed no evidence of change with time and were thus given values of 1.0 for annual ratio of change in coverage.

4.6 Interaction Factors

The value of an interaction factor for two or more conservation measures ranges from zero to one. An interaction of zero would indicate that the total effectiveness of two measures is simply equal to the effectiveness of the measure to which another is being added. This is seen in the equation for the combined effectiveness of two measures (Equation 3-4). An example of such an interaction would be a shower flow restrictor with a low-flow showerhead, in which case the addition of the latter measure would not further reduce shower water use. An interaction of 1.0, on the other hand, indicates that the measures being considered act independently in reducing water use and that the total effectiveness is the sum of the individual EFF values. For example, toilet dams and showerheads affect different water uses such that their total effectiveness is additive. Interaction factors that are within the range of zero and one indicate that the reduction in water use due to a combination of measures is less than the sum of the reductions resulting from the measures implemented alone. This case is exemplified by a situation in which a public education campaign and water-saving devices are applied simultaneously. The reduction due to both measures is greater than the reduction from either measure alone but less than the sum of the individual reductions.

Any interactions between the 21 conservation measures considered in this study were presented in Table 3-6. They were determined based on four sources of information which reported reductions due to conservation measures conducted simultaneously. Table 4-24 presents the interaction factors determined from actual data. Interaction factors were calculated as follows: given the reduction reported for a combination of measures, the effectiveness was calculated; subsequently, the individual effectiveness for the interacting measures was calculated; and the interaction factor was determined from equation 3-4, where I_{12} is the only unknown factor.

4.7 Reduction Factors for Peak Flow Dimensions

Determination of how reduction factors varied from those appropriate for average daily flow when considering peak day and peak hourly dimensions was severely hampered by the almost complete lack of data on reductions in these areas. When data were available for peak conditions, it was almost always reported for peak season or peak month. Only in the case of metering was a direct relationship for reduction in terms of peak day obtained. No information was found relating how reductions vary for the peak hourly dimension. For this reason, it was frequently necessary to assume that relationships for reduction between peak month and average daily flow would also hold for the peak daily flow and for the peak hour of the peak day. This is because the measures should still affect the same fraction of water use. The relationships discussed below were used for various classes of conservation measures.

It was reported in Source #113 that, for shallow trap toilets, the peak month percent reduction was the same as the average day percent reduction. Source #171 indicated that, for toilet displacement devices, the peak day reduction equalled the average day reduction. Therefore, for this algorithm, peak day and peak month reductions for toilet devices (measures 3, 4, 5, 6, 7, 8, and 14) are considered to be the same as average day reductions.

For metering, it was reported by source 167 that the peak daily flow reduction for internal residential use was 1.7 times that for average daily flow. This relationship was incorporated directly into the reduction factor tables. It was also reported by source #42 that the peak month exterior residential reduction was 75 percent that of the average daily reduction. This factor was assumed to apply as well to the peak day and hour flow dimensions.

TABLE 4-24

INTERACTION FACTORS AND DATA SOURCES

SOURCE NUMBER	CONSERVATION MEASURES	REPORTED	I_{a-b}*	I_{b-a}
70	Shower-flow Restr., toilet dams, P. aerators/public education (No. Tahoe Public Util. District)	29.7% in IR	I_{2-21} = .789 I_{3-21} = .789 I_{9-21} = .789	I_{21-2} = .917 I_{21-3} = .917 I_{21-9} = .917
118	Restricted Use/Public Education (Westchester Co., NY)	105 mgd, 15% in consumption	I_{18-21} = .934	I_{21-18} = .952
189	Ration/Public Education (L.A., CA)	19% (Goal 10%)	I_{19-21} = .180	I_{21-19} = .580
29	Restricted Use/Ration (Sonora-Jamestown, CA)	67 mgd/ 25% in consumption	I_{18-19} = .55	I_{19-18} = .47

* Subscripts refer to the number assigned to the conservation measure.

Reductions in seasonal exterior residential use reported in sources 116 and 171 indicated a peak seasonal reduction of approximately 1.4 times the average daily flow reduction. This was considered to apply to both restricted use and rationing measures and was assumed to apply to peak daily and hourly flows as well as peak seasonal flow.

For other measures, no relationships were found between peak flow reductions and average daily flow reductions. In these cases, it was concluded that the same reduction factor determined for average daily flow was applicable for peak flow since the same fraction of water use should be affected.

A common conservation option that can be implemented to reduce the peak hourly flow without affecting other dimensions is to regulate the time of day that certain water uses occur. This allows some of the use that normally occurs during the peak hour to occur at another time. The most easily and commonly regulated uses are exterior residential (lawn watering) and public (municipal) use. Thus, the capability of reducing the peak hourly flow rate to reflect regulating the time of use of such flows has been incorporated into the algorithm. If a user desires to enact this option, he must input the percent of peak hourly exterior residential and/or public use that will be removed from the peak hour of the peak day.

5.0 ILLUSTRATIVE EXAMPLES

The methodology developed for the conservation effectiveness module and presented in Section 3.0 was tested by applying it to several hypothetical situations. Three of these cases are included for illustration. In addition, two actual municipal conservation programs have been evaluated and the results obtained from the methodology are compared to the reported reductions in Part 6.0.

5.1 Hypothetical Test Case #1

Consider a 10.1 MGD Average Daily Flow Community initiating in 1983 the use of a moderate program of showerflow restrictors, displacement devices, and a maximum program of public education measures. Evaluate the effectiveness for all water use sectors, and the average day flow dimension, in 1984 and in 1993. Unrestricted projected consumption remains constant over this period.

The breakdown of the 10.1 MGD average daily flow occurs as is input to the algorithm in the following table:

TABLE 5-1

UNRESTRICTED INPUT FLOW

	INT RES	EXT RES	COMMERC	INDUSTR	PUBLIC	UNACCT	TOTAL
FLOW (MGD) 1983							
AVG DAY	3.655	.645	1.600	2.200	.500	1.500	10.100
FLOW (MGD) 1993							
AVG DAY	3.655	.645	1.600	2.200	.500	1.500	10.100

The conditions specified for the conservation measures result in the following input to the algorithm.

TABLE 5-2

EXAMPLE 1

```
MEASURES BEING CONSIDERED

MEASURE NUMBER    2    SHOWER FLOW RESTRICTORS
        INITIATED IN 1983
        TERMINATED IN 1993
        COVERAGE FACTORS     .40    .00    .00    .00    .20    .00
        ANNUAL RATIO OF CHANGE  .900

MEASURE NUMBER    4    DISPLACEMENT DEVICES
        INITIATED IN 1983
        TERMINATED IN 1993
        COVERAGE FACTORS     .50    .00    .50    .00    .50    .00
        ANNUAL RATIO OF CHANGE  .900

MEASURE NUMBER   21    PUBLIC EDUCATION
        INITIATED IN 1983
        TERMINATED IN 1993
        COVERAGE FACTORS     .90    .90    .75    .75   1.00    .00
        ANNUAL RATIO OF CHANGE 1.100
```

The coverage factors and annual ratio of change have been retrieved from the initial coverage matrix (Tables 3-3 through 3-5) from the moderate programs for shower flow restrictors and displacement devices and from the maximum program for public education.

Based upon this input, the algorithm will use the values of reduction factors (Table 3-2) and interactions (Table 3-6) to calculate effectiveness in all six water use categories for 1984 and 1993. These results are shown below:

TABLE 5-3

EXAMPLE 1

EFFECTIVENESS OF CONSERVATION

	INT RES	EXT RES	COMMERC	INDUSTR	PUBLIC	UNACCT	TOTAL
AVERAGE DAILY FLOW 1984							
UNRESTRICTED							
(MGD)	3.655	.645	1.600	2.200	.500	1.500	10.100

TABLE 5-3 (CON'T)
EXAMPLE 1

	INT RES	EXT RES	COMMERC	INDUSTR	PUBLIC	UNACCT	TOTAL
RESTRICTED (MGD)	2.996	.593	1.399	2.053	.416	1.500	8.957
EFFECTIVENESS (MGD)	.659	.052	.201	.147	.084	.000	1.143
EFFECTIVENESS (%)	18.030	8.062	12.562	6.682	16.800	.000	11.317
AVERAGE DAILY FLOW 1993							
UNRESTRICTED (MGD)	3.655	.645	1.600	2.200	.500	1.500	10.100
RESTRICTED (MGD)	3.188	.588	1.421	2.004	.440	1.500	9.141
EFFECTIVENESS (MGD)	.467	.057	.179	.196	.060	.000	.959
EFFECTIVENESS (%)	12.777	8.837	11.187	8.909	12.000	.000	9.495

For further illustration, the calculation of the individual effectiveness determinations are provided below.

For interior residential water use from Table 3-1, $RFACT_2$ = 0.112 for shower flow restrictors. $COVERG_2$ and $AROC_2$ are given in Table 5-2 above as 0.40 and 0.9, respectively. Therefore from Equation 3-5 for 1984:

$$COVER_2 = (0.40)(0.90)^{1-1} = 0.40$$

From Equation 3-1:

$$EFF_2 = (3.655\ MGD)(0.112)(0.40) = 0.1637\ MGD$$

Similarly for displacement devices:

$RFACT_4$ = 0.129 from Table 3-1
$COVERG_4$ = 0.50 from Table 5-2
$AROC_4$ = 0.90 from Table 5-2

$COVER_4 = (0.50)(0.90)^{1-1} = 0.50$ (Eq. 3-5)
$EFF_4 = (3.655\ MGD)(0.129)(0.50)$
$= 0.2357\ MGD$ (Eq. 3-1)

and for public education:

$$RFACT_{21} = 0.089 \text{ from Table 3-1}$$
$$COVERG_{21} = 0.90 \text{ from Table 5-2}$$
$$AROC_{21} = 1.10 \text{ from Table 5-2}$$
$$COVER_{21} = (0.90)(1.1)^{1-1} = 0.90 \qquad \text{(Eq. 3-5)}$$
$$EFF_{21} = (3.655)(.089)(0.90)$$
$$= 0.2923 \text{ MGD} \qquad \text{(Eq. 3-1)}$$

The overall effectiveness for interior residential water use from the three measures is:

$$EFF = EFF_{21} + ACT_{21-4}EFF_4 + ACT_{21-2}ACT_{21-2}EFF_2 \qquad \text{(Eq. 3-11)}$$

From Table 3-6: $ACT_{21-4} = 0.917$, $ACT_{21-2} = 0.917$, and $ACT_{4-2} = 1.0$

Thus:

$$EFF = 0.2923 \text{ MGD}+(.917)(0.2357 \text{ MGD})+(.917)(1.0)(0.1637 \text{ MGD})$$
$$= 0.659 \text{ MGD as was shown in Table 5-3 above.}$$

Similar determinations have been made for the other water use sectors for both 1984 (shown in Table 5-4) and 1993 (shown in Table 5-5).

5.2 Hypothetical Test Case #2

For a community with a present (1983) 10.0 MGD average daily flow, projected to be 14.0 MGD in 1993 and 16.8 MGD in 2003, initiate dual flush toilet installations and public education and pipeline leak repair measures at moderate coverage. Assume that funding for both ongoing management programs ceases in 1990. The pipeline leak repair program is designed to achieve reduction to 10 percent unaccounted-for water by 1988 and to maintain that until it is terminated. Evaluate the effectiveness for all water use sectors and the average daily flow dimension in 1988 and 1998.

The breakdown of the unrestricted average daily flows occur as is input to the algorithm in the following table (Table 5-6). Since more than the first and last year are given the module will calculate flows between 1983 and 1993 or between 1993 and 2003 by linear interpolation.

TABLE 5-4

DETERMINATION OF EFFECTIVENESS - EXAMPLE 1, 1984

Factor	Water Use Sector					
	IRES	ERES	COM	IND	PUB	UNAC
Shower Flow Restrictors (2)						
$RFACT_2$ (Table 3-1)	0.112	0	0	0	0.112	0
$COVERG_2$ (Table 5-2)	0.40	0	0	0	0.20	0
$AROC_2$ (Table 5-2)	0.90	0	0	0	0.90	0
$COVER_2$ (Eq. 3-5)	0.40	0	0	0	0.20	0
EFF_2 (MGD) Eq. 3-1	0.164	0	0	0	0.011	0
Displacement Devices (4)						
$RFACT_4$ (Table 3-1)	0.129	0	0.129	0	0.129	0
$COVERG_4$ (Table 5-2)	0.50	0	0.50	0	0.50	0
$AROC_4$ (Table 5-2)	0.90	0	0.90	0	0.90	0
$COVER_4$ (Eq. 3-5)	0.50	0	0.50	0	0.50	0
EFF_4 (MGD) Eq. 3-1	0.236	0	0.103	0	0.032	
Public Education (21)						
$RFACT_{21}$ (Table 3-1)	0.089	0.089	0.089	0.089	0.089	0
$COVERG_{21}$ (Table 5-2)	0.90	0.90	0.75	0.75	1.00	0
$AROC_{21}$ (Table 5-2)	1.1	1.1	1.1	1.1	1.1	0
$COVER_{21}$ (Eq. 3-5)	0.90	0.90	0.75	0.75	1.00	0
EFF_{21} (MGD) Eq. 3-1	0.293	0.052	0.107	0.147	0.045	0
Overall						
ACT_{21-4} (Table 3-6)	0.917	--	0.917	--	0.917	--
ACT_{21-2} (Table 3-6)	0.917	--	--	--	0.917	--
ACT_{4-2} (Table 3-6)	1.00	--	--	--	1.00	--
EFF (MGD) Eq. 3-11	0.659	0.052	0.201	0.147	0.084	0.0
EFF (%)	18.03	8.06	12.56	6.68	16.80	0.0

TABLE 5-5

DETERMINATION OF EFFECTIVENESS - EXAMPLE 1, 1993

Factor	Water Use Sector					
	IRES	ERES	COM	IND	PUB	UNAC
Shower Flow Restrictors (2)						
$RFACT_2$ (Table 3-1)	0.112	0	0	0	0.112	0
$COVERG_2$ (Table 5-2)	0.40	0	0	0	0.20	0
$AROC_2$ (Table 5-2)	0.90	0	0	0	0.90	0
$COVER_2$ (Eq. 3-5)	0.155	0	0	0	0.077	0
EFF_2 (MGD) Eq. 3-1	0.063	0	0	0	0.004	0
Displacement Devices (4)						
RFACT (Table 3-1)	0.129	0	0.129	0	0.129	0
COVERG (Table 5-2)	0.50	0	0.50	0	0.50	0
AROC (Table 5-2)	0.90	0	0.90	0	0.90	0
$COVER_4$ (Eq. 3-5)	0.194	0	0.194	0	0.194	0
EFF_4 (MGD) Eq. 3-1	0.091	0	0.040	0	0.013	0
Public Education						
$RFACT_{21}$ (Table 3-1)	0.089	0.089	0.089	0.089	0.089	0
$COVERG_{21}$ (Table 5-2)	0.90	0.90	0.75	0.75	1.00	0
$AROC_{21}$ (Table 5-2)	1.1	1.1	1.1	1.1	1.1	0
$COVER_{21}$ (Eq. 3-5)	1.0*	1.0*	1.0*	1.0*	1.0*	0
EFF_{21} (MGD) Eq. 3-1	0.325	0.057	0.142	0.196	0.045	0
Overall						
ACT_{21-4} (Table 3-6)	0.917	--	0.917	--	0.917	--
ACT_{21-2} (Table 3-6)	0.917	--	--	--	0.917	--
ACT_{4-2} (Table 3-6)	1.00	--	--	--	1.00	--
EFF (MGD) Eq. 3-11	0.467	0.057	0.179	0.196	0.060	0
EFF (%)	12.78	8.84	11.19	8.91	12.00	0

* maximum COVER value used in algorithm

TABLE 5-6

EXAMPLE 2

UNRESTRICTED INPUT FLOW

	INT RES	EXT RES	COMMERC	INDUSTR	PUBLIC	UNACCT	TOTAL
FLOW (MGD) 1983							
AVG DAY	3.555	.645	1.600	2.200	.500	1.500	10.000
FLOW (MGD) 2003							
AVG DAY	5.972	1.084	2.688	3.696	.840	2.520	16.800
FLOW (MGD) 1993							
AVG DAY	4.997	.903	2.240	3.080	.700	2.100	14.020

The conditions specified for the conservation measures result in the following input to the algorithm:

TABLE 5-7

EXAMPLE 2

MEASURES BEING CONSIDERED

MEASURE NUMBER 8 DUAL FLUSH TOILETS
INITIATED IN 1983
TERMINATED IN 2003
COVERAGE FACTORS .05 .00 .05 .00 .05 .00
ANNUAL RATIO OF CHANGE .900

MEASURE NUMBER 21 PUBLIC EDUCATION
INITIATED IN 1983
TERMINATED IN 1990
COVERAGE FACTORS .75 .50 .50 .50 .75 .00
ANNUAL RATIO OF CHANGE 1.100

MEASURE NUMBER 16 PIPELINE LEAK REPAIR
INITIATED IN 1983
TERMINATED IN 1990
COVERAGE FACTORS .00 .00 .00 .00 .00 .75
ANNUAL RATIO OF CHANGE 1.000
ACHIEVEMENT GOAL OF 10% FOR YEAR 1988

The coverage factors and annual ratio of change have been taken from the initial coverage matrix (Tables 3-3 through 3-5) from the moderate programs for the three measures. Note that the achievement goal of 10% for the percent unaccounted-for water flow for 1988 has been included.

Based on this input, the algorithm will use the values of reduction factors (Table 3-2) and interactions (Table 3-6) to calculate effectiveness in all six water use categories for 1988 and 1998. These results are shown below.

TABLE 5-8

EXAMPLE 2

EFFECTIVENESS OF CONSERVATION

	INT RES	EXT RES	COMMERC	INDUSTR	PUBLIC	UNACCT	TOTAL
AVERAGE DAILY FLOW 1988							
UNRESTRICTED (MGD)	4.276	.774	1.920	2.640	.600	1.800	12.010
RESTRICTED (MGD)	3.869	.724	1.783	2.468	.543	1.134	10.521
EFFECTIVENESS (MGD)	.407	.050	.137	.172	.057	.666	1.489
EFFECTIVENESS (%)	9.518	6.460	7.135	6.515	9.500	37.000	12.398
AVERAGE DAILY FLOW 1998							
UNRESTRICTED (MGD)	5.368	.974	2.416	3.322	.755	2.265	15.100
RESTRICTED (MGD)	5.223	.958	2.371	3.267	.735	2.089	14.643
EFFECTIVENESS (MGD)	.145	.016	.045	.055	.020	.176	.457
EFFECTIVENESS (%)	2.701	1.643	1.863	1.656	2.649	7.770	3.026

Again, for illustration, the calculation of the effectiveness for interior residential use will be demonstrated for 1998 and unaccounted-for water in 1988.

For interior residential water use from Table 3-1, $RFACT_8$ = 0.190 for dual flush toilets. $COVERG_8$ and $AROC_o$ are given in Table 6-7 as 0.05 and 0.90, respectively. Therefore, from Equation 3-5 for 1998:

$$COVER_8 = (0.05)(0.90)^{15-1} = 0.0114$$

From Equation 3-1:

$$EFF_8 = (FLOW)(0.19)(0.0114)$$

The interpolated unrestricted flow for 1998 is 5.368 MGD, thus:

$$EFF_8 = 0.012 \text{ MGD}$$

Similarly for public education

$RFACT_{21}$ = 0.089 from Table 3-1
$COVERG_{21}$ = 0.75 from Table 5-7
$AROC_{21}$ = 1.1 before 1990 and 0.8 afterwards (Table 3-3)

For 1998:

$$COVER = [COVER_{1990}](0.8)^{7-1} \quad \text{(Eq. 3-5)}$$

$$\text{or } COVER = [(0.75)(1.1)^{8-1}](0.8)^{7-1} = 0.279$$

$$\text{then } EFF_{21} = (5.368 \text{ MGD})(.089)(0.279) = 0.13 \text{ MGD}) \quad \text{(Eq. 3-1)}$$

The pipeline leak repair measure does not impact interior residential use; therefore, the overall effectiveness for the interior residential use category is:

$$EFF = EFF_{21} + ACT_{21-8}EFF_8 \quad \text{(Eq. 3-4)}$$

since ACT_{21-8} = 1.0

EFF = 0.012 MGD + 0.133 = 0.145 which is given in Table 6-8.

For the unaccounted-for water use category, the only measure with an impact is the pipeline leak repair measure. For this measure, the reduction is determined such that the achieved reduction of 10 percent unaccounted-for water (independent of considering any other conservation measures) is met in 1988 and maintained while the measure is in effect.

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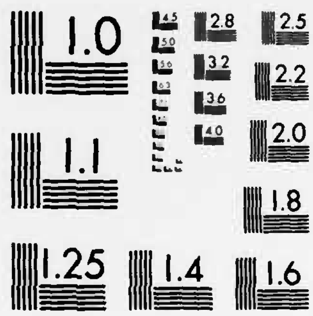

MICROCOPY RESOLUTION TEST CHART
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The unrestricted total flow in 1988 is interpolated linearly between the given flows in 1983 and 1993 and is 12.01 MGD. The similarly determined 1988 unaccounted-for water use is 1.80 MGD. To obtain reduction to the 10 percent unaccounted-for use in 1988, the effectiveness must be such that:

$$\frac{\text{UNACCT (restricted)}}{\text{TOTAL(unrestricted)} - \text{UACCT(effectiveness)}} = 0.10$$

Also, UNACCT (unrestricted) = UNACCT (restricted) + UNACCT (effectiveness).

Since in 1988 the TOTAL (unrestricted) is 12.01 MGD and the UNACCT (unrestricted) is 1.80 MGD, both equations can be solved to determine the effectiveness for unaccounted-for water use as 0.666 MGD. Thus, the restricted unaccounted-for water is 1.80 - 0.666 or 1.134 MGD. These are given in Table 5-8.

Similar determinations have been made for the other water use sectors for both 1988 (shown in Table 5-9) and 1998 (shown in Table 5-10).

TABLE 5-9

DETERMINATION OF EFFECTIVENESS - EXAMPLE 2, 1988

Factor	Water Use Sector					
	IRES	ERES	COM	IND	PUB	UNAC
Dual Flush Toilets (8)						
$RFACT_8$ (Table 3-1)	0.190	0	0.190	0	0.190	0
$COVERG_8$ (Table 6-7)	0.05	0	0.05	0	0.05	0
$AROC_8$ (Table 6-7)	0.90	0	0.90	0	0.90	0
$COVER_8$ (Eq. 3-5)	0.033	0	0.033	0	0.033	0
EFF_8 (MGD) Eq. 3-1	0.027	0	0.012	0	0.004	0
Public Education (21)						
$RFACT_{21}$ (Table 3-1)	0.089	0.089	0.089	0.089	0.089	0
$COVERG_{21}$ (Table 6-7)	0.75	0.50	0.50	0.50	0.75	0
$AROC_{21}$ (Table 3-3)	1.1	1.1	1.1	1.1	1.1	0
$COVER_{21}$ (Eq. 3-5)	1.0*	0.73	0.73	0.73	1.0*	0
EFF_{21} (MGD) Eq. 3-1	0.381	0.050	0.125	0.172	0.053	0
Pipeline Leak Repair (16)						
% UNACCT	0	0	0	0	0	10
UNACCT (unrestricted)	0	0	0	0	0	1.80
TOTAL (unrestricted)	0	0	0	0	0	12.01
UNACCT (restricted)	0	0	0	0	0	1.134
EFF_{16} (MGD)	0	0	0	0	0	0.666
Overall						
ACT_{21-8} (Table 3-6)	1.0	--	1.0	--	1.0	--
EFF (MGD) Eq. 3-4	0.407	0.050	0.137	0.172	0.057	0.666
EFF (%)	9.52	6.46	7.14	6.52	9.50	37.00

TABLE 5-10

DETERMINATION OF EFFECTIVENESS - EXAMPLE 2, 1998

Factor	Water Use Sector					
Dual Flush Toilets (8)						
$RFACT_8$ (Table 3-1)	0.190	0	0.190	0	0.190	0
$COVERG_8$ (Table 6-7)	0.05	0	0.05	0	0.05	0
$AROC_8$ (Table 6-7)	0.90	0	0.90	0	0.90	0
$COVER_8$ (Eq. 3-5)	0.011	0	0.011	0	0.011	0
EFF_8 (MGD) Eq. 3-1	0.012	0	0.004	0	0.002	0
Public Education (21)						
$RFACT_{21}$ (Table 3-1)	0.089	0.089	0.089	0.089	0.089	0
$COVERG_{21}$ (Table 6-7)	0.75	0.50	0.50	0.50	0.75	0
$AROC_{21}$ (Table 3-3)	0.80	0.80	0.80	0.80	0.80	0
$COVER_{21}$ (Eq. 3-5)	0.279	0.186	0.186	0.186	0.279	0
EFF_{21} (MGD) Eq. 3-1	0.133	0.016	0.040	0.055	0.019	0
Pipeline Leak Repair (16)						
% UNACCT	0	0	0	0	0	14.00
UNACCT (unrestricted)	0	0	0	0	0	2.265
TOTAL (unrestricted)	0	0	0	0	0	15.100
UNACCT (restricted)	0	0	0	0	0	2.089
EFF_{16} (MGD)	0	0	0	0	0	0.176
Overall						
ACT_{21-8} (Table 3-6)	1.0	--	1.0	--	1.0	--
EFF (MGD) Eq. 3-4	0.145	0.016	0.045	0.055	0.020	0.176
	2.70	1.64	1.86	1.66	2.65	7.77

6.0 VERIFICATION

The water conservation effectiveness module was verified by applying it to two actual multiple measure water conservation programs that have been reported in the literature. These test cases were in Westchester County, New York, and in Hamilton Township, New Jersey.

6.1 Westchester County, New York

Westchester County, NY, with an unrestricted flow of 105 MGD, implemented a mandatory restricted use program and a strong public education program during a drought emergency in 1980-81. As of the end of the program in April 1981, the county reported they had achieved a 15% cutback in total water use.

For the purposes of using the water conservation effectiveness module, the 105 MGD unrestricted demand was accorded to the six water use categories consistent with the percentages indicated in Table 4-2. These data are reported in Table 6-1. Because the restricted use program was mandatory and the strong public education was initiated during a drought emergency, the maximum program coverage values were selected from Tables 3-3 through 3-5. No change in unrestricted flow was assumed between 1980 and 1981. Because no specific measures were taken to reorient exterior residential or public use, no reduction in peak hourly use through that option was considered. The input data for the restricted use and public education measures are shown in Table 6-2.

The conservation effectiveness module, as shown in Table 6-3, predicts a water conservation effectiveness of 16.67 MGD or 16.4%. This is compared to the actual reported value of 15.0%.

TABLE 6-1

WESTCHESTER COUNTY, NEW YORK

UNRESTRICTED INPUT FLOW

	INT RES	EXT RES	COMMERC	INDUSTR	PUBLIC	UNACCT	TOTAL
FLOW (MGD) 1980							
AVG DAY	38.380	6.770	12.180	23.100	5.250	15.750	101.430
FLOW (MGD) 1985							
AVG DAY	38.380	6.770	12.180	23.100	5.250	15.750	101.430

TABLE 6-2

WESTCHESTER COUNTY, NEW YORK

MEASURES BEING CONSIDERED

MEASURE NUMBER 18 RESTRICTED USES
INITIATED IN 1980
TERMINATED IN 1985
COVERAGE FACTORS .00 1.00 1.00 1.00 1.00 .00
ANNUAL RATE OF CHANGE 1.000
PEAK HOUR REDUCTION EXT RES = .00 PUBLIC = .00

MEASURE NUMBER 21 PUBLIC EDUCATION
INITIATED IN 1980
TERMINATED IN 1985
COVERAGE FACTORS .90 .90 .75 .75 1.00 .00
ANNUAL RATE OF CHANGE 1.100

TABLE 6-3

WESTCHESTER COUNTY, NEW YORK

EFFECTIVENESS OF CONSERVATION

	INT RES	EXT RES	COMMERC	INDUSTR	PUBLIC	UNACCT	TOTAL
AVERAGE DAILY FLOW 1981							
UNRESTRICTED (MGD)	38.380	6.770	12.180	23.100	5.250	15.750	101.430
RESTRICTED (MGD)	35.306	4.767	8.729	16.555	3.653	15.750	84.760
EFFECTIVENESS (MGD)	3.074	2.003	3.451	6.545	1.597	.000	16.670
EFFECTIVENESS (%)	8.009	29.586	28.333	28.333	30.419	.000	16.435

6.2 Hamilton Township, New Jersey

Hamilton Township initiated a program of distributing water saving devices (toilet dams and low flow showerheads) as well as public education literature to all its residential customers in early 1978. No effort was made to reach other use categories. The township reported a reduction of 9.4% in its total use as compared to the year before. Unrestricted average daily flow in 1977 was 5.275 MGD. The township also reported coverage factors of 0.65 for low flow showerheads and 0.51 for toilet dams.

Again, the 5.275 MGD average daily flow was distributed among the six water use categories in accordance with the percentages indicated in Table 4-2. These data are reported in Table 6-4. Coverage factors were used as reported for the low flow showerheads and toilet dams and for a maximum program for public education, but were applied only to residential water use categories to remain consistent with how the program was conducted. The input data for the three conservation measures are given in Table 6-5.

As shown in Table 6-6, the water conservation effectiveness module predicts a conservation effectiveness of 0.453 MGD or 8.6%. This is compared to the actual reported reduction for Hamilton Township of 9.4%.

TABLE 6-4

HAMILTON TOWNSHIP, NEW JERSEY

UNRESTRICTED INPUT FLOW

	INT RES	EXT RES	COMMERC	INDUSTR	PUBLIC	UNACCT	TOTAL
FLOW (MGD) 1977							
AVG DAY	1.938	.340	.844	1.101	.264	.792	5.279
FLOW (MGD) 1979							
AVG DAY	1.938	.340	.844	1.101	.264	.792	5.279

TABLE 6-5

HAMILTON TOWNSHIP, NEW JERSEY

MEASURES BEING CONSIDERED

```
MEASURE NUMBER     1     LOW FLOW SHOWERHEADS
        INITIATED IN 1978
        TERMINATED IN 1979
        COVERAGE FACTORS     .64    .00    .00    .00    .00    .00
        ANNUAL RATE OF CHANGE 1.000

MEASURE NUMBER     3     TOILET DAMS
        INITIATED IN 1978
        TERMINATED IN 1979
        COVERAGE FACTORS     .51    .00    .00    .00    .00    .00
        ANNUAL RATE OF CHANGE  .900

MEASURE NUMBER    21     PUBLIC EDUCATION
        INITIATED IN 1978
        TERMINATED IN 1979
        COVERAGE FACTORS    1.00   1.00    .00    .00    .00    .00
        ANNUAL RATE OF CHANGE 1.100
```

TABLE 6-6

HAMILTON TOWNSHIP, NEW JERSEY

EFFECTIVENESS OF CONSERVATION

	INT RES	EXT RES	COMMERC	INDUSTR	PUBLIC	UNACCT	TOTAL
AVERAGE DAILY FLOW 1979							
UNRESTRICTED							
(MGD)	1.938	.340	.844	1.101	.264	.792	5.279
RESTRICTED							
(MGD)	1.515	.310	.844	1.101	.264	.792	4.826
EFFECTIVENESS							
(MGD)	.423	.030	.000	.000	.000	.000	.453
EFFECTIVENESS							
(%)	21.827	8.824	.000	.000	.000	.000	8.581

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