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Water Conservation and Supply Information Transfer and Analysis Program

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The information contained in this volume is designed to assist planners in the application of the planning methodology described in The Evaluation of Water Conservation for Municipal and Industrial Water Supply: Procedures Manual. The primary objectives of this volume are to update and revise the existing Annotated Bibliography on Water Conservation, making it a more useful reference for planners, and also to identify, describe, and discuss the underlying rationale, special problems, and useful sources of information for each of the required steps in the Procedures Manual.

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FOR WATER SUPPLY AND CONSERVATION TECHNIQUES

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TABLE OF CONTENTS

PREFACE

The information contained in this volume is designed to assist planners in the application of the planning methodology described in The Evaluation of Water Conservation for Municipal and Industrial Water Supply: Procedures Manual (Procedures Manual). The primary objectives of this volume were: (1) to update and revise the existing Annotated Bibliography on Water Conservation in order to make it a more useful reference for planners; and (2) to identify, describe, and discuss the underlying rationale, special problems, and useful sources of information for each of the required steps in the Procedures Manual.

Chapter I is a concise introduction of water conservation planning organized under five headings: (1) Introduction, (2) Water Conservation Defined, (3) The Procedure: An Overview, (4) Federal Guidelines and Corps' Engineer Regulations, and (5) Format of Report. Chapters II, III, and IV refer to each of three major tasks of the general procedure: (1) Measure-Specific Analysis, (2) Evaluation of water conservation measures, and (3) Integration of water conservation into water supply plans. Each of the three chapters contains an overview of each particular step, describing all issues common for the steps under consideration, followed by a description of each step in terms of (1) the underlying rationale or purpose, (2) the identification of major issues and problems, and (3) a brief presentation of available exemplary and useful references relevant to the step.

A comprehensive survey of available literature relevant to water conservation was initiated in May 1981. Information was obtained from published and unpublished sources including governmental manuals, research reports, theses and doctoral dissertations, and proceedings of conferences. Three computer literature searches of three independent data bases were conducted resulting in over 2,000 references which pertain to water conservation. In addition, the 54 state water resources research centers, supported by the U.S. Office of Water Resources and Technology, were contacted to obtain their recent reports and documents. Forty-eight of the centers replied and provided an additional 83 publications that were relevant to water conservation. Finally, a personal inspection was made of the major water resources and engineering journals published since 1977, the date of the publication of the last annotated bibliography.

Of the more than 2,000 sources of information that were reviewed, only those that were considered most helpful in the implementation of the steps identified in the Procedures Manual were selected for publication in this volume. The 308 selected references are annotated and arranged in alphabetical order as Appendix A of the report. A subject index of each of the references according to their relevance to each of the steps in the Procedures Manual appears prior to Appendix A. A periodical index and an author index are included at the end of the volume.

CHAPTER I
WATER CONSERVATION PLANNING

INTRODUCTION

Water conservation planning has captured national prominence in resource planning and management and is likely to play an important role in water resources planning in the future. It is reasonable to assume that the full implications of conservation in an engineering, economic, social, and environmental sense are not fully understood and that further research and experience will provide useful information. The Task Committee on Water Conservation of the Water Resources Planning Committee of American Society of Civil Engineers (ASCE) in 1981 noted: "[there are] many areas of water conservation in which our knowledge of technology, impact assessment, and plan evaluation is insufficient to permit rational comparison of water conservation alternatives with alternatives involving the development of new water supplies."

These deficiencies can be eliminated to a large extent by realizing that water conservation is only a part of the broader objective of total water management and as such should be looked at through Federal planning principles described in Principles and Standards for Planning Water and Related Land Resources (Principles and Standards). This would significantly help resolve the problem of plan evaluation. Undoubtedly, many technical and environmental aspects of water conservation need to be further explored; however, these shortcomings are present to a comparable degree in consideration of the full range of structural as well as non-structural alternatives.

The role of water conservation in the planning and management of municipal and industrial water supply is likely to become increasingly attractive. The costs of augmenting existing supplies have risen enormously and will likely continue. In addition, the choices have been severely constrained because of several factors: the scarcity of new reservoir sites; higher standards for environmental quality; the inadequacy of groundwater; and political and institutional constraints, particularly with respect to interbasin transfers. Nevertheless, the demand for urban water continues to rise, especially in those areas of the country experiencing rapid growth.

The potential of water conservation in the future was recognized by the Water Resources Research Review Committee, National Research Council. The committee identified the need for more research in order to evaluate better the beneficial and adverse effects of potential conservation measures. Moreover, the President's Intergovernmental Water Policy Task Force (1980) concluded that by the year 2000, approximately 75 to 110 billion dollars will be needed for urban water supply in the United States, with 20-25 billion needed for new supplies. Hence, there is an attractiveness toward those measures that modify or obviate the need for new supplies. Those measures are expected to become increasingly competitive.

WATER CONSERVATION DEFINED

Comprehensive water supply planning requires the evaluation of two basic sets of alternatives: (1) those alternatives that reduce water use and/or loss; and (2) those alternatives that augment supply. The objective is to determine the optimum combination of alternatives in planning for future urban water supply. An immediate question arises concerning the first set of alternatives, those commonly referred to as conservation: Should all alternatives or measures that reduce water use or loss be implemented? And, if so, to what extent; that is, how much reduction in water use? Answers to these very basic questions require a precise and practical definition of water conservation.

Only those measures that reduce the use, or loss, of water without disproportionately increasing the use of other resources can qualify as a conservation measure. Simply stated, for each conservation measure, the total beneficial effects of the reduction in water use and/or water losses must be greater than total adverse effects.

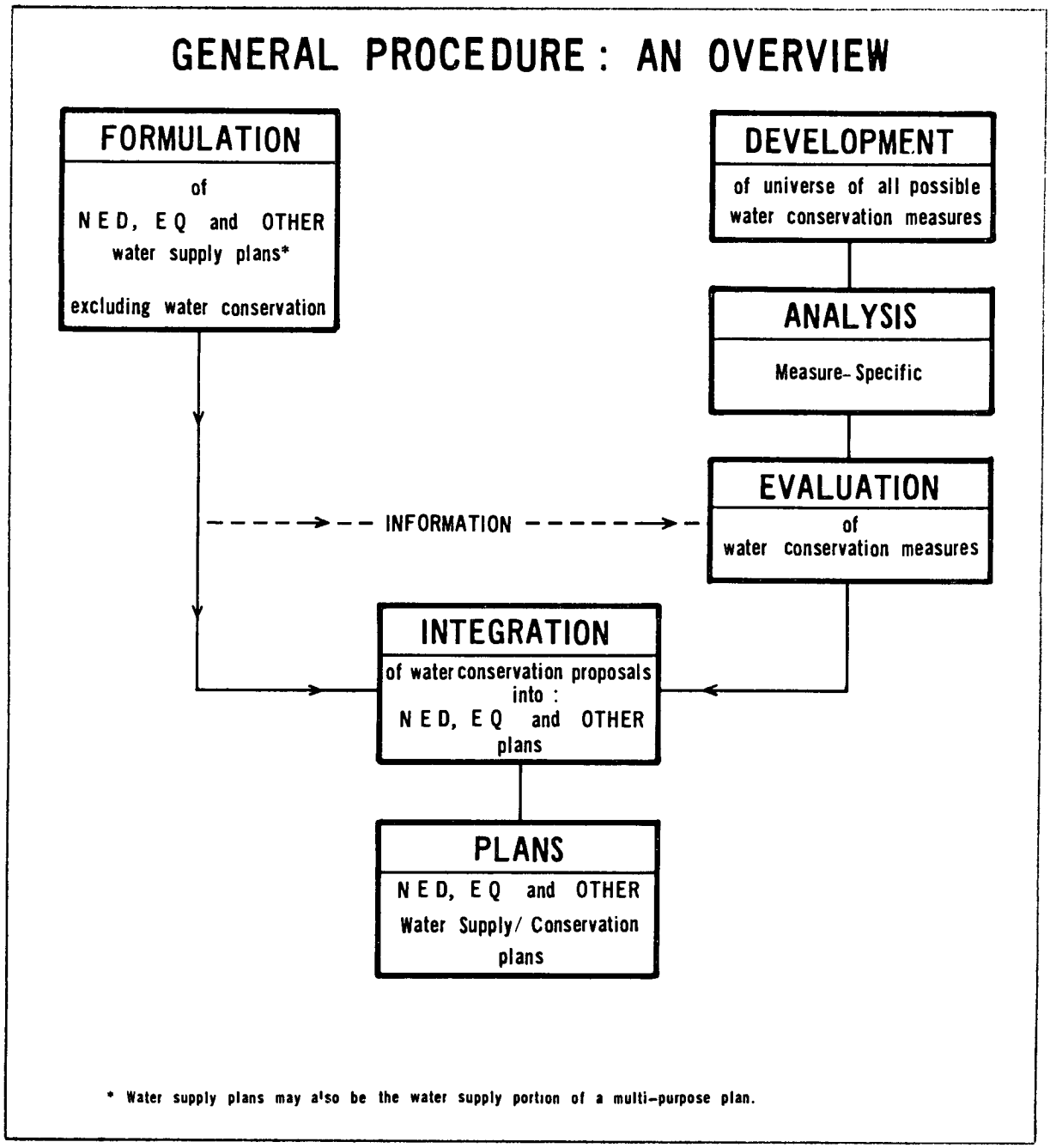
Therefore, water conservation is defined as any beneficial reduction in water use or water loss. More specifically, the potential conservation measure must result in water use (or loss) that is less than it would have been had the measure not been implemented. The end result is in the reduction of water use (or loss) so that a segment of existing or future water supply is available for uses that otherwise would not have been served except by the provision of new supplies. Then the question is raised as to whether or not the reduction in water use (or loss) is beneficial. That is, in order to qualify as a conservation measure, does implementation of the measure result in a net positive contribution to the National Economic Development (NED) objective, the Environmental Quality (EQ) objective, or both.

THE PROCEDURE: AN OVERVIEW

The U.S. Army Corps of Engineers, recognizing the potential value of water conservation, has developed a planning procedure which would serve to adequately and fairly evaluate the conditions under which water conservation should be implemented. The Evaluation of Water Conservation for Municipal and Industrial Water Supply: Procedures Manual (Procedures Manual) describes the concepts, procedures, and measurement techniques that can be used in developing and evaluating water conservation proposals applicable to municipal and industrial uses of water. The present volume further elaborates on this procedure by providing an information base for transferring the latest information and technology into direct application.

The method (Fig. 1) described in the Procedures Manual was developed to formulate the optimum combination of supply augmentation and demand reduction alternatives. The extent to which water conservation measures should be included in a particular water supply plan is determined by evaluating each possible conservation measure against that plan, identifying and measuring the advantageous and disadvantageous effects. The method consists of three basic phases. Prior to initiating the first

FIGURE 1


GENERAL PROCEDURE : AN OVERVIEW
FORMULATION
of
N E D, E Q and OTHER
water supply plans*
excluding water conservation
DEVELOPMENT
of universe of all possible
water conservation measures
ANALYSIS
Measure-Specific
EVALUATION
of
water conservation measures
INFORMATION
INTEGRATION
of water conservation proposals
into :
N E D, E Q and OTHER
plans
PLANS
N E D, E Q and OTHER
Water Supply/ Conservation
plans
* Water supply plans may also be the water supply portion of a multi-purpose plan.

phase, a list of all possible water conservation measures is developed for subsequent analysis.

Measure-Specific Analysis

The first phase is the Measure-Specific Analysis. The characteristics and effects of each potential measure are identified independent of the water supply plans. Those measures that are technically feasible and environmentally applicable to the study area are selected. The others are excluded. Investigation of the social acceptability of the remaining measures may further result in excluding some as unacceptable. The remaining potential water conservation measures are further analyzed to determine the implementation conditions, the effectiveness of each measure (that is, the amount of expected water-use reduction if implemented), and the specific advantageous and disadvantageous effects. In summary, the water conservation measures that pass the test of applicability, the test of technical feasibility, and the test of social acceptability, become the potential water conservation measures that, if implemented, could be expected to reduce water use. It then remains to determine whether or not they would be beneficial; hence, those measure-specific disadvantageous effects (e.g., implementation costs, negative environmental effects, and consumer dissatisfaction) and the advantageous effects need to be identified, independent of the characteristics of any water supply plans.

Evaluation

The second phase is labelled Evaluation, which now analyzes the effects of the conservation measures with respect to the characteristics of the specific water supply plans. To each of the remaining potential water conservation measures, determined in the Measure-Specific Analysis, are now added the costs, cost-savings, and other information to obtain additional and final advantageous and disadvantageous effects of both NED and EQ objectives that result from reduced water use. Supply costs are analyzed to obtain a separate supply-cost/water-use reduction relationship for each water supply plan under consideration. Then the estimate of effectiveness for each potential conservation measure is used to determine the foregone supply cost for each water supply plan.

Stated differently, each potential water conservation measure is evaluated with respect to the extent of modification of each alternative Federal water supply plan thereby giving the remaining advantageous and disadvantageous effects of that measure. The net advantage with respect to the NED objective and with respect to the EQ objective can now be determined for each conservation measure <u>when implemented alone</u>, assuming a particular water supply plan.

Integration

The third major phase is Integration, the process of integrating water conservation into the Federal plans. The first step is to arrange the eligible water conservation measures in merit order according to the advantageous and disadvantageous effects. The first conservation measure in a merit order is the measure which, when implemented alone, would provide the largest net contribution to the relevant objective, e.g., NED or EQ. Individual conservation measures are then added one at a time in decreasing merit order. When the net contribution to the relevant objective reaches a maximum, the trial proposal becomes the final proposal, and is integrated into the water supply plan. The advantageous and disadvantageous effects of the included measures, adjusted for interactions, alter the beneficial and adverse effects of the water supply plan to produce the beneficial and adverse effects of the combined water/conservation plan.

Water Supply/Conservation Plan Performance under Drought

The final test is the reliability of the plan during the planning period assuming design drought conditions. The extent of severity of measures required for supply plans that incorporate conservation should not exceed those for the corresponding supply plan without conservation. If they do, then the supply should be increased to achieve the same level of assurance.

FEDERAL GUIDELINES AND CORPS' ENGINEER REGULATIONS

Federal Legislation Affecting the Corps' Role in Municipal and Industrial Water Supply

Several Congressional Acts have affected the Corps' role in municipal and industrial water supply. The Corps has the authority to provide municipal and industrial water supply storage in existing and proposed multiple-purpose projects. The user is required to pay the cost allocated to such storage. A summary of these acts is provided below. The ultimate basis for Corps involvement is contained in the Water Supply Act of 1958, as amended.

Flood Control Act of 1944. The Secretary of the Army was authorized to sell surplus impounded water in Corps projects.

Water Supply Act of 1958 (PL85-500 Title III). This act provides for the addition of municipal and industrial water supply storage space at any time. The storage must be the least cost alternative for providing the supply. The local or state interests must contract with the Corps for payment of the costs allocated to water supply within the life of the project and within 50 years after the water supply storage is first used. The local interests are given a permanent right to use the storage after payments are complete.

Northeastern Water Supply Studies (PL89-2981, October 1965). Congress authorized the Corps to conduct a regional water supply study for the northeastern United States. The study determined the adequacy of future water supplies in this area.

Other Special Authorities

Water Resources Development Act of 1974 (PL93-251). Section 82 of this Act gave authority to the Chief of Engineers to provide emergency water supplies when existing supplies are contaminated and are a threat to public health and welfare.

Disaster Relief Act of 1974 Appropriations (PL95-51). This Act provides the Secretary of the Army acting through the Chief of Engineers authority under certain statutory conditions to construct wells and to transport water to farmers, ranchers, and political subdivisions within areas the Chief determines to be drought distressed.

Corps' Engineer Regulations and Manuals

ER 500-2-2. This regulation provides guidance with respect to use of the authority to provide emergency water supplies under Section 82 of the Water Resources Development Act of 1974.

ER 1105-2-141. This regulation provides contract formats for use in contracting with non-Federal interests for water supply from Corps of Engineers projects. Article 7 of the water storage contract and Article 1(3) of the water withdrawal contract both provide for water conservation by requiring a "management plan which incorporates loss reduction measures and demand management practices which ensure that the available supply is used in an economically efficient and environmentally sensitive manner." Time phased measures must be specified and provisions made for their implementation. The plan is to be reviewed at intervals not to exceed five years.

ER 1110-2-1941. This ER provides policy and guidance for the preparation of drought contingency plans as an integral part of the Corps of Engineers overall water control management plans. Drought contingency plans must be developed for Corps projects. One aspect of these plans is the provision of rank-order actions based on the conservation-effectiveness of the options. Water conservation measures could play a very definitive role in these plans.

ER 1130-2-417. This ER provides guidance and procedures on requirements for major rehabilitation or modifications for dam safety at completed Corps projects.

ER 1165-2-105. The manual describes policies for the inclusion of municipal and industrial water supply in reservoir projects under the jurisdiction of the Chief of Engineers. It is applicable to all elements of Corps of Engineers performing civil works functions.

Principles and Standards--Water Conservation Alternatives

The Principles and Standards has been revised during the last two years. As a result of these revisions, water conservation has been "fully integrated into project and program planning and review as a means of achieving both the NED and EQ objectives." Water conservation is defined as actions that (1) reduce the demand for water, (2) improve efficiency in use and reduce losses and waste, and (3) improve land management practices to conserve water. The specific section of the Principles and Standards that addresses municipal and industrial water conservation is shown in Table 1. Table 2 includes procedures for the evaluation of national economic development benefits involving water conservation.

FORMAT OF REPORT

The purpose of this volume is designed to assist planners in the application of the method described in the Procedures Manual. There are 16 steps required to complete the three major phases of the procedure. The major purpose, rationale, and salient problems are described for each of the three major phases: (1) Measure-Specific Analysis, (2) Evaluation, and (3) Integration. Likewise, for each of the 16 steps under the major phases, similar information is provided: (1) the rationale and major purpose of the step; (2) salient problems or issues, presented in the form of questions and answers; and, finally, (3) the most useful references for each step.

The appendix of the report contains an annotated bibliography which consists of the revised abstracts of the original Annotated Bibliography on Water Conservation with the inclusion of new publications accumulated since 1978. To further assist the planner, the references in the annotated bibliography are indexed by subject, author, and journal.

The first index entitled Subject Classification Index, which appears prior to Appendix A, is comprised of a list of all 308 references arranged in alphabetical order by author. The order exactly matches their placement in the annotated bibliography. All abstracts are numbered, assigned to specific steps in the Procedures Manual, and also classified by means of 9 general content categories. Moreover, a second index is in the form of a matrix, the Cross-Reference Matrix, which is a further condensation of the Subject Classification Index whereby the most relevant sources are indicated by abstract number. The third and fourth indices are located at the end of the volume. The third index, the Periodical Index, identifies all journals and three other types of published materials included in the bibliography by page number; and finally, the fourth index or conventional Author Index includes the names of all authors and the corresponding page number of their publication.

TABLE 1
WATER CONSERVATION SECTION
FROM PRINCIPLES AND STANDARDS

Subpart E—Alternative Plans

§ 711.50 General.

(e) Water conservation is to be fully integrated into plan formulation as a means of achieving NED and EQ objectives. Water conservation consists of actions that will—

(1) Reduce the demand for water;

(2) Improve efficiency in use and reduce losses and waste; and/or

(3) Improve land management practices to conserve water.

A clear contrast is drawn between the above conservation elements and storage facilities. A range of measures that can, over time, balance water demand for various purposes with water availability is to be considered.

SOURCE: Federal Register, Water Resources Council, Part II, Vol. 45, No. 190, September 29, 1980.

TABLE 2
PROCEDURES FOR EVALUATION OF
NED BENEFITS INVOLVING WATER CONSERVATION
FROM PRINCIPLES AND STANDARDS

§ 713.115 Evaluation procedure: Identify the deficit between future water supplies and use.

Projected water use shall be compared with future water supplies to determine whether any deficits exist in the study area. An analysis shall be made of the intensity, frequency, and duration of the expected deficits. Deficits shall be addressed in three basic options: (a) Reduce projected water use by implementation of nonstructural or conservation measures that are not part of the without-project condition; (b) increase and/or more efficiently use water supplies through structural measures; and (c) accept and plan to manage water supply shortages. Plans generally are formulated to include some or all of these options.

§ 713.123 Evaluation procedure: Compute M&I water supply annual benefits.

(a) Annualized benefits of the Federal water supply plan are equal to the cost of the most likely alternative. When applicable, the evaluation shall reflect differences in treatment, distribution, and other costs compared to the most likely alternative.

(b) The alternative cost of providing a water supply for smaller communities (population of 10,000 or less) may be extremely expensive on a per capita basis because these communities lack the efficiencies of large scale development. If such communities are not able to afford an alternative water supply comparable to the Federal water supply plan as identified in the procedure described above, that alternative may not be used as the basis for evaluating the benefits of the Federal water supply plan. In this case, the benefit shall be equal to the cost of the separable M&I facilities plus an appropriate share of the remaining joint cost of the project. Documentation of the without-project condition shall be provided.

SOURCE: Federal Register, Water Resources Council, Part IX, Vol. 44, No. 242, December 14, 1979.

CHAPTER II
MEASURE-SPECIFIC ANALYSIS

INTRODUCTION

The term "water conservation measure" applies to a large and dissimilar group of regulations, devices, practices, and other measures having one common characteristic: each reduces water use in a way that is judged to be beneficial to the interests of society. Water conservation planning consists of finding that set of measures which is both feasible (providing a beneficial reduction in water use) and optimal (yielding the largest possible combined net beneficial effect).

Water conservation planning within the Corps of Engineers is normally conducted as a part of water supply planning. Its purpose, in this application, is to provide a balanced treatment of supply and demand management measures, so that supply augmentation is considered alongside possibilities for more efficient utilization of present and future supplies. Optimal water supply/conservation plans are those which combine supply augmentation and conservation measures in a way which results in the largest possible net beneficial effect. The complex and multi-objective nature of water supply planning, however, often leads to the development of several alternative supply plans, differing in their contributions to economic efficiency, environmental quality, and other social goals. Since the contribution of water conservation to these goals depends on the nature of the supply increment which conservation replaces, alternative supply plans imply alternative conservation plans.

Various possible regulations, devices, practices, and programs must therefore be subjected to several levels of analysis. They must be screened for those activities or requirements which (1) can be implemented in the study area, (2) actually reduce water use, (3) provide net beneficial effects, and (4) should be included in a particular water supply/conservation plan. In principle, this process must be repeated for each alternative plan. In practice, much of the analysis is common to all plans and need be undertaken only once for any particular planning activity. Also, some parts of the overall analysis can be arranged in a way which minimizes the analytical effort devoted to measures which are not subsequently included in a plan.

These considerations lead to the notion of Measure-Specific Analysis, consisting of all those steps which are common to all alternative plans. In each planning application, Measure-Specific Analysis is undertaken only once and provides a set of possible water conservation measures, fully described and documented with the exception of effects which depend on the characteristics of a particular water supply plan. Measure-Specific Analysis is divided into eight discreet steps. The first three steps provide a coarse screen, designed to eliminate all those measures clearly not feasible in the planning area. Alternative measures are defined very broadly at this point as to minimize analytical effort. Beginning with Step 4, which identifies potential water conservation

measures, each measure is defined in considerable detail, as required by the steps which follow.

Water conservation measures have many different effects, some representing positive movements toward social goals, some negative in their impact. Water supply measures also result in positive and negative impacts, termed beneficial and adverse effects, respectively. Since one of the major positive effects of water conservation is a reduction in the adverse effects of water supply, there is some potential for confusion in terminology when water conservation and water supply plans are integrated. To minimize this possibility, the Procedures Manual refers to the positive effects of water conservation measures as advantageous effects; the negative effects are referred to as disadvantageous effects. These advantageous and disadvantageous effects are ultimately combined with the effects of the water supply measures to give the beneficial and adverse effects of the water supply/conservation plan or plans.

STEP 1--DETERMINATION OF APPLICABLE MEASURES

Purpose

The universe of all possible water conservation measures includes a great variety of regulations, devices, practices, and programs, many of which will not be selected for implementation for one or more reasons. The purpose of Step 1 is to move as quickly and efficiently as possible from the full range of possibilities to those measures which require specific analysis. This is done by defining all possible measures broadly, and by applying the three-point test of applicability given in the Procedures Manual, Section 4-3.

Issues and Problems

1. *How broadly can possible measures be defined at Step 1?*

   The starting point is Table 3-1 in the Procedures Manual. Categories shown there may be further subdivided as necessary to provide unambiguous answers to the applicability tests of Section 4-3. No further detail is needed at this time.

2. *Suppose that a conservation-oriented plumbing code has been implemented in one community within the planning area, but not elsewhere?*

   The plumbing code measure is then subdivided into a plumbing code for the community in question and a plumbing code for all other communities. The first subdivision is not applicable due to prior implementation; the second subdivision is applicable.

3. *Can a water supply/conservation plan include water conservation measures that a community would have implemented in the future without the plan?*

The principle to be applied here is the same as that applying to supply augmentation measures--measures for which definite commitments for future implementation have been made are part of the "without project" condition and are not analyzed. These measures are ruled not applicable at Step 1. They must be considered in the water-use forecast used in Step 6, however.

Exemplary References

Listings of all possible water conservation measures are indispensable in this step. These can be drawn from Flack (1981), U.S. Environmental Protection Agency (U.S. EPA) (1980), New England River Basins Commission (1980b), Stone (1978), Schaefer (1979), Lattie and Vossbrink (1977), Fletcher and Sharpe (1978), Milne (1976, 1979), and Minton, Williams, and Murdock (1979). In some of the above references, conservation measures are categorized into groups. Flack (1981) distinguishes four broad categories: (1) structural--metering, flow control devices, recycling systems and horticultural changes; (2) operational--leakage detection, water-use restrictions, and pressure reduction; (3) economic--pricing policy, incentives (such as rebates, tax credits, or subsidies), penalties and demand metering; and (4) socio-political--public education and laws. In the Procedures Manual, conservation measures are categorized into three major classes according to the originating action, i.e., measures resulting from (1) regulatory actions, (2) management actions, and (3) regulatory efforts. This classification scheme is used in Table 3 which lists various water conservation techniques reported in the literature. This list should be consulted while preparing an initial array of applicable measures.

STEP 2--DETERMINATION OF TECHNICAL FEASIBILITY

Purpose

For applicable measures to merit further consideration, they must, when implemented, be capable of producing a reduction in water use. Estimating and forecasting the magnitude of that reduction requires detailed analysis which is undertaken in Step 6. The purpose of Step 2 is to eliminate categories of measures which will clearly not result in water-use reduction, as calculated in Step 6. Step 2 also serves the function of identifying areas where existing knowledge may be insufficient to determine technical feasibility or effectiveness. These measures are retained as potentially feasible pending further data collection and analysis.

TABLE 3
ILLUSTRATIVE LISTS OF
WATER CONSERVATION MEASURES

MANAGEMENT

METERING
METER MAINTENANCE
PRESSURE REGULATION
LEAK DETECTION AND REPAIR
SYSTEM REHABILITATION
PRICING (CONSERVATION ORIENTED)
- marginal cost pricing
- seasonal peak load pricing
- uniform unit pricing
- demand charges
- summer surcharge
- excess-use charge
- increasing unit
- hook-up fees
- penalty charges

ECONOMIC INCENTIVES
- rebates
- tax credits
- subsidies
- penalties

IMPLEMENTING WATER-SAVING DEVICES
- Devices for new construction
  - shallow trap toilet
  - pressurized tank toilet
  - vacuum toilet
  - incinerator toilet
  - pressurized flush toilet
  - wastewater recycling toilet
  - oil flush toilet
  - freeze toilet
  - packaging toilet
  - composter toilet
  - dual flush toilet
  - micropore toilet
  - premixed water system
  - water recycling system
  - compressed air toilet
- Retrofit devices
  - water closet inserts
  - water dams
  - toilet flush adapters
  - flush valve toilets
  - shower mixing valves
  - shower flow-control devices
  - air-assisted showerheads
  - pressure-reducing valves
  - toilet inserts
  - facet aerators
  - faucet flow restrictors
  - spray taps
  - pressure balancing mixing valves
  - hot water pipe insulation
  - swimming pool covers
  - low water-using dishwashers
  - low flush toilets
  - thermostatic mixing valves
  - minuse showers
  - low flow showerheads
  - low water-using clotheswashers
- Devices for landscape irrigation
  - moisture sensors
  - hose meters
  - sprinkler timers

Distribution of water conservation kits
Free distribution and installation of water-saving devices
Distribution of leak detection kits
Reuse of water works facility washwater

TABLE 3
ILLUSTRATIVE LISTS OF
WATER CONSERVATION MEASURES
(Cont.)

REGULATIONS

FEDERAL AND STATE LAWS AND POLICIES
LOCAL CODES AND ORDINANCES
- plumbing codes for new structures
- retrofitting resolutions
- sprinkling ordinances
- changes in landscape design
  - reduction in lawn sizes
  - increases in impervious area
  - planting of low-water using plants
- water recycling
- hook-up moratorium

RESTRICTIONS
- Rationing by
  - fixed allocation
  - variable percentage plan
  - per capita use
  - prior use bases
- Determination of priority uses
  - restrictions on private and public recreational uses
  - restrictions on commercial and institutional uses
  - banned wasteful practices
    - car washing
    - pool filling
    - landscape irrigation
    - watering with hand-held hose only
    - scheduled irrigation

EDUCATION

DIRECT MAIL
- pamphlets
- leaflets
- posters
- bill inserts
- newsletters
- handbooks
- buttons
- bumper stickers

NEWS MEDIA
- radio/TV ads
- movie
- radio announcements
- newspaper articles

PERSONAL CONTACT
- speaker program
- slide show
- booths at fairs
- customer assistance

SPECIAL EVENTS
- school talks
- slogan/poster contests
- posters around town
- billboards
- displays
- reminder items
- decals
- serving water on request in restaurants
- county fair exhibit

Issues and Problems

1. *How much analysis of measure effectiveness is required at Step 2, as opposed to Step 6?*

Step 2 requires only enough analysis to determine that a measurable reduction in water use will or will not occur. If that determination requires that the measure be described in detail and subjected to analysis comparable to that specified for Step 6, the measure should be classified as potentially feasible and determination of technical feasibility postponed to Step 6.

2. *Suppose that a broadly-defined measure such as peak-load pricing is under consideration. Some forms of peak-load pricing may reduce water use; others may not. Is this measure technically feasible?*

If a measure will reduce water use in one of its forms, it is considered technically feasible. Later stages of analysis will remove the infeasible versions of the measure.

3. *Many rate-making policies which may be considered as possible conservation measures seem likely to reduce water use at certain times (summer, for example), while increasing it at other times (winter). Is such a measure considered technically feasible?*

Yes. If a measure reduces water use at any time, it is included. Later analysis will determine whether the advantageous effect of the reduction outweighs the disadvantageous effect of the increased water use.

4. *Suppose a water conservation device is considered for which no independent effectiveness data exist. How can a determination of technical feasibility be made?*

The purpose of Step 2 is to eliminate measures that are clearly not feasible. Limited field tests of the device may reveal that it does not function as intended and can be eliminated, or they may show some promise. In the latter case, the device is considered potentially feasible, pending further analysis. Manufacturer's claims, when not obviously unsupportable, may be taken as a basis for potential feasibility.

Exemplary References

Technical feasibility of a particular water conservation measure can be judged on, for example, field test of water-saving devices. California Department of Water Resources (1976) has tested several interior fixtures (Table 2, p. 18). Appendices G and H of A Pilot Water Conservation Program (Johnson, Brown and Robie, 1978) contain valuable information on the implementation of home water-saving devices

in California. Milne (1976, 1979) evaluated over 40 commercially available water-saving devices, and discussed the design and installation of small on-site residential water reuse systems. Shelton and Soporowski (1976) are editors of the Proceedings of the New Jersey Conference on Water Conservation with Water-Saving Devices which includes six papers discussing needs and methods of conservation by the use of water-saving devices and their impact on water supply and drainage systems. Additional information can be obtained from Bailey, et al., (1969); AWWA (1971); Alderfer (1979); Flack, Weakley, and Hill (1977); Moran (1978); White, et al., (1980); and Hancock (1979).

STEP 3--DETERMINATION OF SOCIAL ACCEPTABILITY

Purpose

The overriding purpose of measuring the social acceptability of the conservation measures under consideration is to estimate the probable response of the community. More specifically, it is essential to substantiate with empirical data the extent of adoption of each specific measure. These data or information are of major importance: (1) the estimate of the degree of adoption is needed to calculate the effectiveness of each measure; (2) it is critical to know early in the planning process which measures might be unacceptable to the public, or which sub-groups of the population would be opposed; and (3) an understanding of the reasons for opposition to specific measures is useful information in the development of public information programs and in the development of detailed, specific measures.

Properly gathered empirical data are important because they provide the necessary information and insights mentioned above and also serve to minimize biases of the planner. Hence, the required social, political, and institutional data can be obtained by numerous techniques and approaches but according to professional standards.

Issues and Problems

1. *Can an existing public involvement program provide the necessary information for the determination of the social acceptability of conservation measures?*

   The answer to this question is yes, if--a very important qualification--the public involvement program includes a systematic collection of the required data from the various water-use sectors (residential, commercial, industrial) and from other relevant special interest groups and institutions. The problem is that most public involvement programs are not designed to collect the necessary information through a scientifically valid method, thus avoiding biases in the data and eventually in judgment.

2. *The determination of social acceptability seems to be a difficult, expensive, and time-consuming effort. Is that really necessary?*

To arrive at the answer one must first ask: What is the cost error and how does it compare to the cost of the determination of social acceptability? For example, if a proposed set of conservation measures is not adopted or opposed, then the entire water supply/conservation plan is in jeopardy and would need to be modified.

Exemplary References

There is a large number of studies which are related to the subject of social acceptability of water conservation, some providing survey data on adoption of water conservation measures. The assessment of social and political acceptability of water conservation is discussed by Flack, Weakley and Hill (1977). Snodgrass and Hill (1977) developed a statistically sophisticated method for identifying community acceptance of conservation measures which was tested in Lafayette and Louisville, Colorado. Survey data on adoption of water conservation measures can be found in references collected in Table 4. Not included in Table 4 are numerous studies which investigated public attitudes toward the use of renovated water. These include: Bruvold (1971, 1979b), Bruvold and Ward (1972), Bruvold and Ongerth (1974), Baumann and Kasperson (1974), Baumann and Dworkin (1975), and Sims and Baumann (1974).

STEP 4--IDENTIFICATION OF POTENTIAL WATER CONSERVATION MEASURES

Purpose

Steps 1, 2, and 3 provide a coarse screen, eliminating broadly defined categories of measures which clearly fail the tests of applicability, feasibility, and acceptability. The purpose of Step 4 is to provide a list of more narrowly defined measures, based on those categories of measures which remain after the first three steps. Measures included on this list, now called potential water conservation measures, will be subjected to full analysis in subsequent steps.

Issues and Problems

1. *Steps 1 through 3 required only broad definitions of measures, for example, direct mail educational campaigns. How can these measures be expressed in narrowly defined terms?*

A broadly defined measure is usually subdivided into constituent parts. A direct mail educational campaign can be subdivided into specific campaigns to educate residential consumers in lawn sprinkling

TABLE 4
LITERATURE DATA ON ACCEPTABILITY OF
WATER CONSERVATION MEASURES

Source	Conservation Measure	Subjects
Abbot, Cook, and Sleight, 1972	Short-term water-use restrictions	Managers and customers of 17 eastern United States water utilities
Bailey, et al., 1969	Flow-reduction devices	Plumbers, architects, equipment manufacturers, and houseowners
Bruvold, 1977, 1979b	Drought emergency water conservation programs	Sample of 900 consumers served by 9 water agencies in San Francisco Bay Area
Cartee and Williams, 1979	Domestic water-conserving technology	Home builders and municipal officials in Mississippi
Lee, 1981	Mandatory and voluntary water conservation measures	Personal interviews of 56 policy-makers of 12 Iowa communities
Morgan and Pelosi, 1980	Freely distributed 3-part water conservation kits	A sample of 637 households in the City of Oxnard, California
Nelson, 1979	Four rationing procedures: percentage reduction of prior use, seasonal allotment per capita, fixed allotment, and total sprinkler ban	North Marin County Water District in California
White, et al., 1980	Long-term and short-term water conservation measures: universal metering, low-flow devices, native vegetations for new landscapes, increasing block pricing, public education, non-drinking reuse, growth restrictions, implementation of restrictions and allotments, and surcharges on prices for metered services.	A sample of 105 customers in each of 7 small towns in Northern Colorado and also water officials
Watkins, 1972	Water conservation measures identified by respondents	Consumers in Homestead and Palm Beach, Florida

practices or in the use of water within the home, or commercial users, for instance, in the design and maintenance of public restrooms. Since the more general measure has been found to be applicable, feasible, and acceptable, it is likely that the more narrowly defined measures will be applicable, feasible, and acceptable as well.

2. *What about a case where the broadly defined measure has been found potentially acceptable?*

Information collected in the course of the social acceptability analysis may permit the identification of narrowly defined measures which are socially acceptable. For example, if there is support for a summer surcharge pricing system, but concern about its effects on a local tourist industry, a pricing system can be considered which exempts seasonal and tourist-oriented users from the summer surcharge provision. Where acceptability problems cannot be avoided in this manner, the narrowly defined measures may be included as potentially acceptable measures.

3. *How can the planner be assured that all plausible measures have been included at this point?*

Unfortunately, due to the nearly endless list of possible variants of measures, there is no rigorous test for comprehensiveness. If the planner has investigated all likely categories of measures, such as those shown in the Procedures Manual on Table 3-1, in Steps 1 through 3, and has subdivided surviving categories into all plausible narrowly defined categories in Step 4, the resulting list can be considered comprehensive. Some sub-optimization can be employed here: Many variations of a measure are possible, but one or a few can frequently be seen to dominate the others. Only the dominant measures need be considered.

Exemplary References

Although this step does not require any data from literature sources, some examples of defining water conservation measures can be found in Morris and Jones (1980) and Minton, Williams, and Murdock (1979). Both sources evaluate effectiveness of several conservation measures.

STEP 5--ANALYSIS OF IMPLEMENTATION CONDITIONS

Purpose

Step 4 results in a list of potential water conservation measures, with each measure stated in specific, narrowly defined terms. Further analysis requires knowledge of the details of implementation, such as

responsible agency, timing, and methods. Step 5 includes investigation of these issues and provides the data to support later analyses of effectiveness and implementation cost, as well as permits measures having significant implementation problems to be identified early in the process.

Issues and Problems

1. *Suppose that institutional arrangements in the study area suggest that a measure, already found feasible, will not be effectively implemented. Should that measure remain in the analysis?*

   If a study of the implementation conditions for that measure indicates that implementation would be non-existent, or so ineffective that no reduction in water use would occur, the measure may be dropped as infeasible. If some reduction in water use would occur, the measure is retained, but the estimate of effectiveness in Step 6 must take account of implementation conditions.

2. *How much information on implementation conditions is required?*

   Enough information on implementation conditions is required to verify feasibility, to support estimates of effectiveness (Step 6), and to permit calculation of implementation costs (Step 8).

Exemplary References

The role of individual agencies and companies in implementation of several conservation measures (retrofit devices, devices for new construction, regulatory code changes, metering, pricing, leak detection, water reuse, sharing water supplies, and public education) was identified by the U.S. Water Resources Council (1980), (Table 5-1, pp. 5-6). The Council also listed 27 Federal agencies whose programs affect development and use of water and distinguished types of use which are affected (Table 3-1, pp. 3-5). Hoffman, et al., (1979) analyzed the policy-making process of choosing strategies to cope with drought and assessed administrative feasibility of different drought policies. Minton, et al., (1980) used a conservation suitability criterion in their institutional analysis of municipal water supply in Anchorage, Alaska.

New England River Basins Commission (1980b) prepared a list of fixtures for achieving a reduction in average and peak use which are additionally separated into long-term and short-term categories (Tables 21 and 23, p. 98). With respect to public education, the Commission separated educational methods into those appropriate for small communities and those for large urban areas (Table 20, p. 92).

In order to investigate implementation conditions, water conservation measures may be examined for their consistency with existing or projected land-use patterns. Alderfer (1979) considered the relationship between regional land-use planning decisions and water conservation opportunities. White, et al., (1980) provided a set of recommendations for the development of implementable water conservation programs in small towns in Northern Colorado, while Flack (1981) identified the information needed for the implementation of various measures. Brainard (1979) pointed to the problems which may constrain implementation of a leak detection and repair program.

Additional information useful for the assessment of implementation conditions can be found in Lee (1981); Johnson, et al., (1978); Bruvold (1979a); Cartee and Williams (1979); Hancock (1979); and McDonald, et al., (1981).

STEP 6--DETERMINATION OF EFFECTIVENESS

Purpose

All water conservation measures must result in a reduction, at some time, in water use. Some of the advantageous effects resulting from water conservation depend upon the size and timing of the reduction in water use, including those project-specific effects analyzed in Steps 9 through 12. The determination of effectiveness is, therefore, a fundamental part of the analysis of any water conservation measure.

Issues and Problems

1. *Why is a disaggregate water-use forecast required as the basis for this step?*

   Water conservation measures frequently affect different classes of water use in markedly different ways, or they may not affect some classes at all. Attempts to calculate the effectiveness of these measures on an aggregate basis could result in serious error.

2. *Sometimes the literature contains various estimates of the fraction reduction in water use which a particular measure might achieve. Some of these estimates may be engineering calculations; others may be the results of actual application. Which type of estimate is preferred?*

   Generally, actual results are preferred. Engineering calculations may not take into account many adjustments and complications that actual practice entails. Empirical results must be reviewed closely, however, to ascertain that implementation conditions were comparable and that results were not biased in one or more ways.

Exemplary References

Estimates of the fraction reduction in water use achieved by particular measures can be obtained from various literature sources. The most comprehensive survey of literature on effectiveness of conservation measures has been done by the New England River Basins Commission (1980b). Table 5 describes in general terms the type of information which is reported in condensed form by the Commission and two other references.

Actual calculations of a measure's effectiveness is presented in Morris and Jones (1980). The authors estimated long-term water savings from metering, implementation of water-saving toilets, shower flow restrictors and reduced lot size for Denver, Colorado. Similar calculations were performed by Minton, Williams and Murdock (1979). U.S. EPA (1981) provides a series of tables with the assumptions and exemplary calculations of water and energy savings for six different types of water-saving devices.

A procedure for predicting unrestricted water use during drought has been developed by California Department of Water Resources (1978a). This technique separates the natural fluctuations in urban water use caused by the climate from the effects of water conservation programs.

A technique for forecasting long-term unrestricted water use for disaggregated municipal and industrial sectors--known as the MAIN II (Municipal and Industrial Needs) model--has been developed by Hittman Associates, Inc. (1969). Practical applications and discussion of this methodology can be found in Boland (1971, 1978, 1979). Thompson, Smith and Colvin (1976) described a method of estimating commercial/institutional parameters for the MAIN II model. Other alternative forecasting procedures are described by Maddaus and Feuerstein (1979), Sonnen and Evenson (1977, 1979) and Whitford (1970, 1972). Additional information on forecasting water use can be located through An Annotated Bibliography on Techniques of Forecasting Demand for Water (Planning and Management Consultants, 1981a).

STEP 7--DETERMINATION OF ADVANTAGEOUS EFFECTS

Purpose

There are some measure-specific effects of water conservation measures which represent positive movements toward a goal such as economic efficiency or environmental quality. Since they do not depend upon the characteristics of the water supply and wastewater disposal systems, these advantageous effects are said to be indirectly related, or unrelated to the reduction in water use measured in Step 6. Those advantageous effects which are directly related to reduction in water use are evaluated in Steps 9 through 12. The purpose of Step 7 is to identify and evaluate any measure-specific advantageous effects. These may include, for example, energy savings due to decreased hot water use (indirectly related to water-use reduction) or improved environmental quality due to better lawn watering practices (unrelated to water-use reduction).

TABLE 5
ESTIMATES OF EFFECTIVENESS OF
WATER CONSERVATION MEASURES

REFERENCE	CONSERVATION MEASURE(S)	INFORMATION REPORTED	COMMENTS
Minton, Williams and Murdock, 1979			
Table 4, p. 494	Education, shower restrictions, low flush toilet, metering and pricing, freeze protection-leak repair	Estimates of costs and reductions in water consumption in 1978, 1980 1990, 2000, at three levels of conservation intensity for Anchorage, Alaska	Measure effectiveness based on other literature sources
New England River Basins Commission, 1980b			
Table 11, pp. 105-8	Pricing structures	Information on implementation program: location, duration, conditions, costs, water saved, money saved, and comments	Summarized 13 sources on residential, industrial/commercial water use
Table 13, pp. 115-7	Regulation: restrictions on lawn sprinkling, car washing pool filling and average use	(as above--Table 11)	Summarized 6 sources on residential, industrial/commercial, and 9 sources on public water systems
Table 15, pp. 124-5	Various education techniques	(as above--Table 11)	Summarized 6 sources on residential use
Table 17, p. 131	Metering	(as above--Table 11)	Summarized 6 sources on residential, industrial/commercial use

TABLE 5
ESTIMATES OF EFFECTIVENESS OF
WATER CONSERVATION MEASURES
(Cont.)

REFERENCE	CONSERVATION MEASURE(S)	INFORMATION REPORTED	COMMENTS
Table 19, pp. 136-7	leak detection and repair	(as Table 11)--Information on implementation program, location, duration, conditions, costs, water saved, money saved, and comments	Summarized 9 sources on public water systems and 1 on industrial/commercial
Table 21, p. 140	Pressure reduction	(as above, Table 11)	Summarized 4 sources
Table 22, pp. 145-50	62 water-saving fixtures	Cost of implementation, percent reduction in water use, comments on implementation conditions	Primary source: Milne, 1976
Table 23, pp. 152-6	Water-saving fixtures	Identifies literature sources containing information on devices listed in Table 22, indicates sources containing data on the actual use of a fixture	97 sources identified
Table 24, pp. 157-65	Water-saving fixtures, other conservation measures	Information on implementation program: location, duration, conditions, costs, water saved, money saved, and comments	Identified 30 references on residential water conservation and 20 references on industrial/commercial

TABLE 5
ESTIMATES OF EFFECTIVENESS OF
WATER CONSERVATION MEASURES
(Cont.)

REFERENCE	CONSERVATION MEASURE(S)	INFORMATION REPORTED	COMMENTS
Table 26, pp. 175-80	Water reuse and recycle systems	(as above, Table 26)	Identified 6 references on residential reuse, 22 references on industrial/ commercial, 3 references on public water systems
Table 27, pp. 185-90	Public education water conservation kits, use restrictions, others included in water conservation programs	Data on communities which have implemented water conservation programs	Identified 31 cases (by community or water districts)
U.S. EPA, 1981			
Table 7, p. 33 Table C-1, p. 86	Water-saving devices: toilets, showers, kitchen and lavatory faucets, pressure reducing valve, hot water pipes, clothes washer, and dishwasher. Education	Conservative estimates of costs and water/energy savings from indoor residential information	

Issues and Problems

1. *Water conservation measures may result in postponing or re-scaling locally-planned water supply and wastewater disposal facilities. Why aren't these cost savings included as measure-specific effects, as they are not affected by Federally-planned project alternatives?*

It is not clear that locally-planned facilities are independent of Federal project planning. Alternative Federal plans may produce alternative local plans, especially in the case of wastewater facility planning. Also, the computation of foregone supply cost for locally-planned facilities is parallel, frequently using the same data sources, as that for Federally-planned facilities. For these reasons, all analyses based on foregone supply cost are combined as Tasks 9 and 10.

Exemplary References

Advantageous effects of water conservation measures are only rarely mentioned in the literature. Kingston (1979) presented an operational procedure for benefit-cost analysis of leak survey. Among the advantageous effects considered by the author were prevention of property damage, refutation of claims, improved meter reading, improved public relations, savings in leak repair crew time due to more accurate leak location, and postponement of time-of-day power charges in pumped service zones.

Middleton, Saunders and Warford (1978) considered benefits and costs of water metering which account for such items as marginal foregone cost of supply and disposal, metering costs, consumer personal inconvenience and expenditure on plumbing repairs, and consumer's foregone consumption benefits. U.S. EPA (1981) provided estimates and exemplary calculations of annual household energy savings for several water-saving devices (see Table 5 in this volume).

Additional sources which report on expected energy savings from adopting water conservation measures include: Feldman (1977); California Department of Water Resources (1978b); Meier, DeZellar and Miller (1981); Sharpe (1978d); and Shelton and Soporowski (1976).

STEP 8--DETERMINATION OF DISADVANTAGEOUS EFFECTS

Purpose

Where Step 7 identified and evaluated those advantageous effects which are common to all alternative plans (measure-specific effects), Step 8 identifies and evaluates all disadvantageous effects which are common to all alternative plans. Perhaps the most important category of measure-specific disadvantageous effects is the implementation cost associated with each water conservation measure. Other effects, for

example, include lost consumer surplus (decreased consumer satisfaction) and reduced environmental quality as a result of severe sprinkling restrictions.

Issues and Problems

1. How can decreased consumer satisfaction be measured?

The basis for any measurement of decreased consumer satisfaction would be the willingness of consumers to pay for restoration of the pre-conservation level of satisfaction. Where suitable market data exist, econometric analysis would be required to obtain such a measurement. Otherwise, two courses of action are possible. In many applications, it can be argued that the reduction in consumer satisfaction is minimal, if present at all. In these cases, this effect can be ignored. Where the reduction in satisfaction is not minimal, but no data exist which would permit quantitative measurement, a qualitative judgment may be included, stating the source and probable extent of the dissatisfaction. This determination would be treated in a manner similar to statements regarding environmental quality changes.

Exemplary References

Most literature sources reporting on the implementation costs of various water conservation measures are identified in Table 5. Additional, more recent studies treating this issue include: Clouser and Miller (1979); Kingston (1979); and Morris and Jones (1980).

Bishop, et al., (1981) considered a drop in property value and the loss of jobs as a result of reduction in water use in the area of French-Broad River Basin, Tennessee. Morris and Jones (1980) estimated the loss of satisfaction to the consumer (consumer surplus) because of decreased use of water. The authors also considered three types of environmental costs: loss of green lawns, higher density living, and potential health effects of gray water in toilets.

CHAPTER III
EVALUATION OF WATER CONSERVATION MEASURES

INTRODUCTION

As described in the previous chapters, Measure-Specific Analysis consists of those steps common to all alternative water supply plans. It results in a set of potential water conservation measures which are applicable, technically feasible, and socially acceptable. (In some cases, measures which are potentially feasible or acceptable may also be included.) The potential measures have been carefully described, their implementation conditions and expected effectiveness have been determined, and estimates are available for certain of the advantageous and disadvantageous effects of each measure.

In order to complete the evaluation of these potential measures, the remaining advantageous and disadvantageous effects must be identified and estimated. These effects depend upon the characteristics of the water supply and wastewater removal systems which will be in use during the planning period. Since these characteristics differ among alternative Federal plans, the effects of water conservation measures differ as well. Steps 9 through 13, therefore, which include evaluation of each potential measure, are repeated for each alternative plan.

Prior to initiating this phase of the analysis, comprehensive information on the future costs of water supply and wastewater removal must be available. Cost data on the Federally-planned elements of alternative water supply/wastewater removal systems are available from the formulation phase of alternative project planning, conducted prior to, or concurrently with, the Evaluation phase. In addition, projections of operation, maintenance, and replacement costs must be obtained or developed for all existing or locally-planned elements of the water/wastewater systems in the planning area. Projected costs and construction dates must be available for locally-planned facilities programmed for the planning period. These projections and data provide the basis for Step 9, the measurement of foregone supply cost.

The Evaluation phase concludes with lists of eligible water conservation measures, one list for each alternative plan. Each of the measures included in these lists has been found to provide a reduction in water use, for which advantageous effects outweigh disadvantageous effects. Any one of these measures would, if implemented alone, improve the net beneficial effect of the associated alternative plan.

STEP 9--DETERMINATION OF FOREGONE SUPPLY COSTS

Purpose

In order to minimize analytical effort, the Procedures Manual proposed a parametric approach to estimating the supply-cost savings which can be expected from reduction in water use. Step 9 is an incremental analysis of foregone supply costs (including wastewater costs), designed to yield a set of foregone cost factors which can be applied to water-use reductions calculated in Step 6. In most cases, the incremental costs can be calculated once for each alternative plan, then applied to the various potential mesaures. Some elements of Step 9, those which apply to facilities common to all plans, may be performed only once for all alternatives.

Issues and Problems

1. *Supply costs are generally not linear. How can incremental costs calculated for an arbitrary reduction in water use, say 1.0 mgd, be applied to water-use reductions of all sizes?*

   Individual conservation measures typically result in comparatively small reductions in water use, by comparison to total use levels. In these ranges, the linear approximation is probably adequate, and its use greatly reduces analytical effort. Where a particular measure or combination of measures reduces water use by such a large amount that these assumptions become suspect, then foregone supply cost can be readily re-calculated for that specific situation.

2. *Why are foregone supply costs calculated separately for Federally-planned and locally-planned facilities?*

   There are two reasons: (1) in many cases, locally-planned facilities are common to all Federal plan alternatives, so that these foregone supply costs need not be recalculated each time; and (2) the foregone supply costs of the two types of facilities lead to two types of advantageous effects which enter into project benefit-cost analysis in different ways. The advantageous effect of foregone Federally-planned supply cost is a reduction in project adverse effects; the advantageous effect of foregone locally-planned supply cost is an increase in project beneficial effects.

3. *Why is it necessary to consider different dimensions of water use, such as maximum day or seasonal use?*

   Water conservation measures affect water use in an uneven way; for example, sprinkling restrictions reduce seasonal use, but not

nonseasonal use, while water-saving toilets reduce nonseasonal use but not seasonal use. Since different types of water supply and wastewater disposal facilities have different design criteria, it is necessary to determine foregone supply costs separately for each dimension of water use.

Exemplary References

Although incremental supply-costs functions are site-specific and must be estimated for each locality separately, the publications which follow may be helpful in depicting various problems which may arise in such calculations. Anderson (1978) estimated incremental water supply costs associated with the provision of various levels of water supply for four Virginia cities. Clouser and Miller (1979) compared the costs of alternative water supplies and savings for consumers resulting from reduced water consumption for two Indiana communities. Dworkin (1975) analyzed costs of water reuse compared with costs of supply augmentation for Colorado Springs, Colorado. Gilbert and Associates (1977) compared the incremental costs of conservation plans with incremental costs of supply-augmentation projects for water supply in San Francisco Bay area. McDonald and Barney (1978) analyzed present value costs for various reservoir capacities for the city of Oceanside, California. Morris and Jones (1980) compared the costs of obtaining new water sources as compared to the costs of water conservation for Denver, Colorado.

STEP 10--DETERMINATION OF FOREGONE NED BENEFITS

Purpose

The determination of foregone supply costs in Step 9 indicates that the potential conservation measures, if adopted, will cause certain planned supply facilities to be reduced in size, or postponed, or both. Where those facilities include a Federally-planned multi-purpose water resource project, size reductions or postponements may reduce the net beneficial effects expected with respect to other purposes, such as recreation or hydropower generation. Step 10 is intended to provide an opportunity to investigate such possibilities, so that any such reduction can be recorded as a disadvantageous effect attributable to the water conservation measures.

Issues and Problems

1. *If it is true that in a multi-purpose project, each purpose must be incrementally justified, how can the incorporation of conservation into the water supply plan affect other purposes?*

Since conservation reduces the amount of water that will be withdrawn, and therefore the water supply benefit, in future years, the effect of water conservation may be to postpone the time by which the project can satisfy all the feasibility criteria, or to

reduce the optimal project size. In either case, other purposes must still provide net beneficial effects, but the size of the net benefits provided may be reduced. These lost net NED benefits should be counted as disadvantageous effects of water conservation.

2. *Should the determination of foregone NED benefits be made on a measure-by-measure basis, as proposed in the Procedures Manual, or should it be carried out after the optimal water supply/conservation plan has been determined?*

The advantage of performing this determination at this point in the analysis is that measures which cause comparatively large reductions in net benefits accruing to other purposes, and which do not provide commensurate advantages, can be eliminated at the earliest possible stage in the analysis. The disadvantage is the necessity of treating adverse effects on other purposes as essentially linear throughout the relevant range. This assumption is comparable to that adopted in the case of foregone supply costs, and is justified in the same way.

Exemplary References

None of the publications which were surveyed discussed calculation of foregone NED benefits. The procedures described in Principles and Standards and documentation of any Federal multi-purpose water supply plans remain the only sources of information for this step.

STEP 11--DETERMINATION OF REDUCED NEGATIVE EQ EFFECTS

Purpose

The EQ effects of a water resource project can seldom be tied to specific levels of use of the project, particularly in the case of water supply. They are more likely to be related to the construction of the project, the simple existence of the project, and to other factors not obviously variable with water use. Where water conservation measures affect the scale or the timing of a facility, however, they may affect the EQ impacts of that project. Step 11 is intended to examine cases where project effects which are negative with respect to the EQ objective (net adverse EQ effects) are reduced because of water conservation.

Issues and Problems

1. *Why isn't the determination of reduced EQ effects postponed until after selection of the optimal set of water conservation measures?*

As in the case of Step 10, considering the issue at this step has the advantage of permitting the integration phase to fully con-

sider all effects, so that undesirable measures are excluded before they are integrated into a plan. On the other hand, a certain linearity of these EQ effects, at least within the relevant range, is assumed.

2. *What about changes in positive EQ effects?*

It is assumed in the Procedures Manual that the net EQ effect of a major water resource project is negative. In that case, the only effect of a water conservation measure would be to decrease or to increase that negative effect. If a net positive effect were found, the analysis could be easily adapted to that situation.

Exemplary References

Studies which refer to environmental effects of water conservation measures usually do not deal with negative impacts of water supply projects. These can be identified by consulting Environmental Impact Statements required by the NEPA Act of 1969. Morris and Jones (1980) considered environmental effects of raw water development projects for Denver, Colorado. These included: (1) salinity in the Colorado River, (2) elimination of recreation area, and (3) loss of wildlife habitat.

The reduction of negative effects resulting from reduction in volume of effluent discharged to the environment was evaluated by Bishop and Jacobs (1980) and Maier, DeZellar and Miller (1981).

STEP 12--DETERMINATION OF INCREASED NEGATIVE EQ EFFECTS

Purpose

Step 12 completes the task begun in Step 11. If differs in only one respect: Increases, rather than decreases, in net negative EQ effects are considered, to the extent that they may occur.

Issues and Problems

1. *Where do increased negative EQ effects from water conservation occur?*

Increased negative EQ effects are unlikely to be associated with the construction and operation of a water supply reservoir. Here the probable effect of water conservation would be to reduce negative EQ effects. Increases in negative EQ effects are likely to occur elsewhere in the planning area, for example, reduced return flow from the wastewater system or odors from a more sluggish-flowing sewerage system.

Exemplary References

Increased negative EQ effects that result from reduced discharge of effluent are rarely mentioned in the literature. Maier, DeZellar, and Miller (1981) describe negative effects of reduction in sewage flow such as sediments accumulation, formation of sulfide gas, and insufficient separation of solids in a wastewater treatment plant. Other effects can be identified through sources mentioned in Step 11.

STEP 13--DETERMINATION OF MEASURE ELIGIBILITY

Purpose

Steps 7 through 12 have provided estimates of the advantageous and disadvantageous effects, with respect to any planning objective, for potential water conservation measures. These estimates have been separately developed, where appropriate, for each of the alternative water supply plans under consideration. Step 13 provides for a summary of the advantageous and disadvantageous effects for each measure/alternative plan combination and a determination of eligibility in each case. Measures which pass the eligibility criteria are retained for further analysis, and those which do not are dropped from further consideration, as they cannot be associated with a net beneficial impact.

Issues and Problems

1. *Why are measures which fail the NED criterion retained for further analysis?*

   Such measures are retained only if they appear to provide a net advantageous impact on the EQ objective. In this case, they will probably not appear in any NED plan, but may be considered for integration into an EQ plan, or perhaps into other plans, where the net EQ advantage is considered to outweigh the net NED disadvantage.

2. *Since all eligible measures pass the Principles and Standards tests of acceptability, effectiveness, efficiency, and completeness, why are further analytical steps required? Why not simply incorporate eligible measures into the related water supply plan?*

   When conservation measures are implemented together, there are frequently interactions with respect to effectiveness and implementation cost. These interactions mean that subsets of the group of eligible measures are likely to exist which are preferable to the sum of all eligible measures. The integration phase of the analysis attempts to identify these subsets.

Exemplary References

None of the studies surveyed contained a description or presentation of eligible measures which would be helpful in performing this step.

CHAPTER IV
INTEGRATION OF WATER CONSERVATION INTO WATER SUPPLY PLANS

INTRODUCTION

Steps 1 through 13 provide, for each alternative plan, a list of eligible water conservation measures. These measures must now be integrated into the associated water supply plan to obtain alternative water supply/conservation plans. Steps 14, 15, and 16 describe the process of choosing the optimal subset of eligible conservation measures, of testing the resulting water supply/conservation plan for compliance with reliability criteria, and of documenting the resulting alternative plan. This process is repeated for each alternative plan identified in the plan formulation phase, giving the same number of alternative water supply/conservation plans.

STEP 14--DEVELOPMENT OF ALTERNATIVE CONSERVATION PROPOSALS

Purpose

Each of the eligible water conservation measures identified in Step 13 provides a beneficial reduction in water use when implemented alone. When they are implemented in combination with other measures, however, advantageous and disadvantageous effects summarized in Step 13 may no longer apply. The effectiveness of two measures implemented together (for example, rate structure changes and educational campaigns) may be less than the sum of the two measures implemented separately. Also, the implementation cost of several measures implemented together may be less than the sum of their individual implementation costs. These interactions mean that the sum of all eligible measures is not necessarily the optimal set of water conservation measures.

This step provides a procedure whereby the optimal set of water conservation measures can be quickly approximated. Measures are listed in merit order, in accordance with the goals of the related alternative water supply plan, and an interactive process is used to test each measure for possible inclusion in the plan. At the completion of this process, a tentative water supply/conservation plan has been identified, subject to further tests of supply reliability (Step 15).

Issues and Problems

1. Why is the consideration of interactions deferred until now?

Interactions can only be considered in the context of specific proposals for implementing a particular set of measures. They are not generalizable. Step 14 is designed to minimize the number of interaction analyses required.

2. *What is the purpose of placing measures in merit order?*

A given set of measures could provide a very large number of subsets. Ten eligible measures, for example, could be implemented in 1,023 different combinations of one to ten measures each. It is not reasonable to search for each possible combination, investigate the interactions of each, and find the one set which yields the largest net advantage. By beginning with the measure having the largest net advantage, adding the next best measure, adjusting for interactions, adding the next best, adjusting again, and continuing on, the analysis moves quickly to an approximation of the best combination, while skipping over obviously inferior subsets.

3. *Why are potentially feasible and potentially acceptable measures given special consideration?*

The Procedures Manual calls for the preparation of two water conservation proposals for each alternative plan: one including all eligible and potentially eligible measures, whether or not potentially feasible and/or acceptable measures; and a second which excludes potentially feasible and/or acceptable measures. The difference in net advantage between these two proposals, then, provides an indication of the lost beneficial effect associated with whatever impediments to feasibility and/or acceptability may exist. Where the difference is small, it may be reasonable to omit the doubtful measures; where the difference is large; it may justify additional review of the impediments or constraints.

Exemplary References

Although for certain combinations of conservation measures the effects in reduction of water use are clearly additive (for example, leakage control and implementation of shallow-trap toilets), the interaction effects between a larger number of measures implemented will be increased. This problem is briefly discussed by Morris and Jones (1980). Other studies do not take these interactions into account in an explicit way. Flack (1981) illustrated a combined effect of three water conservation measures (metering, price increase, and implementation of water-saving devices) for a hypothetical example of a residential community of 40,000 population. Minton, Williams, and Murdock (1979) assumed no interactions among education, shower restrictors, low-flush toilet, and metering and pricing. Only a freeze protection-leak repair measure has been excluded in arriving at total water savings.

An indirect method for estimating the interaction effects for each conservation measure would be through comparison of the engineering estimate of effectiveness for a given measure with actual total reduction in use observed when the measure under consideration was employed in a water conservation program. This would allow determination of the "vulnerability" of a given measure to interactive effects of other measures. Table 5 (Step 6) may be used to identify literature sources

reporting on effectiveness of water conservation programs.

No literature sources discussing the interaction for advantageous and disadvantageous effects were identified.

STEP 15--SUPPLY RELIABILITY ANALYSIS

Purpose

The effectiveness of water conservation measures in reducing water use, determined in Step 6, is translated into foregone supply cost in Step 9. The determination of foregone supply cost makes use of the design criteria for water supply facilities, converting a reduction in water use to a reduction in needed supply capacity. Care must be taken, however, that the use of conventional design criteria does not mask unintended changes in supply reliability. Water supply agencies rely on the possibility of drought management measures to assist them in meeting demands during water supply deficit periods. Drought management measures may include sprinkling restrictions, appeals for voluntary conservation, reductions in public uses of water, and mandatory curtailment. Water conservation measures, when implemented as part of a water supply/ conservation plan, may preempt some of these drought management measures, reducing the ability of the water supply agency to cope with shortages. Step 15 is intended to permit the analyst to detect such instances and to make necessary changes in the plan so that supply reliability is unchanged as a result of water conservation.

Issues and Problems

1. *Many local water supply agencies have no stated drought management plan, relying on ad hoc responses to conditions as they develop. How can a drought management plan be developed and evaluated in these cases?*

   Drought management measures are nothing more nor less than contingent water conservation measures. In this application, however, they need not be subjected to evaluation of their advantageous and disadvantageous effects. The techniques for identifying possible measures, determining their feasibility and acceptability, and estimating their effectiveness are the same techniques described earlier for water conservation measures.

2. *Where the reliability of the system with conservation is to be identical with that without conservation, will consideration of supply reliability effectively eliminate the advantage of water conservation?*

   No. Experience thus far indicates that even where water conservation programs have a substantial effect on the effectiveness

of drought management programs, the increment of supply which must be restored in the interest of reliability is strictly smaller than the increment which was eliminated by water conservation. The water supply/conservation plan is still less costly than the water supply plan without conservation.

3. *When adjustments to restore supply reliability are needed, they have the effect of reducing the advantageous effects of water conservation (foregone supply cost). Doesn't this undermine the basis of the previous analysis?*

Strictly speaking, it does. Certain water conservation measures may have been included which, considering their effect on supply reliability, are actually ineligible. Still, supply reliability cannot be assessed on an incremental basis, or on the basis of individual conservation measures. The analysis can only occur after the complete supply/conservation plan is available. When this leads to substantial adjustments, it may be advisable to test alternate water supply/conservation plans (eliminating the measure or measures most likely to interfere with drought management), in the event that another final plan (after adjustment) is preferable.

Exemplary References

Boland, Carver, and Flynn (1980) demonstrated an operational procedure for preparing probabilistic forecasts of water-supply deficits from water-use forecasts and statistical analysis of supply data. This procedure can be used to examine the reliability of a water supply/conservation plan with preempted conservation potential. Nicolson (1979) forecasted annual reservoir failures with two sets of demands for water and found that conservation had more impact on reducing failures when the probability of failure is high than when it is low.

Russell (1979) discussed a planning framework for drought contingency programs and considered data requirements and limitations of water deficit planning. Other sources of information useful for supply reliability analysis are: Ecological Analyst, Inc. (1977); Goicoechea (1981); Nicolson (1979); Russell, Arey and Kates (1970); Schnizinger and Fagin (1979); Sheer (1980), and Taylor (1979).

STEP 16--DOCUMENTATION OF WATER SUPPLY/CONSERVATION PLANS

Purpose

This step is intended to provide a concise record of the analysis and evaluation of water conservation. It must not only indicate which measures are included and why they are included, but which measures have been omitted and the reasons for each such action. Such a tabulation is particularly important in the case of water conservation measures,

which are drawn from what is, in effect, an open set. No matter how many possible measures the planner may consider, it will always be possible to propose another one. The Procedures Manual specifies an approach that moves steadily from the general to the specific. Even though every possible permutation cannot be included, those likely to prove advantageous are given full consideration. The documentation should make this clear to the reviewer.

In addition, the documentation must indicate the full equivalence of the water supply/conservation plan to the water supply plan on which it was based. Both plans contemplate the same without-project condition and both fully address the anticipated needs of the planning area. In the water supply plan, those needs are met by managing supply, as contrasted to the combination of supply and demand management strategies incorporated into the water supply/conservation plan. Both plans meet future needs at the same level of system reliability as well. This equivalence must be fully supported by the documentation.

Exemplary References

For final report preparation guidance see Civil Works Planning Guidance Notebook, U.S. Army Corps of Engineers, October, 1981.

REFERENCE CONTENT INDICES

EXPLANATION OF INDICES

Four indices have been prepared to help in the easy identification of those references which are most useful in the preparation of water supply/conservation plans according to the Procedures Manual.

I. Subject Classification Index. This first index contains the list of the 308 annotated references arranged in alphabetical order by author and the year of publication, matching the order of abstracts in the annotated bibliography. Accordingly, all abstracts are numbered and assigned to specific steps of the Procedures Manual to which they are mostly applicable. Additionally, the content of each indexed publication is described by means of 9 general categories. These categories are:

(1) GENERAL--indicates publications which provide general discussion of the subject;

(2) COMPREHENSIVE--indicates publications which describe a comprehensive study or analysis and which are comprehensive in respect to the approach to the problem and/or their scope;

(3) PLANNING MODELS AND PROCEDURES--indicates publications which describe and/or discuss procedures designed for planning purposes related to water conservation;

(4) CONSERVATION PROGRAM HISTORY AND/OR EVALUATION--indicates publications which contain a description of actual or planned water conservation programs;

(5) CASE STUDY(S)--indicates publications which describe the investigation of one or more actual water supply systems;

(6) DATA: EMPIRICAL, STATISTICAL--indicates a source which provides: survey data, water-use statistics, results of field tests of conservation devices, and other engineering or empirical estimates of reductions in water use for specific or combined water conservation measures;

(7) POLICY ISSUES AND/OR LEGAL/INSTITUTIONAL ASPECTS--indicates sources which pertain to the above aspects of water conservation including national policies, legal and institutional barriers, institutional arrangements, and other related issues;

(8) WATER USE: ANALYSIS, FORECASTING, MODELING--indicates publications which investigate municipal and industrial water use and develop predictive models for forecasting future water consumption in various use sections; and

(9) SPECIFIC WATER CONSERVATION MEASURE(S)--indicates those sources which specifically consider one or more water conservation measures.

All the above categories, when used in various combinations, describe the contents of each publication included in the annotated bibliography. For example, Abstract No. 17, Baumann and Kasperson, 1974, should be read as "provides empirical data on public acceptability of specific water conservation measure (in this case, water reuse)." Similarly, Abstract No. 27, Boland, 1979, "provides a general discussion of water demand forecasting." This Subject Classification Index has been further condensed in the Cross-Reference Matrix in order to indicate the most relevant sources of information.

II. Cross-Reference Matrix. The next index constitutes a summarized form of the Subject Classification Index in which the abstracts of relevant publications are indicated by number. The matrix is formed by the step numbers in rows and contents categories in columns. The latter are the same as those in the Subject Classification Index.

III. Periodical Index. Following the annotations, the third index contains the list of journal titles and three other types of published materials, i.e., conference proceedings, reports, and books, which are identified by the page number as they appear in the bibliography.

IV. Author Index. Finally, following the Periodical Index, the conventional Author Index includes the names of all authors arranged in alphabetical order and identified by page number.

SUBJECT CLASSIFICATION INDEX

Abstract No	Reference Author(s)	Year	Step No.	General	Comprehensive	Planning Models & Procedures	Conservation Program History Evaluation	Case Study(s)	Data: Empirical, Statistical	Policy Issues and/or Legal tional Aspects	Water Use: Analysis, Forecasting Modeling	Specific Water Conservation Measures(s)
1	ABBOTT, COOK & SLEIGHT	1972	3,6						X			
2	ALDERFER	1979	1,2,5,7,8	X		X						
3	ANDERSON	1967	6				X	X				X
4	ANDERSON	1978	6,9	X		X		X				
5	ANDREWS & HAMMOND	1970	5,6								X	
6	ANGELIEDES & BARDACH	1977	1	X						X		
7	ASCE TASK COMMITTEE	1981			X	X				X		
8	ATLANTA REGIONAL COMMISSION	1980	5	X					X			
9	AWWA	1971	2	X						X		X
10	AWWA	1973a	6			X					X	
11	AWWA	1973b	6		X				X			
12	AWWA	1974	1,6		X				X			X
13	BAILEY, ET AL.	1969	1,2,3,6,8		X				X			X
14	BARNES, BORRELLI, POCHOP	1979	1,6					X	X			X
15	BAUMANN & DWORKIN	1975	1,2,3		X							X
16	BAUMANN, DWORKIN, ET AL.	1976		X		X				X		
17	BAUMANN & KASPERSON	1974	3						X			X
18	BEATTY & PIERCE	1976	3		X				X	X		
19	BILLINGS & AGTHE	1980	6					X			X	
20	BISHOP & JACOBS	1981	11,12					X				
21	BISHOP, ET AL.	1981	3,8		X			X		X		
22	BLACKBURN	1978	6		X		X	X	X			X
23	BOGUE	1963		X				X			X	
24	BOHAE & SIERKA	1978	7,8		X							
25	BOLAND	1971	6	X				X	X		X	
26	BOLAND	1978	6	X	X						X	
27	BOLAND	1979	6	X							X	
28	BOLAND & CARVER	1979	6	X							X	
29	BOLAND, CARVER & FLYNN	1980	15		X	X		X	X	X	X	
30	BOLAND, HANKE, ET AL.	1975	1,5,6		X			X	X	X	X	
31	BOLAND & MALORY	1973	6	X							X	
32	BOLLMAN & MERRITT	1977	3,6				X	X	X			X
33	BONEM	1968	7,8	X								
34	BOWER	1966		X							X	
35	BOWLES, ET AL.	1980	15									
36	BRAINARD	1979	1,2,5,7,8	X								X
37	BREWER	1964	1	X								X
38	BREWER & MCAULEY	1976	6	X						X		
39	BRIGHAM	1975	6				X	X	X			X
40	BRIGHAM	1976a	6				X	X				
41	BRIGHAM	1976b	6				X	X				
42	BRUNER	1969	6					X	X		X	
43	BRUVOLD	1971	3					X				X
44	BRUVOLD	1977	3					X	X			
45	BRUVOLD	1979a	3						X			X
46	BRUVOLD	1979b	3,5,6					X	X			
47	BRUVOLD & ONGERTH	1974	3					X	X			
48	BRUVOLD & WARD	1972	3					X	X			
49	BURNS, ET AL.	--	6					X			X	X
50	CALIFORNIA DEPT. OF WAT. RES.	1976a		X			X					
51	CALIFORNIA DEPT. OF WAT. RES.	1976b	1		X					X		
52	CALIFORNIA DEPT. OF WAT. RES.	1976c	6	X								
53	CALIFORNIA DEPT. OF WAT. RES.	1977	6		X		X					
54	CALIFORNIA DEPT. OF WAT. RES.	1978a	6			X					X	
55	CALIFORNIA DEPT. OF WAT. RES.	1978b	1,7		X		X					
56	CALIFORNIA GOVERNOR'S TASK FORCE	1978		X			X					
57	CAMP	1978	6						X		X	
58	CARMICHAEL	1973	9					X				
59	CARTEE & WILLIAMS	1979	1,3,5					X				X
60	CARVER	1978	6,7,8		X				X			X
61	CARVER & BOLAND	1980	6	X							X	
62	CHO	1976	1,2	X								
63	CLARK	1976	6,9						X			
64	CLARK & GODDARD	1977	9					X	X			
65	CLOUSER & MILLER	1979	6,8,9					X				
66	CLOUSER & MILLER	1980	8					X			X	
67	COHEN & WALLMAN	1974	1,2,6						X			X
68	COMMISSION ON NAT. RES.	1978		X						X		
69	COMPTROLLER GENERAL	1978	1,6	X						X		
70	COTTER & CHAVEZ	1979	6					X	X			X
71	CREW & ROBERTS	1970		X								
72	CREWS & TRIESHMAN	1979		X			X	X				
73	CURTIS & SCHAAKE	1979	15		X	X		X				
74	DANIELSON	1979	6						X		X	
75	DANIELSON, FELDHAKE & HART	1981	6									
76	DANIELSON, HART, ET AL.	1980	6,8					X	X		X	
77	DARR, FELDMAN & KAMEN	1976	6		X			X	X		X	
78	DAVIS & BURSZTYNSKY	1980	8					X				
79	DIEBERT	1978	3,6				X	X				
80	DE ROOY	1974	6						X		X	
81	DUNCAN	1979		X		X						
82	DUNN & LARSON	1963	6					X	X		X	
83	DWORKIN	1975	9			X		X				X
84	ECOLOGICAL ANALYST, INC.	1977	15		X			X	X		X	
85	ELLIS	1978		X		X				X		
86	ELLIS	1966		X						X		
87	ERTEL & KOCH	1977	3						X	X		
88	FELDMAN	1975	2,5	X								X
89	FELDMAN	1977	6,7		X							X
90	FETH	1973		X					X		X	
91	FLACK	--	5,6	X								X
92	FLACK	1967		X						X		
93	FLACK	1971		X						X		
94	FLACK	1976		X								

Abstract No	Reference Author(s)	Year	Step No.	General	Comprehensive	Planning Models & Procedures	Conservation Program History Evaluation	Case Study(s)	Data: Empirical, Statistical	Policy Issues and/or Legal tional Aspects	Water Use: Analysis, Forecasting Modeling	Specific Water Conservation Measures(s)
95	FLACK	1981	1,5,14									
96	FLACK & ROUSSOS	1978	5					X				X
97	FLACK, WEAKLEY & HILL	1977	1,2,3,5	X		X						X
98	FLETCHER & SHARPE	1978	1,3	X								X
99	FORD & ZIGLER	1980	6						X		X	
100	FOSTER & BEATTIE	1979	6						X		X	
101	FOX	1966		X							X	
102	FRANKEL	1967	8,9						X			X
103	FRNKA	1979			X	X			X		X	
104	GALLAGHER, BOLAND, ET AL.	1980	6		X						X	
105	GALLAGHER & ROBINSON	1977	6		X				X		X	X
106	GALLUP POLL	1973	3						X			
107	GALOWIN	1979	3,5							X		
108	GARDNER	1977	1,5,6					X	X			X
109	GARLAND	1975	2				X					X
110	GERLACH & HINE	1973		X								
111	GILBERT	1978		X			X	X				
112	GILBERT & ASSOCIATES	1977	8,9									
113	GOICOECHEA	1981	15		X	X						
114	GOTTLIEB	1963	6					X	X		X	
115	GRAF & WHALEN	1977										X
116	GRANGER	1955	6									X
117	GREBSTEIN & FIELD	1979										
118	GRIFFITH	1978		X			X		X			
119	GRIMA	1972			X			X	X		X	
120	GROOPMAN	1968					X		X			
121	GRUNEWALD, ET AL.	1975	6		X				X		X	
122	GUARISO, ET AL.	1978										
123	GYSI	1971	6,9	X		X						X
124	GYSI & LOUCKS	1971	6	X		X						
125	HANCOCK	1979	2,5	X						X		
126	HANKE	1970	6					X	X			X
127	HANKE	1972	6	X					X			X
128	HANKE	1978a		X					X			
129	HANKE	1978b		X								
130	HANKE & BOLAND	1971	6					X	X			X
131	HANKE & DAVIS	1971						X				
132	HANKE & FLACK	1968	7,8	X		X						X
133	HANKE & MAHREZ	1979	6								X	
134	HARNETT	1978	6		X		X					
135	HARRIS	1977	3		X	X						
136	HEADLEY	1963	6								X	
137	HECKROTH	1977		X						X		
138	HEGGIE	1957	6					X	X			X
139	HERRINGTON	1976			X	X						
140	HITTMAN ASSOCIATES, INC.	1969	6		X	X		X			X	
141	HITTMAN ASSOCIATES, INC.	1970	6		X	X			X			
142	HOFFMAN, GLICKSTEIN & LIROFF	1979	2,3,5				X	X				
143	HOGARTY & MACAY	1975	6						X		X	
144	HOLLMAN & PRIMEAUX	1973	6						X		X	
145	HOWE	1968		X							X	
146	HOWE	1971	1		X				X			
147	HOWE, ET AL.	1980	5				X		X	X		
148	HOWE & LINAWEAVER	1967	5,6		X				X		X	
149	HUDSON	1964		X								X
150	HUDSON	1975	1	X								X
151	HUDSON	1978a	1	X								X
152	HUDSON	1978b	1	X								X
153	HUGHES & GROSS	1979	6		X	X						
154	ISSEN & SALLWEG	1969	3						X			
155	JAMES	1974		X								
156	JAMES & ANDREWS	1978			X		X					
157	JEZLER	1975					X					
158	JOHNSON, BROWN & ROBIE	1978	1,2,3,5,6,7,8		X				X			X
159	JOHNSON, BROWN & ROBIE	1979										
160	JOHNSON	1974	3	X								
161	KELLER	1976	5									X
162	KIM & MCCUEN	1979	6						X		X	
163	KINGSTON	1979	7,8			X		X				X
164	KLIMEK	1970	6					X	X		X	
165	KO & DUCKSTEIN	1972	7,8									X
166	KURY	1977		X								
167	LARKIN	1978	8				X	X	X			
168	LARSON & HUDSON	1951									X	
169	LATTIE & VOSSBRINK	1977	1				X					X
170	LAVERTY	1977	6				X					X
171	LAVERTY	1979	6,8				X					X
172	LEE	1977	5	X						X		
173	LEE	1981	3,5						X			X
174	LEONE, GINN & LIN	1974	6		X				X		X	
175	LEOPOLD & LANGBEIN	1960			X							
176	LINAWEAVER, GEYER & WOLFF	1967	6						X		X	
177	LUPSHA, SCHLEGEL & ANDERSON	1975	3,6						X		X	
178	LYNNE, LUPPOLD & KIKER	1978	6						X		X	
179	LYON	1978	6	X								X
180	MAASS	1966		X								
181	MACDONALD & BARNEY	1978	9					X	X			X
182	MADDAUS & FEUERSTEIN	1979	6,8,9			X			X		X	
183	MAIDMENT	1979			X						X	
184	MAIER, DEZELLAR & MILLER	1981	7,11,12	X								
185	MALE, ET AL.	1979	6					X				
186	MARSHALL	1966		X								X
187	MCDONALD, ET AL.	1981	5					X		X		
188	MCGARRY & BRUSNIGHAN	1979	3,5,6					X	X			X
189	MCLEON	1976		X				X				
190	MCPHERSON	1976a		X							X	
191	MCPHERSON	1976b		X							X	
192	MCPHERSON	1976c	5,6	X							X	
193	MCPHERSON	1978		X							X	
194	MCPHERSON	1979	14	X						X	X	

Abstract No	Reference Author(s)	Year	Step No.	General	Comprehensive	Planning Models & Procedures	Conservation Program History Evaluation	Case Study(s)	Data: Empirical, Statistical	Policy Issues and/or Legal tional Aspects	Water Use: Analysis, Forecasting Modeling	Specific Water Conservation Measures(s)
195	MIDDLEMAS	1961	6					X				X
196	MIDDLETON, SANDERS & WARFORD	1978	7,8			X			X			X
197	MILLER	1978	6				X		X			
198	MILNE	1976	1,2,5,6		X							
199	MILNE	1979	1,2,5,6		X							
200	MINTON, WILLIAMS & MURDOCK	1979	1,4,6,14		X			X				X
201	MINTON, WILLIAMS & MURDOCK	1980	5		X			X		X		
202	MITCHELL	1957	6				X					
203	MORAN	1978	2									X
204	MORGAN	1973	6	X							X	
205	MORGAN	1974	6					X	X		X	X
206	MORGAN	1979		X								X
207	MORGAN	1980		X								
208	MORGAN & PELOSI	1980	3,5,6				X	X	X			
209	MORGAN & SMOLEN	1976	6		X				X		X	X
210	MORRIS & JONES	1980	4,6,8,9,11,14		X		X	X	X	X	X	X
211	MURRAY	1970			X				X		X	
212	NAT'L ACADEMY OF SCIENCES	1971	2,3	X							X	
213	NAT'L WATER COMMISSION	1973		X						X		
214	NAT'L WATER COMMISSION	1976		X		X				X	X	
215	NAT'L WATER CONSERV. CONF.	1981			X							
216	NATIONAL WATER COUNCIL	1977	3,6		X		X					X
217	NELSON	1979	3,6				X					X
218	NELSON	1977	1,2,6									X
219	NEW ENGLAND RIVER BASINS COMM.	1980a			X	X						
220	NEW ENGLAND RIVER BASINS COMM.	1980b	1,5,6,7		X				X			X
221	NICOLSON	1979	15	X		X						
222	NORTH CAROLINA DEPT. OF NAT. RES.	1980		X								
223	OFFICE OF SCIENCE AND TECHNOL.	1978		X						X		
224	OFFICE OF WATER RESOURCES	1972	1,3,6		X		X		X			
225	PAGORSKI	1974	3						X			X
226	PHILLIPS	1974	2									X
227	PLANNING & MANAGEMENT CONSULT.	1981a	6		X						X	
228	PLANNING & MANAGEMENT CONSULT.	1981b	6			X			X		X	
229	POPE, STEPP & LYTHE	1975	6		X				X			X
230	POWELL	1977	6						X			X
231	PRATTE & LITSKY	1979	2,3,6						X			X
232	PRESIDENTS INTERGOVERNMENTAL WATER POLICY TASK FORCE	1980		X						X		
233	PRIMEAUX & HOLLMAN	1974	6						X		X	
234	REES	1969	6						X		X	
235	REES & REES	1972							X		X	
236	REID	1971		X		X					X	
237	RICE & SHAW	1978	6				X					X
238	RIDGE	1972	6		X				X			X
239	RILEY & SCHERER	1979	5	X								
240	ROBIE	1978	6				X					
241	ROBIE	1980	5	X						X		
242	ROMM	1977	6			X					X	
243	RONDON	1980	1	X								
244	RUSSELL	1979	15	X		X				X		
245	RUSSELL, AREY & KATES	1970	15		X	X	X	X	X	X		
246	SABADELL	1979		X			X					
247	SCHAAKE & MAJOR	1972	6			X					X	
248	SCHAEFER	1979	1		X							X
249	SCHNIZINGER & FAGIN	1979	15		X	X	X	X				
250	SCHUFLE	1968		X								
251	SEWELL & BOUECHE	1974	6						X			X
252	SEWELL, BOWER, ET AL.	1968	6		X						X	
253	SHARPE	1976	1,2,4,6		X				X			X
254	SHARPE	1978a	1,2		X							X
255	SHARPE	1978b			X							
256	SHARPE	1978c	8	X			X	X				X
257	SHARPE	1978d	6,7					X				X
258	SHARPE	1978e		X						X		
259	SHARPE & FLETCHER	1975			X							
260	SHARPE & FLETCHER	1977	1,2,6,7,8		X		X	X	X			
261	SHEER	1980	15			X		X	X			
262	SHELTON & SOPOROWSKI	1976	8,7		X							X
263	SHUVAL	1977			X							X
264	SIMS & BAUMANN	1978	3						X			X
265	SMITH	1979	2,3		X							X
266	SMITH & WALBER	1975		X								
267	SMITH	1977	1							X		
268	SNDDGRASS & HILL	1977	3			X		X	X			
269	SONNEN & EVENSON	1977	6			X		X	X		X	
270	SONNEN & EVENSON	1979	6			X		X	X		X	
271	STERLING & ANTCLIFFE	1974	6			X					X	
272	STONE	1978	1,6	X								X
273	SWEAZY	1979	5	X						X		
274	TATE	1977	6		X						X	
275	TAYLOR	1979	7,8,15		X			X				
276	THOMPSON, SMITH & GOLVIN	1976	6			X		X			X	
277	THOMPSON & YOUNG	1973		X								
278	TURNOVSKY	1969	6						X		X	
279	TURVEY	1976	9	X								
280	UPPER MISSISSIPPI RIVER BASIN COM	1978				X						
281	U.S. ARMY CORPS OF ENGINEERS	1976	1,5,6	X			X					
282	U.S. ARMY CORPS OF ENGINEERS	1978	1					X				
283	U.S. EPA	1978			X							
284	U.S. EPA	1980	1,6,7		X							
285	U.S. EPA	1981	6,7,8		X	X						
286	U.S. GAO	1977		X						X		
287	U.S. WATER RESOURCES COUNCIL	1978			X				X			
288	U.S. WATER RESOURCES COUNCIL	1980	5		X	X						
289	WADE	1978		X								
290	WAPORA, INC.	1978	5					X			X	X
291	WARFORD	1968		X								
292	WASSERMAN	1978	1,2,3	X								X

Abatract No	Reference Author(s)	Year	Step No.	General	Comprehensive	Planning Models & Procedures	Conservation Program History Evaluation	Case Study(s)	DATA: Empirical, Statistical	Policy Issues and/or Legal tional Aspects	WATER USE: ANALYSIS, FORECASTING MODELING	Specific Water Conservation Measures(s)
293	WATER RESOURCE POLICY STUDY	1977		X						X		
294	WATKINS	1970										X
295	WATKINS	1972	3					X	X			
296	WEEKS & MCMAHON	1974	6								X	
297	WHIPPLE	1979		X								
298	WHITE, DINATALE, ET AL.	1980	1,2,3,5						X			X
299	WHITE HOUSE DROUGHT STUDY GROUP	1977										
300	WHITFORD	1970	6,15			X				X		X
301	WHITFORD	1972	6,15			X				X		
302	WILSON & HUANG	1977	6	X								X
303	WOLF	1977	1									X
304	WOLFF, LINAWEAVER & GEYER	1966	6									
305	WONG	1972	6						X		X	
306	YARBOROUGH	1956						X			X	
307	YOUNG	1973	6					X			X	
308	YOUNG & GRAY	1972		X								

CROSS-REFERENCE MATRIX
by Abstract Number

Step Number and Name / Content Classification	General	Comprehensive	Planning Models and Procedures	Conservation Program--History and/or Evaluation	Case Study(s)	Data. Empirical Statistical Estimates	Policy Issues and/or Legal/Institutional Aspects	Water Use: Analysis Forecasting Modeling	Specific Water Conservation Measure(s)
1 Determ. of Applicable Measures	95,98,272	95,198,199,200, 248,284		169	200				95,98.169, 200,248,272
2 Determ. of Technical Feasibility	2,9,97,125,	13,158,198,199, 262				13,158,198,199, 297	9,125		9,13,97,158, 203,297
3 Determ. of Social Acceptability	97	16	268	44,46,208,217	44,45,46,47, 48,59,208, 268,295	1,13,17,44,46 47,48,173,208 295,297			13,16,17,45, 59,97,173, 217,264,297
4 Ident. of Potential Water Cons. Measures		200			200				
5 Analysis of Implementation Conditions	2,36,91, 125	95,158,201, 220,288	95,142,288	142	45,59,187, 201	45,158,173,220, 278	125,187,201		36,59,95,158, 173,220,278
6 Determ. of Effectiveness	25,26,27	26,140,200,210, 220,227,285, 299,300	54,140,182, 276,285,	140,210,276	25,200,210 269,270	25,182,210, 220,269,270	299,300,	25,26,27,54, 140,182,210, 227,269,270, 276	200,210,220
7 Determ. of Advantageous Effects	184	55,89,262,285	163,196,285	55	163,257	196,285			89,163,196, 262
8 Determ. of Disadvantageous Effects		20,200,210		210	20,65,163, 210	200	20		163,200,210
9 Determ. of Foregone Supply Costs			83	112	4,65,112, 181,210	83,112,181, 210			83,181
10 Determ. of Foregone NED Benefits									
11 Determ. of Reduced Neg. EQ Effects	184				1,21,210	210			
12 Determ. of Increased Neg. Effects	184								
13 Determ of Measure Eligibility									
14 Devel. of Alt. Consideration Proposals	95,210		95		200,210				
15 Supply Reliability Analysis	45,221,244	29,73,113, 245,275	29,73,113, 221,244, 245,261	245	29,73,245, 261,275	29,245,261	29,244,245	29	
16 Docum. of Water Supply/Cons. Plans									

APPENDIX A

1

Abbott, H. E., K. G. Cook, and R. B. Sleight. 1972. Social Aspects of Urban Water Conservation. Century Research Corporation. Report prepared for the Office of Water Resources Research.

This report presents the results of a survey of the managers and the customers of 17 Eastern United States water utilities that imposed short-term water-use restrictions. Almost all communities imposed the restrictions on uses of water outside and appealed for less use inside the house. The survey of customers revealed that most agreed that outside uses are least essential (only 5 to 12% of the respondents rated stoppage of various outside uses to involve "much" inconvenience compared to 41 to 54% for various inside uses). Cooperation was excellent and continued even after the emergency ended. These measures achieved from 18 to 50% reduction in water use with voluntary measures being as effective as compulsory.

The report recommends voluntary measures be tried first. Most consumer respondents (80%) did not want restrictions in normal times, but half of the respondents were not willing to pay 10% more for their water to insure adequate supplies. In drought areas, 75% of the respondents preferred metered to flat rates. There was strong objection (92% of the respondents) to dyeing or giving the water an unpleasant taste as a warning to consumers to save water. Estimates by respondents of the amount of water used for various purposes were wildly inaccurate, indicating that instruction from public officials on in-house water reduction should be very specific rather than call for percent reductions or for limits to a specific number of gallons per person or household. The report concludes: (1) People of the Eastern United States are quite ignorant of their water use and supplies. Most people are willing to save water in emergencies but don't know how. A continuing educational campaign by the utilities to correct this situation is needed. (2) Emergency restriction plans should be prepared in advance (examples are given). Most respondents preferred that the declaration of emergency come from the water official (60%) than another city official (23%). But the report notes that the water official may be too busy to make a public announcement. One of the most important aspects of an emergency plan is to have all information funneled through one office to avoid confusion. Most often lacking were official announcements of the end of the emergency.

The information presented in the report is applicable to the evaluation of effectiveness of water conservation measures as well as to determination of social acceptability.

2

Alderfer, Ronald G. 1979. Water Conservation and Land-use Planning. In Proceedings, National Conference on Water Conservation and Municipal Wastewater Flow Reduction, EPA/430/9-79-015, pp. 226-43.

The author's purpose was to examine ways in which regional land-use planning decisions influence water consumption and water conservation opportunities. Water consumption and water conservation were examined in the hydrologic/ecologic context with the inclusion of a methodology

for gathering hydrologic and land-use data.

The criteria for the evaluation of water conservation opportunities were briefly described and include: (1) effectiveness, (2) cost of implementation, (3) consistency with existing land-use patterns or projections, (4) maintenance requirements, (5) environmental effects, and (6) aesthetics.

The paper is a useful reference for preliminary determination of applicability of various water conservation measures and in the consideration of several other activities involved in water conservation planning.

3

Anderson, Raymond W. 1967. Pawtucket, Rhode Island and the Drought. Journal of New England Water Works Association 81:301-303.

The City of Pawtucket Water System supplies 130,000 people--an average consumption of 17.5 mgd in 1965. During the summer of 1964 and 1965, the average consumption for the month with the greatest demand averaged just below 20 mgd with the maximum day equal to 26 mgd. During drought conditions in 1966, meetings were held with the mayor, the Water Conservation Committee, Chamber of Commerce and all businesses and industries to formulate plans for water conservation. Voluntary conservation helped, but during the summer, more drastic measures were needed. Two ordinances were passed: an emergency ordinance banning all use of water for watering lawns, car washing and any unnecessary use when the supply in the 2 reservoirs dropped below 50%; and an ordinance permanently forbidding the use of water for air-conditioning without the use of cooling towers or other reclaiming methods.

When both of these ordinances were put in force, the total monthly reduction savings were around 100 million gallons when compared to a similar month in 1965: 3.3 mgd or 16 to 18% of expected demand for that month. This information can serve as a rough estimate of effectiveness for these 2 combined conservation measures.

4

Anderson, W. B. 1978. An Economic Approach to Water Supply Planning in Southeastern Virginia. Virginia Polytechnic Institute and State University, Department of Agricultural Economics (Ph.D. Dissertation), Blacksburg, Virginia.

The purpose of this study was to develop an economically efficient solution for water supply problems of the four southeastern Virginia cities of Portsmouth, Norfolk, Virginia Beach, and Chesapeake. The analysis involved estimating costs and benefits for projected levels of water use and for reductions in those levels achieved with the use of quotas, price increases, and water-saving devices. Optimal schedules for the development of additional water sources were derived through the examination of water demand, relative to the cost of operating and expanding water supply and wastewater treatment facilities.

The analysis constitutes an example of determining incremental costs for additions to supply capacity which are necessary to determine foregone supply costs. It also discusses the effects of price change on water use in the long run, which are important in estimating measure effectiveness.

5

Andrews, R. A., and M. R. Hammond. 1970. Characteristics of Household Water Consumption in Three New Hampshire Communities. Water Resources Research Center report no. 3. Durham: University of New Hampshire.

This report outlines the results of a water-use study of 361 households in Durham, Epping, and Portsmouth, NH. Billing records and interviews were used to obtain data on water consumption and household characteristics. Average daily per capita water use was 42, 52, and 59 gpcd for these cities with standard deviations of 22, 26, and 22 gpcd, respectively. The survey showed that lawn watering was not a major household water-use category in this area. Also, water use was found to be significantly related to the number of persons, while the presence of septic systems as opposed to sewers did not influence water use. Price was not examined as an explanatory variable.

The author's findings may be helpful in determining implementation conditions and to a lesser extent preliminary estimates of unrestricted water use in the residential sector.

6

Angeliedes, Steven P., and Eugene Bardach. 1977. Water Banking by Local Districts Would Increase Flexibility and Reduce Waste. Discussion Paper, Graduate School of Public Policy, University of California, Berkeley, California.

This paper outlines the present system of water allocation in California, discusses the waste and inflexibility involved in this system, and examines changes in the law to remove these problems.

The conclusions of the report are:

1. A free market system, although fine in theory, will be hindered by institutions now in place. Realistically, these institutions cannot be eliminated. The transaction costs of a free market water transfer system are not necessarily smaller.

2. An administered market system is a more incremental change from the present institutional structure. However, it does not deal adequately with the risk of losing the water right faced by the potential transferer who must initiate the transaction. Both administered and free market systems will not work well with district supplied water which accounts for the vast majority of surface supplied water in California.

3. Water banking as practiced on the state level in 1976-77 would work well at the district level. This system should be adopted at the present time. The administered market system, unlike the free market system, is not inconsistent with local water banking but should be adopted at a later time to avoid confusion with the more important concept of water banking.

The authors' analysis yields useful information for determining the applicability of water banking as a conservation measure.

7
ASCE Task Committee on Water Conservation. 1981. Perspectives on Water Conservation. Journal of the Water Resources Planning and Management Division, ASCE 129:225-38.

This article constitutes a summary of the Task Committee's initial report on water conservation which was provided to the ASCE Committee on National Water Policy for use in preparing an ASCE statement for congressional hearings on National Water Policy proposals.

The authors considered different aspects of water conservation including (1) concepts of conservation today and in the past; (2) reasons for adopting water conservation; (3) level and specifics of conservation planning (long-term versus emergency conservation) including incentives for its encouragement; (4) regional differentiation in opportunities for water conservation stemming from sectoral variability of use and variability of supply; (5) methods for conservation of both supply (utilization of excess runoff and efficient distribution) and demand (reduction in usage through education, management, and technology); (6) relation of water conservation to energy conservation; and (7) relation of water conservation to water laws.

The following are guidelines formulated by the Committee in order to assist in prudent conservation planning:

1. Water is a renewable and reusable resource which varies with time, location, quantity, and quality. It may be used or lost depending upon local conditions.

2. Wise management of our water resources requires total water management, i.e., the conservation of supply and demand. Water conservation should be made part of this total water perspective.

3. Water conservation planning should be site specific. Programs should be tailored to the climate, type of use, and nature of supply and operation.

4. Effects of water conservation on the quantity and quality of surface and groundwater resources, on the interlinkage between water supply and wastewater systems and upon in-stream needs should be understood and assessed.

5. Conservation measures should be evaluated based upon their economic, social, and environmental benefits and costs, and upon their ability to achieve desired objectives.

6. Increases or decreases in energy consumption of conservation measures should be explicitly evaluated.

7. Water system reliability should be assessed and the system's capabilities understood. Design droughts should be made explicit and an emergency response plan required.

8. Reductions in assumed demand should also be made explicit and supported by continuing education.

This article is a valuable guide for water conservation planning for it provides a comprehensive presentation of many aspects of this subject in very condensed form.

8

Atlanta Regional Commission. 1980. Water Pricing and Water Conservation: An Evaluation of Alternative Rate Structures. Staff Working Paper, Metropolitan Atlanta Water Resources Study, Atlanta, Georgia.

This paper considers long-range water supply alternatives for the Atlanta Region and addresses several alternative water and sewer rate structures, their relationship to water demand, impacts on utility revenues, overall economic consideration, and institutional arrangements. Based on the studies of water and sewer rates of the Atlanta Region and their comparison to those of the Fairfax County Water Authority and the Washington Suburban Sanitary Commission, the report outlines a set of questions to be addressed in the further study of the regional water and sewer pricing problem. These questions generally refer to (1) the availability of current operating and billing records permitting the analysis of consumption patterns by user class, season, and service area; (2) system changes necessary to create appropriate operating and billing records; (3) the relationships between rates and peak-season use in different user classes; (4) the relationship between peak demands and seasonal low stream flows; and (5) others.

Although the discussion of these issues is rather general, the paper may be consulted as a reference for determining implementation conditions of redesigned water rates.

9

AWWA. 1971. Policy Statement on the Use of Reclaimed Wastewaters as a Water Supply Source. Journal of the American Water Works Association 63:609.

The AWWA stated that current knowledge is "not advanced sufficiently to permit direct use of treated wastewaters as a source of public water

supply." However, "the Association encourages the use of reclaimed wastewaters for beneficial purposes such as industrial cooling and processing, irrigation of crops, recreation, and (within the limits of historical practice), groundwater recharge." Further research on direct reuse was urged.

10

AWWA Committee on Water Use. 1973a. Review of the Johns Hopkins University Research Project Method for Estimating Residential Water Use. Journal of the American Water Works Association 65:300-301.

This article reviews the 1966 John Hopkins University residential water-use research report for possible practical application in estimating average and peak residential water use in individual communities. The committee's conclusion was that the applicability of this method for estimating total future residential water requirements of a particular city may be subject to question for a number of reasons mostly related to nonavailability of all required data. It recommended further research on its application.

The article contains useful comments on the selection of an appropriate technique for forecasting unrestricted water use.

11

AWWA Committee on Water Use. 1973b. Trends in Water Use. Journal of the American Water Works Association 65:285-99.

This article reports and discusses the results of a survey of water-use data for 94 individual utilities across the United States during the period 1960-70. The purpose of this analysis was to assess current trends in customer (household, business establishment, industry, etc.) water consumption in order to assist in the projection of future water requirements.

The total customer water-use data for each utility were disaggregated by three customer categories, i.e. residential, commercial, and industrial or larger nonindustrial customers. In the next step, the data were spatially reaggregated into eastern and southern, central, and western regions of the United States. Total overall average water use (expressed in gpcd) for all areas was found to be increased over the period of investigation for all customer categories.

The article contains valuable information for preliminary estimation of unrestricted water consumption in various use sectors.

12

AWWA. 1974. How Cities Lose Water. The American City:98.

Charles W. Keller is quoted as stating that if 10% of the water produced is lost or unaccounted for, the system can be rated as excellent and a loss of 20% is considered reasonable. Inaccurate water metering of input can account for a large percentage lost. In one city (unnamed), a 37% loss was reduced to 17% loss by correcting the meter measuring input. "A 1965 survey of 476 cities calculated water losses by state. . . . The ranking showed Wyoming with the lowest loss (1.85%) and Louisiana with the highest (27.93%)."

This information may be used for determination of applicability and effectiveness of metering.

13

Bailey, J. R., R. J. Benoit, J. L. Dodson, J. M. Robb, and H. Wallman. 1969. A Study of Flow Reduction and Treatment of Wastewater from Households. Federal Water Quality Administration program no. 11050 FKE, contract no. 14-12-428. (Summarized in Water and Sewage Works 85:57-66.)

This report examines potential means of waste flow reduction. The information used in this study was gathered from an extensive literature survey and from manufacturers of reduction devices. Using these data, it was estimated that for a family of 4, limited flow control valves for showers and faucets would save 24 and 2 gal/day respectively and shallow-trap (single-family) toilets (3.5 vs. present 5 gal/flush) would save 30 gal/day while vacuum-flush toilets for new multi-family units would save 90 gal/day. Table IX presents costs for these and a number of other devices (both new and old construction costs).

The study found that these devices and lower-use clothes washers with suds-savers are economically justifiable for new homes with flow control devices justifiable for installation in existing houses (faucet devices only marginally so). Reuse of wash water for toilet flushing was found to be economic for new houses in areas of fair to poor soil drainage (when septic tanks are used). All other systems to reduce use or to treat wastewater on site were judged uneconomic. A survey of the acceptability of various devices was made of plumbers, architect-engineers, equipment manufacturers, and houseowners. Of note is that 82% and 86% of the homeowners and architect-engineers indicated acceptance of the use of wash water for toilet flushing. Little opposition to flow-reduction devices was also found.

The information presented in this report may be very helpful for determination of applicability, acceptability, effectiveness, and negative effects of these flow-reducing devices.

14
Barnes, John, John Borrelli, and Larry Pochop. 1979. Optimum Lawn Watering Rates for Esthetics and Conservation. Journal of American Water Works Association 71:204-9.

The major finding of this study was that the actual lawn water application rates by individual homeowners in Laramie and Wheatland, Wyoming, were respectively 125% and 175% of the average seasonal evapotranspiration rates, while an esthetically pleasing lawn can be achieved with an average application rate equal to or less than the seasonal evapotranspiration rate.

These estimates are of primary utility in identifying applicable water conservation measures and their potential effectiveness.

15
Baumann, Duane D., and Daniel M. Dworkin, eds. 1975. Water Reuse Practices, Prospects, and Problems. U.S. Army Engineer Institute for Water Resources report on seminar, contract nos. DACW31-75-M-1344 and DACW31-75-C-0199.

This report presents 10 papers on the subject of water reuse. Included are papers on (1) "Planning for Reuse," by the editors; (2) "Water Reuse in the U.S. Army Corps of Engineers Urban Studies and Wastewater Management Program: An Overview," by James F. Johnson; (3) "The U.S.E.P.A. and Water Reuse," by Paul Durand; (4) "Status of Wastewater Reuse in South Africa," by L. R. J. Van Vuuren; (5) "Selected Health Aspects of Reclaimed Wastewater in South Africa," by W. H. J. Hattingh; (6) "Economic Consideration in the Reuse of Urban Wastewater," by John H. Sims; (8) "Opportunities and Constraints in the Reuse of Wastewater," (with reference to the Chicago area), by Donald E. Matchske; (9) "Water Reuse in Agriculture, Industry and Recreation," (with reference to the Lubbock, Texas area) by James E. Bertram; and (10) "Planning for Water Reuse in Denver, Colorado," by Richard Heaton.

These papers contain information relevant to determining applicability, technical feasibility, and acceptability of water reuse.

16
Baumann, Duane D., Daniel Dworkin, Scott Sebastian, Barbara Andrews, and David Holtz. 1976. Planning Alternatives for Municipal Water Systems. Indianapolis: Holcomb Research Institute, Butler University.

The purpose of this book was to present issues involved in the management of municipal water systems. Topics covered include projections of demand and water supply, the balancing of supply and demand, and the acceptance by the public and professional sectors of different alternatives. The book is concise and presents a valuable summary of current and future planning alternatives for municipal water systems. It may be used as introductory reference to water conservation planning.

17
Baumann, Duane D., and R. E. Kasperson. 1974. Public Acceptance of Renovated Wastewater: Myth and Reality. Water Resources Research 10:667-74.

The authors' purpose was to present the evidence that there is no support for the belief among water management officials that public opposition is an important obstacle in the adoption of potable wastewater reuse. The authors quoted the study conducted in 37 communities in Texas, Kansas, Illinois, and Massachusetts by telephone survey. A majority (62%) of the 722 respondents expressed willingness to drink reused water, while few (8%) expressed either no opinion or indecision. Another nationwide survey among 300 municipal water managers revealed that nearly 40% of respondents were opposed to wastewater reuse.

Based on their own research and other studies on public acceptance, the authors concluded that there is evidence which suggests that the public will accept renovated wastewater for drinking provided that it is aware of the technological efficacy of water treatment.

The results of this study and discussion of the problem make this article a valuable reference for determining public acceptance of water reuse for municipal supply.

18
Beatty, K. M., and J. C. Pierce. 1976. Representation and Public Involvement in Water Resource Politics: A Comparison of Six Participant Types. Water Resources Bulletin 12:1005-18.

The purpose of this article was to explore the question of whether water politics participants are in fact unrepresentative of the general public and, by distinguishing among several types of participants, to compare responsiveness levels of alternative participant groups. The assumption of the paper was that the representativeness of water resource policy turns on 2 linkages: first, how similar the general public and the participating public are in certain relevant ways; and second, how responsive policymakers are to the participating public. This paper, while the importance of the second is realized, focuses only on the first linkage.

A 10-page questionnaire focusing on water resource policy was mailed to 1,127 potential respondents. Six hundred and eighty-seven questionnaires were returned at least partially completed. The sample selection was not discussed. It is believed that there may be a systematic sample bias toward involvement in water resource policy because that was the thrust of the questionnaire. The questionnaire obtained the following: (1) information concerning the amount of participation in water resource policy planning by the respondent; (2) types of planning activities participants had been involved in (6 categories were derived); (3) background variables such as age, occupation, income, and various uses of water; (4) the respondent's level of satisfaction with current water resource policy; and (5) a preference ranking for 7 alternative uses of water (such as agriculture, industry, recreation).

Citizen advisory committees are the participation groups which are least representative of the general public in background characteristics. They tend to be better educated, have higher incomes, are waterfront property owners, and heavy water users. The participation groups most similar to the general public are those who sign petitions. Participants in water resource policy, regardless of the nature of this participation, tend to be more dissatisfied with water resource policy than does the general public. A rather high degree of representativeness between all participants and non-participants was exhibited concerning the preference ranking of alternative water uses. The authors cautioned that this does not necessarily imply that the same agreement would exist regarding how these alternative uses should be achieved. These findings are important for determining social acceptability of water conservation measures.

19

Billings, R. Bruce, and Donald E. Agthe. 1980. Price Elasticities for Water: A Case of Increasing Block Rates. Land Economics 56:73-84.

The authors of this paper used 2 price-related variables in order to avoid the biased estimates of price elasticity which result when average price is used for block rate schedules. These variables were used together with income and 2 measures of the weather variability to construct the water-demand model of the general form: $Q = f(P,D,S,Y,W)$. The dependent variable Q measures monthly water consumption of the average household (100 cubic feet), while P = marginal price facing the average household (¢/100 cubic feet), Y = personal income per household ($/month), and W = evapotranspiration minus rainfall (inches). Quantitative relationships of either linear or log-linear form were estimated for monthly data from January 1974 to September 1977 obtained from the Tucson (Ariz.) Department of Water and Sewers.

This is a valuable analysis of residential water demand, since it takes account of marginal prices and also defines precisely all variables used in the demand model. The information provided by the authors may be helpful in determining unrestricted water use for the estimation of measure effectiveness.

20

Bishop, Creg S., and Robert R. Jacobs. 1981. Evaluation of the Impact Imposed upon Surface Water Sources by Implementation of the Federal Water Conservation and Reuse Policy in a River Basin with a Water Surplus. Tennessee Water Resources Research Center report no. 84. Knoxville: University of Tennessee.

The authors' purpose was to determine the impact of 3 water conservation and reuse scenarios on the quality of the Nolichucky River water and associated tributaries in Washington County, Tennessee. Based on the analysis of water-quality data, the authors concluded that even 30% reduction in water use would not significantly alter the quality of the river water, thus neither decreasing nor increasing negative environmental quality (EQ) effects.

This study is a useful example for determination of negative environmental quality effects (EQ effects) which may result from reduction in water use.

21
Bishop, D. S., G. T. Broach, W. H. Hester, and V. A. Sikora. 1981. Evaluation of Selected Environmental, Socio-Economic, and Industrial Effects of Implementation of the Federal Water Conservation and Reuse Policy in a River Basin with a Water Surplus. Tennessee Water Resources Research Center report no. 85. Knoxville: University of Tennessee.

The purpose of this study was to describe both the positive and negative effects of the national policy on water conservation and reuse on the French-Broad River Basin of Tennessee. Specifically, the report describes selected economic, sociological, legal, and environmental impacts of a hypothetical 10- and 30-percent reduction in water usage in this area--the authors' interpretation of a possible outcome of this policy.

Unstructured interviews and a telephone survey with local residents showed that there was little support for a national water conservation/reuse policy and that, for example, a hypothetical mandated 30% reduction program would produce public resistance and frustration. Legal responses to the program would also cause problems in such areas as changing the rate structures, developing a plumbing code, and restructuring the housing code.

An economic impact would involve a drop in property value and the loss of 300 jobs in the area. This would result in the loss of over $1 million in yearly income and a subsequent decrease in tax revenues. With respect to water utilities, rates for water use and wastewater disposal would have to be increased by 40% if the consumption rates decreased by 30%.

Considering the positive effects, the programs would result in considerable savings stemming from reduced costs of water and wastewater treatment systems with the greatest potential for savings in individual wastewater disposal systems (septic tanks).

In general, the report indicates that a 30% reduction in water use through a program imposed by the government in the area would not meet the criteria of both social and economic feasibility. This publication provides information for consideration of acceptability of water conservation as well as disadvantageous effects associated with reduced consumption of water.

22
Blackburn, Anne M. 1978. Management Strategies Dealing with Drought. Journal of the American Water Works Association 70:51-59.

This article reviews the steps taken by the Thames Water Authority to deal with the 1976 drought in the United Kingdom. "A major regional

publicity campaign on water conservation (during the drought) brought a voluntary reduction in use of 20%. . . . A pressure reduction of 25% throughout the (London) metropolitan water-supply distribution system was also introduced; it produced a 10% water saving." Later all outside uses of water were banned. Sewage effluent from London was made available to grass race-course owners at no cost, but they had to pay for its transportation and spreading from tank trucks. Seventeen hour-cutoffs (per day) were imposed on Southern Wales to achieve up to 50% total reductions. One problem with these statistics, particularly the effect of pressure reduction, is the necessary guess-work involved in separating out the effect of different measures.

The data presented here may be used in estimating the effectiveness of educational campaigns and other water conservation measures.

23

Bogue, Stuart H. 1963. Trends in Water Use. Journal of the American Water Works Association 55:548-54.

In this article the author makes some general comments about the use of municipal water, based on generalized data from the Detroit metropolitan area. The following factors that affect water use were identified: (1) size and type of community, (2) location, (3) water quality, (4) pressure, (5) sewers, (6) metering, (7) age of community, (8) lawn sprinkling, (9) cost, and (10) air conditioning. The author did not attempt to analyze these factors in greater detail.

Although no empirical data are provided, the article may be used as an introductory reference for water conservation planning.

24

Bohae, Charles E., and Raymond A. Sierka. 1978. Effect of Water Conservation on Activated Sludge Kinetics. Journal of Water Pollution Control 50:2313-26.

The authors reviewed the literature concerned with the effectiveness and implementation of water conservation programs and noted that the widespread application of such programs would result in marked increases in the substrate concentrations reaching activated sludge wastewater treatment processes. While reductions in wastewater flows can be expected generally to reduce the cost of wastewater collection and disposal systems, the impact on the design parameters and cost of activated sludge unit processes was not so obvious.

The authors first constructed a mathematical model of an activated sludge process, where influent volume and substrate concentration can be varied to simulate the impact of a water conservation program. Bench scale experiments conducted with a synthetic sewage material were then used to evaluate the coefficients of the mathematical model and to test various hypotheses concerning the results. It was concluded that changes in substrate removal efficiencies resulting from increases in influent

substrate concentrations (water conservation) ranged from 0 to a few percent. Effluent BOD and COD concentrations, therefore, were found to change almost proportionately with influent BOD and COD concentrations. The implementation of water conservation programs, then, may make effluent concentration standards more difficult to meet, although there was no evidence that an activated sludge plant's ability to meet a mass loading discharge requirement would be impaired. Optimal aeration tank volume was found to be essentially unchanged by water conservation, reflecting the relatively constant nature of total organic loading. Finally, where reuse of the treated wastewater is a potential consideration, attention must be given to the effect of water conservation on the salinity of the effluent. A 20% reduction in wastewater flow resulting from a water conservation program was found to increase effluent TDS as much as 70 mg/liter.

These considerations are relevant for determining advantageous and disadvantageous effects indirectly related to water-use reduction.

25
Boland, John J. 1971. The Micro Approach--Computerized Models for Municipal Water Requirements. In Treatise on Urban Water Systems, ed. Albertson et al., pp. 295-316. Fort Collins: Colorado State University.

This article was drawn from a lecture given at the Institute on Urban Water Systems at Colorado State University in June 1970. It consists of a general discussion of water-use forecasting, followed by a detailed exposition of the MAIN II forecasting system, as developed by Hittman Associates, Inc. Since the MAIN II system estimates water use from demographic and socio-economic data only, it can be used to backcast, where water use estimated for an earlier period is compared to known water use for the same period. Boland presented the results of a number of backcasts, including 1 for Baltimore, Maryland; 6 for Park Forest, Illinois; 1 for Baton Rouge, Louisiana; and 1 for a housing development in Anne Arundel County, Maryland. Errors ranged from 0.4% for Baltimore and 0.8% for Baton Rouge to as much as 16% for one attempt to backcast commercial use in Park Forest. The use of the forecasting system was illustrated for the new town of Columbia, Maryland. Data requirements were discussed, and forecast results for the year 2000 were presented.

The MAIN II forecasting system may be used for forecasting long-term unrestricted water use for disaggregated municipal and industrial water-use sectors.

26
Boland, John J. 1978. Forecasting the Demand for Urban Water. In Municipal Water Systems: The Challenge for Urban Resource Management, ed. D. Holtz and S. Sebastian, pp. 91-114. Bloomington: Indiana University Press.

This paper, like the others in this volume, was first presented at a conference held at French Lick, Indiana, in October 1976. It contains a

discussion of various approaches to forecasting urban water use and describes criteria for choosing an appropriate forecasting method. Major stress is given to the observation that forecasting error of any kind is likely to lead to excess costs, whether forecasts are too high or too low.

The second part of the paper summarizes some empirical observations of relationships between water use and certain explanatory variables, including population, number of connections, weather, price, and income. An argument was made for replacing population with number of connections (or of households) and for disaggregating water use by customer class as well as by season.

Detailed water-use data obtained for the Washington Suburban Sanitary Commission service area were used to illustrate these points. Boland reached the following conclusions:

1. Water use is better correlated with number of customer connections than with resident population.

2. Significant differences in the nature of water use exist among the various categories of users.

3. Individual water use within a class is subject to great variability.

4. All classes of water use can be highly seasonal in nature.

5. Economic variables, including water price and water-user income, are important factors in explaining water use.

This article constitutes a comprehensive overview of water-use forecasting--an operation necessary for evaluating the effectiveness of water conservation measures.

27

Boland, John J. 1979. The Requirement for Urban Water--A Disaggregate Analysis. In Proceedings, Annual Conference, American Water Works Association, pp. 51-66. California.

This paper describes the need for better understanding of the requirement for urban water. Improved explanation of water use is prerequisite to improved water-use forecasting methods. Forecasting applications were discussed, including conventional long-range forecasts. Boland described the use of short-range forecasts (for financial planning, for example) and the application of forecasting techniques to the analysis of specific perturbations in future water use (alternative futures).

Present knowledge of the structure of urban water use was summarized. Improved approaches to estimating and forecasting water use were contrasted to present practices, yielding recommendations on subjects ranging from basic data collection to forecasting methods themselves. An extensive bibliography was provided.

The issues discussed in this paper are of primary importance for determining unrestricted water use in various water-use sectors.

28
Boland, John J., and Philip H. Carver. 1979. Predicting Water Use Considering Conservation. In Proceedings, Conference on Water Conservation Needs and Implementing Strategies, pp. 88-93. New Hampshire: Franklin Pierce College.

In this brief paper, the authors summarize the impact of water conservation on water-use forecasting. The authors discuss in turn (1) determining effectiveness of water conservation measures at the appropriate level of water-use aggregation; and (2) identifying suitable forecasting methodology. Both these issues are relevant to the most important task in preparation of water supply/conservation plans, i.e. determining expected reduction in water use.

29
Boland, John J., Philip H. Carver, and Charles R. Flynn. 1980. How Much Water Supply Capacity Is Enough? Journal of the American Water Works Association 72:368-74.

This paper discusses the application of risk management techniques to urban water supply planning. It is argued that, rather than apply standard rules of thumb to obtain supply requirements, water utility managers should attempt to balance the economic, social, and environmental cost of providing increased capacity against the risk and cost of water-use restrictions. In particular, utilities may develop drought management plans which can be used to replace the last, most expensive increments of supply capacity. The paper describes a study performed by the authors for Ecological Analysts, Inc., as a part of a larger investigation for the Washington Suburban Sanitary Commission. In that study, probabilistic forecasts of water supply deficits were developed from water-use forecasts and statistical analysis of supply data. The water-use forecast methods were not discussed in detail in this article, although several of the demand models were presented. The development of alternative drought management plans is reviewed, and the use of those plans, together with the deficit forecasts, to analyze supply augmentation requirements was discussed in detail.

The procedures demonstrated in this article can be used to examine the reliability of water supply/conservation plans with preempted potential for short-term water conservation.

30
Boland, John J., Steve H. Hanke, Richard L. Church, and Philip H. Carver. 1975. An Examination of Alternate Rate-Making Policies for the Washington Suburban Sanitary Commission. Baltimore, Rivus, Inc.

This report describes an analysis, using computer simulation of 3 alternative rate-making policies for the WSSC: a uniform charge, a uniform

charge with a summer surcharge, and an increasing-block rate system. The report also discusses means available for compliance with EPA regulations affecting sewer rate structures as they existed in 1975.

The computer simulation incorporated a disaggregate projection of water use, separately considering 5 different user categories as well as sprinkling use in each of 3 different population density zones. Projections were made a function of, among other things, the applicable water price faced by each customer group. When block-type rate structures were considered, customers were further disaggregated by use block. Existing operating and capital costs faced by the WSSC were modeled and forecast. The computer simulation calculated a rate structure at selected intervals, based on the estimated revenues and costs projected by the mode. Results included forecasts of number of customers, average day water use, maximum day water use, contribution to sewer flow, water costs, sewer costs, total revenue, and rate levels. These forecasts were available for each year of the forecast period, and for each of the chosen rate-making policies. Information was also available regarding the incidence of rate changes on customers at various percentile ranks in each category's water-use distribution.

Rate-making policies were compared and evaluated on the basis of their likely impact on future operations, the incidence of rate changes on various customers, their relative ability to track changes in costs, implementation characteristics, and conformance with EPA regulations. Based on this analysis, the consultants recommended that the uniform charge system then employed be retained. The report also contains considerable statistical data on individual water use within the WSSC service area.

The information included in this report is relevant to determination of applicability, implementation conditions, and also effectiveness of rate changes.

31

Boland, John J., and Charles W. Mallory. 1973. Comments on "Residential Water Demand Forecasting" by Peter W. Whitford. Water Resources Research 9:768-70.

This comment contains some clarification and expansion of Whitford's review of the MAIN II forecasting model, developed by Hittman Associates, Inc., as part of a research effort supported by the Office of Water Resources Research. The authors also presented the procedure to be followed in using the MAIN II system. This procedure permits the water supply planner to perform sensitivity analysis for a given set of assumptions (used in generating a forecast) through repetitive application of the MAIN II algorithm.

32

Bollman, Frank H., and Melinda A. Merritt. 1977. Community Response and Change in Residential Water Use to Conservation and Rationing Measures: A Case Study--Marin Municipal Water District. Fall conference presentation, AWWA, San Jose, California.

This paper presents the preliminary results of a survey of a random sample of 1,000 households in the Marin Municipal District as of March 17, 1977. The report presents some interesting statistics on water use. The 1976 ban on outside water use achieved a 25% reduction in water use. The rationing plan that replaced the ban achieved a total reduction of close to 63% (as of July, 1977). The rationing plan included a $10.00/cu.ft. fine for water use from 46 to 92 gal/cap/day and a $50.00/cu.ft. fine for use beyond 92 gal/cap/day. Eighty percent of the respondents rated the 46 gal/cap/day consumption level as moderately inconvenient or not convenient (as opposed to extremely inconvenient or cause of great hardship). Eight-eight percent gave a level of 100 gal/cap/day or less as the amount of water that they could "conveniently live within future years when a shortage no longer existed" compared to an average pre-drought level of 125 gal/cap/day. Also included were factor analyses of income and temperature effects. The authors imply that further studies of this and other data are forthcoming.

The information presented in this paper may be applied in determining both social acceptability and effectiveness of water conservation measures undertaken in this case.

33

Bonem, G. W. 1968. On the Marginal Cost Pricing of Municipal Water. Water Resources Research 4:191-93.

This commentary discusses the implications of "third party" benefits from the improvement of community appearance through the use of water to maintain yards and gardens. Such "spillover" effects indicate that price should be set below the marginal production cost of the water. Although negative spillover effects from the construction of water supply facilities were not discussed, the article provides some insights into problems which are related to determination of negative and positive effects of various water conservation measures.

34

Bower, Blair T. 1966. The Economics of Industrial Water Utilization. In Water Research, ed. Allen V. Kneese and Stephen C. Smith, pp. 143-73. Baltimore: Johns Hopkins University Press.

This paper presents a general discussion of the issues associated with reducing water use by industry. It was noted that past projections of industrial water "needs" have ignored (1) substitution possibilities among components of industrial water utilization systems; (2) the relationship of water to other factor inputs; and (3) the impact of technological changes. For example, the paper notes that from 1954 to 1959 pulp and paper production increased 26% while the intake of water

increased by only 8.5%. Similarly, from 1949 to 1959 refinery capacity for 104 petroleum refineries increased by 51% while fresh water intake increased by only 5%. At the time of the paper (1966), water utilization costs presented only 0.1% to 3% of total industrial production costs. Of these costs, waste treatment and disposal costs dominated water costs by a ratio of from 3:1 to 6:1.

Major factors affecting water use were given as (1) technology of the production process and final production quality requirements; (2) the quality of raw product inputs; (3) effluent controls; and (4) the cost of intake water. Many examples were cited. Listed as possible methods of affecting industrial water use were imposition of effluent charges or standards; significant increase of the cost of intake water; and fixed physical limitations on the intake water supply and/or permitted discharge. The use of a "water utilization charge" was endorsed. The total amount of this charge would be based on (1) the quantity of water intake; (2) the consumptive use of water; and (3) the waste load in the effluent. Forty-three references were cited.

This paper may be helpful as an introductory reference to municipal water conservation.

35

Bowles, D. S., T. C. Hughes, W. R. James, D. T. Jensen, and F. W. Haws. 1980. Vulnerability of Water Supply Systems to Droughts. Utah Water Research Laboratory report UWRL/P-80/08. Logan: Utah State University.

The purpose of this study was to develop 2 indices assessing the severity of drought and the vulnerability of a water supply system to drought which would be useful in water conservation planning. The authors used the following definitions of these indices:

1. drought severity index, S,

$$S = \frac{U}{D} = \frac{D-F}{D}$$

where U is the unfurnished demand, also defined as the total demand (D) less the furnished demand (F), and

2. drought vulnerability index V(S')

$$V(S') = Pr\ (S > S')$$

which is defined by the probability that the drought severity index (S) will exceed a critical value, S', at which significant economic losses will be experienced.

These drought indices were evaluated for 3 municipal and 3 irrigation water supply systems in Utah based on historical water-use and supply records. The authors concluded that in order to define the effects of

water shortage, a continuous loss-function would be more appropriate than the existing assumption that drought-related losses occur suddenly at a certain degree of water shortage.

The report also describes in general terms the impact of Utah's 1977 drought on municipal and rural water systems with respect to their size and examines 5 stochastic streamflow generating models.

Both indices which were developed and tested by the authors may be used in the analysis of drought performance of water supply/conservation plans.

36

Brainard, Frank S., Jr. 1979. Leak Problems and the Benefits of Leak Detection Programs. Journal of Water Works Association 71:64-5.

In this short article, the author discussed the problems and benefits associated with a leak detection and repair program. Provided that the average daily residential, commercial, and industrial water consumption in the U.S. is 29,000 mgd and water system leakage amounts to 15%, the author estimated a value of waste in water, chemicals, energy, and capacity at $158 million per year.

The benefits that can be weighed against the cost of the program implementation include (1) savings in water usage, energy, customers' money capacity, and capital expense; (2) knowledge and confidence gained by management and directors of a utility in their business judgments; (3) reviewed and improved metering; (4) improved rate setting; and (5) improved control of the distribution system.

Among problems which constrain leak detection and repair were (1) lack of individual meters in some customer connections, (2) lack of proper service of privately owned meters, and (3) existence of too large or too old meters not registering actual water consumption. The author suggested the use of the recent development of the electronic coupler to obtain flow data from sealed register magnetic meters and other types of meters to mitigate the above problems.

This article is a useful reference for preliminary determination of applicability, technical feasibility and implementation conditions of leak detection and repair as a conservation measure. Advantageous and disadvantageous effects of this management practice are also referred to.

37

Brewer, M. F. 1964. Economics of Public Water Pricing: The California Case. In Economics and Public Policy in Water Resources Development, ed. S. C. Smith and E. N. Castle, pp. 222-47. Ames: Iowa State University Press.

This paper discusses 5 possible pricing systems that could be used by regional agencies for transferring Feather River water to local retailing groups. The systems discussed are (1) postal pricing; (2) differentiation

by types of water use; (3) zonal price differentiation; (4) price variations over time; and (5) benefit pricing. These alternatives are compared on the basis of economic efficiency, solvency for the California Water Plan, and prevention of "unjust enrichment."

The policies discussed by the author may be useful in the determination of applicable water conservation measures.

38

Brewer, Robert, and Patrick H. McAuley. 1976. An Analysis of Price/Cost Sensitivity of Water Use in Selected Manufacturing Industries. U.S. Department of Commerce: Bureau of Domestic Commerce Staff Study.

This report describes a study of the effects of an intake water price (tax) on the level of withdrawals for non-contact cooling, cotton textile finishing-processing, kraft papermaking and steelmaking. The analysis in each case is conducted on a hypothetical plant that already meets the P.L. 92-500 requirement of Best Available Treatment Economically Achievable (BAT).

The findings were that, with the exception of textile finishing, only very high prices of water would make reduction in intake water economical for the optimally designed plant. For the 35,000 lb/day textile mill, a price of $0.28/1000 gal brings reduction of intake water from the BAT level of 0.57 mgd to 0.30 mgd while a $1.32/1000 gal reduces water intake to 0.19 mgd. For a draft paper producing 1000 T/day of unbleached linear board, a price of $0.75/1000 gal is needed to reduce water intake from the BAT level of 5.6 mgd to 2.1 mgd. Non-contact cooling and steelmaking will not reduce intake water amounts below the BAT level as long as prices are below $1.30/1000 gal and $0.95/1000 gal respectively.

This information may be helpful in determining the effectiveness of pricing policies in the industrial water-use sector.

39

Brigham, Arthur P. 1975. Public Education Campaigns to Cut Water Use (Waste Reduction). In Proceedings, Conference of the American Water Works Association. Paper no. 8-3a, Minnesota.

The 5-year effort of the Washington Suburban Sanitary Commission serving a suburban area of Washington, D.C., to cut unnecessary water use was described. A handbook of water-saving and waste reduction ideas was distributed to 370,000 water users, water-saving workshops were held, slide-speaker programs were made available to civic organizations, product data on water-saving appliances were made available, and television and radio spot announcements were employed. Later steps included (1) changes in the plumbing code to require water-saving plumbing fixtures in new or remodeled dwellings; and (2) the distribution of toilet leak detector kits, plastic bottles for reducing flush volumes, and shower-head flow reducers. Implementation of these practices and devices was claimed to have been influential in marked (6 to 17%)

reductions in total water use during late 1973 and 1974, as compared to the same month in the previous year.

Although no investigation of alternate or coincident causes (e.g., weather changes) was reported, the data reported here may be used in the preliminary determination of the effectiveness of the above water conservation measures.

40

Brigham, Arthur P. 1976a. Effective Use of Communication Tools to Manage Water Demands and Wastewater Loads. Paper presented, Conference on Planning Alternatives for Municipal Water Systems.

This article describes and discusses the effectiveness of a water conservation campaign in Washington, D.C., by the Washington Suburban Sanitary Commission. The 5-year project aimed at educating the public about water conservation resulted in a 6 to 17% reduction from 1973 through 1974, although the study's statistics are vague and therefore its usefulness is limited.

The author identified 5 important points which must be included as targets of communication effort: (1) rates which must be simply communicated and explained; (2) political and civic relationships; (3) customer service/education; (4) employee relationships; and (5) special projects. A study of the porgram effectiveness was carried out on 2,400 customer units for 6 months and was coordinated by the WSSC's public affairs office and field project engineer. Projects included a water-saving handbook, workshops, speaker programs, and a media campaign.

Although the estimates of effectiveness reported by the author are of limited applicability, the report provides useful information for designing a conservation campaign.

41

Brigham, A. P. 1976b. A Public Education Campaign to Conserve Water. Journal of the American Water Works Association 68:665-68.

The author described a comprehensive community water conservation program and demonstrated its effectiveness in a residential suburban Washington, D.C. area.

The projects which were included in the campaign to increase public awareness of the need for water conservation are (1) flyers, (2) water-saving idea contests, (3) workshops for property managers, (4) speaker programs, (5) assembly of data on water-saving appliances, (6) T.V. and radio spot announcements, and (7) production and distribution of home toilet leak-check kits. Results showed a 4.42% reduction from the anticipated water use and a substantial drop in sewage flow.

The article demonstrates that it is possible to mount an effective conservation campaign in a large metropolitan area. The estimated

reduction in water use may be helpful for determination of effectiveness of public education campaigns.

42
Bruner, J. M. 1969. An Analysis of Municipal Water Demand in the Phoenix Metropolitan Area. (Ph.D. Dissertation).

This dissertation includes a general discussion of municipal water with special reference to the Phoenix area along with statistical examinations of the temporal variations in water use, and several regressions explaining the effect of explanatory variables on municipal water use. Price, value of the residence, and evapotranspiration were found to significantly (.05 level) affect water use.

From a time-series regression on residential billing records for Buckeye, Arizona, a price elasticity estimate of -0.8 was obtained. There is reason to suspect that this estimate is too high since the new desalinization plant that caused the price rise also reduced the corrosiveness of the water allowing for the installation of recycling for evaporation coolers. From cross-sectional studies, a price elasticity estimate of -0.27 was obtained based on a log-linear functional form. The data for this estimate consisted of samples of 20 residences each from 6 towns. One possible difficulty with both regression estimates is that sewer charges were not included. In many areas these charges are based on water use.

The analysis presented by the author provides estimates which are relevant to determining the effectiveness of price change in reducing residential water consumption.

43
Bruvold, W. H. 1971. Affective Response Toward Uses of Reclaimed Water. Journal of Applied Psychology 55:28-33.

The author discussed urban residential use of reclaimed water in the San Francisco area and San Diego area. His purpose was to develop scales assessing public reaction to various suggested uses of reclaimed wastewater.

Three 26-item scales, each consisting of descriptive statements regarding a particular use of reclaimed wastewater (drinking, swimming, laundry), were devised and ranked according to favorableness of each statement. These scales were then administered to 25 respondents in a San Diego suburb which had a history of water shortage and which had used reclaimed wastewater in the past. These scales were also administered to 25 respondents in a San Francisco suburb where there was neither a history of water shortage nor use of reclaimed water. Respondents were asked to check the items on the 3 scales which were closest to their own. The same scales were then administered to the same respondents 2 months later.

The test-retest reliability coefficients indicated that individual scores obtained from the 2 administrations were reasonably stable. The authors

tried to establish validity of the scales by demonstrating that, as one would expect, respondents from the arid town with a history of reclaimed water use exhibited more favorable attitudes toward this process than did the respondents from the other town. Construct validity is also indicated by the fact that, as one would expect (if the instrument were valid), favorability of attitudes toward the reuse of water was inversely related to the closeness of personal contact indicated by the 3 suggested uses.

44

Bruvold, William H. 1977. Consumer Response to Urban Drought in Central California. National Science Foundation grant no. ENV77-16171. Berkeley: University of California.

The author tried to assess consumer attitudes toward residential water conservation programs (mild, moderate, and vigorous) adopted by San Francisco Bay Area districts, to evaluate the effectiveness of the water conservation programs mounted, and to explore relationships between conservation behaviors and beliefs about the seriousness of drought and the necessity for continuing conservation efforts. For the study, 9 water service agencies were chosen according to stringency of the conservation programs mounted (3 each of mild, moderate, and rigorous). Five census tracts were randomly selected for each study site; in turn 25 census blocks were selected randomly from those making up the tracts. Four respondents, 2 males, 2 females, 1 of each pair from 18 to 35 years, the other over 35, were chosen from each block. The total sample was approximately 900.

These data showed clearly that rigorous and moderate conservation programs could be established which were very effective (in the cases examined the stated objectives were exceeded), and which were also judged to be fair and equitable by the regulated consumers. Further, and more specifically, the data showed:

1. There is a certain threshold of seriousness that the proposed conservation program must cross if it is to be effective; thus, rigorous programs are more effective in reaching their greater goals than mild ones are in reaching theirs;

2. The public feels that conservation programs should be mandatory, not voluntary;

3. The public wants any such program enforced, and strictly so; and

4. Allotments should be made on a per capita basis, not on previous use.

Two beliefs, perceived seriousness of the drought and need to continue conservation, were better predictors of conservation behaviors than was either education or income. This may be employed to predict public acceptability of various water conservation measures.

45
Bruvold, William H. 1979a. Public Attitudes toward Community Wastewater Reclamation and Reuse Options. California Water Resources Center contribution no. 179. University of California.

This report presents one of the latest studies on public acceptance of reclaimed water which involved interviewing 140 respondents from each of 10 California cities.

The research had 3 objectives: (1) to assess the relation of individual sociodemographic and belief variables to personal attitude toward reclaimed water, (2) to find the voters' evaluation of specific reuse options (type of treatment vs. health, and environmental and economic impacts), and (3) to assess generalities in option rankings across the 10 cities.

The respondents were selected by probability sampling procedures and were presented a detailed analysis of 3 wastewater treatment and reuse options for their community. The options were selected as to cover the environmental, health, and economic impacts.

The obtained results indicated that respondents were unfavorably disposed toward the use of reclaimed water for drinking and that public attitudes had been stable over the 1970-80 period. The younger, more affluent, and more highly educated respondents had more favorable attitudes than older, less affluent, and less educated respondents. An overall conclusion is that the public favors options that protect public health, enhance the environment, and conserve scarce water resources. These options, according to the author, should be put forward into the public sector for ratification and construction financing.

It was the author's intention to answer the question of how the public actually would respond to the use of renovated water. Undoubtedly, he made a step forward in the determination of the behavioral acceptance; however, it is still only midway. The most critical points of the research--the wastewater reclamation and reuse option statements--are at the same time the weakest elements of the study when considered from the psychological interpretation viewpoint. Nevertheless, these deficiencies do not diminish the value of this study for determining social acceptability of water reuse.

46
Bruvold, William H. 1979b. Residential Response to Urban Drought in Central California. Water Resources Research 15:1297-304.

The objective of this study was to identify residential responses to the 1976-77 California drought through analyzing (1) consumer evaluation of conservation programs mounted by water districts, (2) the effectiveness of conservation programs based on customer billing records and conservation measures adopted, (3) testing preliminary hypotheses which relate belief to behavior, and (4) assessment of consumer preference with respect to local versus regional (San Francisco Bay area) water conservation programs.

Residential consumers in 9 selected water districts were interviewed during the summer of 1977. The respondents' selection was based on a cluster sampling technique which produced 100 respondents in each study area. A carefully designed interview schedule was used for interviewing 50 female and 50 male respondents, with 50 over 35 years of age and 50 from 18 to 35 years of age in each district. Information about water conservation programs was obtained through visiting 27 water service districts or purveyors.

Results showed that water conservation and rationing programs instituted by districts were generally judged quite fair and effective. The concern over fairness was centered upon the use of per capita allotments, while effectiveness concerns were centered upon clarity and communication of the conservation plan. Data on water use showed that rigorous residential conservation programs were able to reduce average use during summer months of 1977 by 50% or more (to 80 gpcd or less) as compared to the summer of 1976. Moderate rationing and mild conservation programs could reduce this by about 37% (to 100 gpcd or less), and by 20% (to 130 gpcd or less), respectively. A belief index of the drought seriousness was the best predictor of personal conservation efforts. Finally, based on the interview results, a majority of respondents favored local rather than regional water conservation programs.

This work constitutes a useful example of a technique for determining social acceptability of water conservation measures and also contains valuable information on implementation conditions.

47

Bruvold, W. H., and H. J. Ongerth. 1974. Public Use and Evaluation of Reclaimed Water. Journal of the American Water Works Association 66:294-96.

The authors' purpose was to develop insight into what the public currently thinks of various uses of recycled water. Five California communities were selected in which recycled water was being used. Five control communities were selected which resembled the "project" communities in size, location, and type of dwelling unit. A cluster sampling technique led to the selection of approximately 100 subjects in each of the 10 communities. Of the 1,050 originally contacted by mail, 972 participated. An hour-long field interview was conducted. The major attitudinal portion of the interview consisted of 25 selected uses of recycled water. Each respondent indicated opposition or non-opposition toward each possible use in the local community.

Not surprisingly, opposition to the use of recycled water rose as the use in question entailed closer personal contact. There were no significant differences in opposition between "project" and control communities. Additionally, attitudes in the 5 "project" communities were assessed regarding the actual recycling project in their particular community. Most responses were indifferent--indicating at least that little community polarization had developed over the recycling project.

The findings of this study provide relevant information for determining public acceptability of renovated water.

48

Bruvold, W. H., and P. C. Ward. 1972. Using Reclaimed Wastewater--Public Opinion. Journal of Water Pollution Control Federation 44: 1690-96.

The authors' purpose was to report data on public opposition to a number of uses of reclaimed water and to explore reasons and factors associated with this opposition. The study on public opinion was conducted in 10 California communities including 5 communities in which recycled water was being used.

A cluster sampling technique was used to select approximately 100 subjects in each community. The 1,050 subjects were contacted by mail, and 972 participated. The major attitudinal portion of the interview consisted of 25 selected uses of reclaimed water. Opposition to the use of recycled water rose from a low of 1% to a high of 56% as the use in question moved from "road construction" to "drinking water." The most frequently mentioned reasons for opposition were "psychological repugnance" or "lack of purity." The results indicate that for each general use studied--commercial, domestic, general, recreation, and food production--two or more specific uses of reclaimed water would not be opposed by the California public.

The article is an excellent source of data on public acceptance; however, the reliability of data may be questioned because of a negatively biased definition of wastewater and reclaimed water. Also, the authors' suggestions on how to foster public acceptance starting with the "ladder" position of lowest opposition and moving upward as reclamation technology improves may not be practical in many instances.

49

Burns, D. R. J., J. R. Gerstle, G. J. Roussos, M. K. Whitaker, and B. Wemple. Undated. The Effect of Price on Residential Water Demand--A Comparative Use Study. Paper, University of Colorado, Boulder, Colorado.

This paper presents the results of a comparison of the water use of 2 Colorado communities: Heatherwood and Table Mesa. Elasticities were calculated by comparing water use for households with estimated house values within specific ranges. This analysis produced price elasticity estimates of -0.20 to -0.38 and -0.27 to -0.53 for in-house water use and sprinkling water use, depending on the house value class. The study also produced estimates of "income" elasticity based on estimated house value. The "income" elasticity estimates for domestic demand were 0.239 and 0.246 for Table Mesa and Heatherwood, respectively, while the estimates for the "income" elasticity for sprinkling demand were 0.310 and 0.257.

There are two possible problems with this study. First, it is difficult to guarantee that the difference in water use between the two towns is not due to some factor other than price. Secondly, since no statistical tests were conducted, it is difficult to know what significance to attach to the results. Therefore, the authors' estimates of price elasticities should be used with caution in estimating price effectiveness in reducing water consumption.

50
California Department of Water Resources. 1976a. The California Drought--1976. California.

This report discusses the effects of the California drought and the measures that were proposed at that time. Areas described include agriculture (both dry-farming and irrigated), the State Water Project, the Central Valley Project, the Delta Urban areas, recreation, fish and wildlife, forestry, energy, and groundwater. Of special interest are the discussions of the early planning of the conjunctive use of groundwater and the water exchange with the Metropolitan Water District of Southern California. These measures proved to be very important in dealing with the drought later in 1976 and 1977.

51
California Department of Water Resources. 1976b. Proceedings, An Urban Water Conservation Conference. California.

This document represents the official record of the Urban Water Conservation Conference held in Los Angeles, January 16-17, 1976. It contains the papers presented at the panel meetings as well as the discussion questions following the presentations. These papers briefly highlight topics concerning (1) commercial water-saving devices and appliances, and home fixtures, (2) technological advances in urban water conservation through plumbing practices, (3) uses of water for landscaping, (4) alternatives to volunteer conservation, (5) pricing and its ramifications, and (6) conservation education and a look into the future.

This publication may be a helpful reference in preliminary determination of applicability of some conservation measures.

52
California Department of Water Resources. 1976c. Water Conservation in California. Bulletin 198. California.

This report presents estimates of present water use and of potential use reduction in California from various techniques. Potential reductions include: 1.24 million acre-feet/year (MAFY) by the year 2000 from the universal application of water-saving devices in households (current urban use is 5.04 million acre-feet/year), 1.20 million acre-feet/year of withdrawals from agriculture from improved farm management (primarily replacing gravity with sprinklers and drip irrigation and lining of canals

and laterals), 0.20 MAFY from leak detection, 0.20 MAFY from improved use practices for residential sprinkling and for 0.15 to 0.30 MAFY from improved commercial and governmental sprinkling. Except for some discussion of exhortation by the Department of Water Resources and changes in pricing policies, there was little discussion of how these reductions might be achieved. There was no discussion at all about transfers of water rights or water banking.

The estimates reported in the bulletin may be helpful for determining the effectiveness of water conservation measures.

53
California Department of Water Resources. 1977. The California Drought 1977--An Update. California.

This publication summarizes the overall impact in California of the drought in 1976 and adds an update to the status of drought conditions as of February 1977. A review of the weather conditions precipitating the drought was given followed by impact statements of the 1970 drought. Impacts were examined on a statewide basis as well as regional and resource impacts. Water availability in 1977 was also examined. Plans for drought management in 1977 were outlined in economic and managerial terms. There were little actual water conservation data, as this was not the purpose of this publication. Appendix E contains information bulletins that contain information about technological appliances and their water-saving properties.

The report is a concise and comprehensive survey of the drought in California and the prescribed steps needed to alleviate the pressures of the drought. The information provided by the report may be helpful for the preparation of drought contingency plans.

54
California Department of Water Resources. 1978a. A Technique for Estimating the Effects of Water Conservation on Urban Per Capita Water Use. District report. California.

The purpose of this study was to develop a procedure that would separate the natural fluctuations in urban water use caused by the climate from the effects of water conservation measures.

The methodology described by the authors may be applied to predict unrestricted water use which is a part of the process of the evaluation of measure-effectiveness.

A regression analysis relating average gallons per capita per day consumption for the month in question to 4 predictor variables, i.e. evaporation, average temperature, number of days of precipitation in excess of 0.1 inch and per capita income, yielded linear-combinations explaining 80% and 78% of the variance in water use during the period of 1960-75 in San Diego and Los Angeles, respectively. The effects of water conservation during the drought years 1976 and 1977 were estimated

through comparison of "backcasted" unrestricted per capita per day water use and the actual consumption during each month. The negative difference between the 2 estimates was considered significantly attributable to conservation measures when its 95% confidence interval had both limits negative.

55
California Department of Water Resources. 1978b. Proceedings, Conference on Industrial Water Allocation and Conservation in California. Concord, and Los Angeles, California.

This volume constitutes a compendium of information for industrial water managers compiled from the proceedings of the drought conference on industrial water allocation and conservation held in July 1977 in Concord, and Los Angeles, California. It contains short problem presentations and discussions grouped under the following headings: (1) statewide drought response, (2) statewide water supplies quality, (3) Northern California industrial water supplies, (4) Southern California industrial water supplies, (5) local agency drought response, (6) industrial conservation programs and techniques, and (7) financing industrial water conservation.

Papers dealing with industrial conservation programs and techniques may be helpful in identifying applicable measures for industrial users of municipal water.

56
The California Governor's Drought Emergency Task Force (1978). 1978. Drought Alternative Strategies for 1978. California.

This report outlined the effects of the drought on California in 1976 and 1977 and recommended actions which should be taken if the drought had continued into 1978. It was anticipated that if the snowpack and rainfall of the 1977-78 winter were as low as that of 1976-1977, the effects would be worse than in 1977 but not catastrophic. Agriculture had almost as many irrigated acres in production in 1976 and 1977 as before but with different cropping patterns and with groundwater depletions averaging 4.2% and 8.4% in each of the years. Higher plumping and well-drilling costs were substantial. Agricultural losses were estimated at $800 million. Continued drought would bring further groundwater depletion.

Based on the 1976 and 1977 experience, municipal deficits up to 50% were considered manageable. Continued drought would necessitate water hauling (tank truckers) to many small communities but not at unmanageable proportions. Electric brownouts and blackouts could be avoided in 1978 (as they were in 1976 and 1977) but replacement of hydro water with fossil fuels is expensive. The fish, wildlife, and forestry situations have been bad and will be worse and will require special attention. In Northern California, recreation has been displaced to the delta and to Donner and Tahoe. Removal of exposed sags and temporary launch facilities are needed. The issues considered in the report are important for drought contingency planning.

57
Camp, R. C. 1978. The Inelastic Demand for Residential Water; New Findings. Journal of the American Water Works Association 70:453-58.

This article presents the results of a multiple regression analysis of 13 variables explaining residential water use. The sample consisted of 288 single-family households randomly selected from 10 service areas in Mississippi. Water use was derived from billing data. The price used was taken from the rate schedule at the mean level of consumption for each city. Data for other determinants of water use were obtained by interview or observation of the household characteristics.

The principal determinants of the level of domestic water use (at the 0.05 significance level) were as follows: (1) number of persons by household, (2) number of clothes washers, (3) educational level of the household head, (4) market value of the residence, (5) price of water, (6) presence of swimming pool, (7) rainfall, and (8) lawn area. The estimated price elasticity was -0.24 for the linear-functional form and -0.31 for the mixed linear-logarithmic form.

The author's findings are relevant to forecasting unrestricted water use.

58
Carmichael, J. 1973. Water Recycling in Southern California. In Our Environment: The Outlook for 1980 (Part 1 of Our Environment: Water), ed. A. J. Van Tassel, pp. 237-55. Lexington, MA: Lexington Books.

This article describes the present water industry in Southern California in detail and estimates the (average) costs of water obtained from different sources. Reclamation projects in Whittier Narrows, Santee and Glendale-Los Angeles were examined. It was estimated that water imported from Northern California cost $57/acre-foot in 1972 and would cost $75/acre-foot in 1980 compared to $11/acre-foot for reclaimed water and $197/acre-foot for desalted seawater. The article concludes that water recycling (by groundwater recharge) is "economically and practically feasible, and reclamation plants are functioning in the area (Southern California) at present." It was noted that present and projected reclamation plants were unlikely to have a major impact on water supply. Today reclaimed water accounts for only 0.2% of water use in Southern California.

The analysis of water supply costs for alternative sources is important in estimating foregone supply costs.

59
Cartee, P., and D. C. Williams, Jr. 1979. A Study of Factors Related to the Implementation and Use of Water Conservation Technology in Mississippi. Study no. NTIS PB80-112709. Mississippi: University of Southern Mississippi.

The purpose of this study was to determine the awareness, status, and current usage of domestic water conserving technology in selected areas

of the Mississippi. The information was collected through the survey of home builders and municipal officials.

The results showed that home builders exercise the greatest election responsibility in choosing water-using equipment in speculatively built houses followed next by the plumbing contractor. Sixty percent of the reviewed builders indicated the use of one or more water-conserving toilets and energy efficient hot water heaters. Almost all of the municipalities viewed their water supplies as adequate, and none had mandated water-conserving equipment requirements. The authors concluded that the attempts at mandated, state level water conservation through equipment regulations had not been successful.

The results of this study are relevant to the determination of applicability, acceptability, and implementation conditions of indoor water-saving devices.

60
Carver, Philip H. 1978. Price as a Water Utility Management Tool under Stochastic Conditions. Johns Hopkins University, (Ph.D. Dissertation), Balitmore, Maryland.

This dissertation examines a wide range of issues associated with the use of price as a management tool in urban water supply. The nature of water utility cost was reviewed, as was the literature on marginal cost and peak-load pricing. Data collected from 13 Washington, D.C. area water utilities were used to estimate short-run and long-run responses to price changes. The application of an innovative pricing policy (a summer surcharge plan) to the Fairfax County (Va.) Water Authority was analyzed in detail, leading to estimates of its effectiveness in changing both peak and average water-use rates. Water-use forecasting techniques were developed and applied to the Washington Suburban Sanitary Commission. These forecasts were combined with a statistical analysis of river flow to give a probabilistic forecast of water supply deficit. The deficit forecast then formed the basis of a financial simulation which revealed the consequences of alternative pricing policies. Consumer surplus measures were used to choose among the various policies according to economic efficiency; other criteria included equity, complexity, and revenue erosion. The dissertation includes listings of computer programs used and an extensive bibliography.

The information contained in this publication will be helpful in determining effectiveness and advantageous and disadvantageous effects related to water conservation through pricing.

61
Carver, Philip H., and John J. Boland. 1980. Short- and Long-Run Effects of Price on Municipal Water Use. Water Resources Research 16:609-16.

The authors discussed the theoretical and practical problems related to the results of several empirical studies on price elasticity of

municipal water demand and compared the reported values to their own estimates of both the long- and short-run responses to price. This article contains a detailed consideration of the factors determining the relationship between short- and long-run price effects on water use which in turn is of primary importance in long-term water conservation planning for estimating measure-effectiveness.

The flow adjustment model with lagged consumption included as one of the independent variables used by the authors was:

$$Qt = ap + (1-p)Q_{t-1} + (b_1p)X_{1t} + (b_2p)X_{2t} + \ldots + (b_np)X_{nt}t + pe_t$$

where Q_t is actual consumption at time t; p is a fraction of planned adjustment in consumption actually achieved; X_{it} are values of exogeneous variables at time t including (1) real household income, (2) real price, (3) average number of residents (employees) per connection, and other; and e_t is random variable. Short-run coefficients are represented by (b_ip) and long-run coefficients by b_i.

The values for the dependent variable consisted of monthly water production records covering six years (1969-1974) for 13 Washington, D.C. area water utilities serving residential areas.

Two separate sets of regressions for seasonal and nonseasonal pooled time series and cross-sectional data sets were evaluated. The results showed that short-run elasticity was less than 0.1 in absolute value, while long-run elasticities of -0.70 and -0.62 were within the range of values reported for purely cross-sectional studies. The elasticities estimated for the seasonal component of water consumption were substantially smaller than those reported by previous investigators, both in the short run and in the long run.

62

Cho, Chun. 1976. Utility Management: Key to Resource Availability, Conservation, and Economy. Industrial Water Engineering 13:17-24.

The author considered possible applications of computer technology for water utility management in industrial plants. The use of digital computers in industrial systems can significantly improve plant performance and save money by minimizing unnecessary water and energy consumption. The ways in which computers can be used were described with regard to specific applications along with some general estimates of costs of implementation and expected savings. For example, expected reduction in operating costs derived from computer management of conventional cooling towers may reach 10 to 15%. However, these estimates were too rough to be used for determining the effectiveness of computerization in reducing industrial water consumption.

63
Clark, Robert M. 1976. Cost and Pricing Relationships in Water Supply. Journal of the Environmental Engineering Division of ASCE 102:361-73.

The purpose of this study was to relate the price of water to several characteristics of the water-supply system, as well as to find the relationship between price and per capita water consumption. The study area included 22 districts within a midwestern SMSA (not named). Data presented were from a utility serving this area. Cost analysis was based on total revenue producing water pumped by the utility during the calendar year 1964-73.

Based on a stepwise regression analysis, the author concluded that population density and the source of raw water were major price determinants. Total population served and total demand play secondary roles. The regression of per capita water use on price yielded price elasticities in the range of -0.6, varying slightly with functional form. These findings are important for determining the effectiveness of pricing policies and also provide some insights into variability in water supply costs.

64
Clark, Robert M., and Haynes C. Goddard. 1977. Cost and Quality of Water Supply. Journal of the American Water Works Association 69:13-15.

A statistical analysis of public water supply cost and consumption data for the Cincinnati SMSA was presented. Information was obtained from 22 separate water suppliers within the metropolitan area. The cost of water was shown to be correlated with the population served, the population density, average daily water use, and various characteristics of the source of supply. Water use, in turn, was shown to be correlated with cost. These findings are important for determination of foregone supply costs.

65
Clouser, Rodney L., and William L. Miller. 1979. Household Demand for Water and Policies to Encourage Conservation. Purdue University Water Resources Research Center technical report no. 124. Purdue: Purdue University, Department of Agricultural Economics.

This report describes the study of 2 rural Indiana communities which was designed to evaluate the alternative water supply plans (see also Clouser and Miller, 1980).

The authors estimated that in a community of 600-1,000 population, the decrease of 7.4 million gallons per year in total pumpage for the community is possible to obtain by employing water conservation kits. This would recult in the saving in water bills per household ranging from $40-$60 annually or approximately $22,000 for the community at a cost of subsidizing the installation of about $2,000. A new well and additional storage alternatives would cost about $1 million and raise minimum charges for customers by 78 to 104%.

The study also considered taxation, regulation, and pricing as other means of controlling demand for water, although its primary usefulness is for determination of disadvantageous effects and foregone supply costs for water conservation measures.

66

Clouser, Rodney L., and William L. Miller. 1980. Household Water Use: Technological Shifts and Conservation Implications. Water Resources Bulletin 16:453-58.

This study investigates the effect of water intensive appliances or activities on household water consumption. The analysis was applied to the results of a questionnaire survey of 406 individual households in 2 Indiana communities and their water utility companies (which provided total water bill and quantity of water used by each household in 1977).

The water demand model included such variables as price paid per 1,000 gallons of water used by the household, number of family members residing in the household, number of bathrooms, the household income, and presence of various water intensive appliances. The demand for water was divided into 3 distinct seasonal periods, and appliances or water intensive practices unique to the various periods were incorporated into the estimation. In the majority of cases, the use of the washing machine, dishwasher, swimming pool, and lawn-watering increased per capita consumption and were statistically significant.

The authors also considered the installation of water-saving devices as an alternative method extending supplies in communities. They concluded that private economic benefits would be low if water charges were between $1.00 and $3.00 per 1,000 gallons; however, aggregate benefits to the community could be large if the cost of drilling new wells or increasing storage facilities could be avoided. These considerations are relevant to determining positive effects of water conservation measures.

67

Cohen, Sheldon, and Harold Wallman. 1974. Demonstration of Waste Flow Reduction from Households. U.S. Environmental Protection Technology Series report no. EPA-670/2-74-071. Groton, CT: General Dynamics.

This report presents the results of a demonstration project in which domestic water-use reduction devices were installed in 8 single-family homes. Three of these homes also had systems installed to recycle laundry and bath water for use in toilet flushing and/or lawn watering. The study concludes:

1. Significant reductions in water use can be obtained from the use of available water conservation devices (shallow trap toilets, toilet inserts, flow-reducing valves, etc.) at net cost savings. Broad-based demonstration projects such as the WSSC program should be implemented;

2. The grey water reuse system used proved "manageable and simple to use, and capable of reliable and safe operation. . . projected economics look marginally favorable for high user charge areas (if water and sewer costs exceed $0.57/1000 gal) and where septic systems are flow-limited." More research is recommended; and

3. The extension of the wash water reuse concept of multiple family dwellings should be investigated in order to determine its potential attractiveness for water conservation and waste flow reduction. Reuse on a multiple-dwelling basis should be more economical than for a single-family dwelling.

Actual percentage reductions from the devices tested were presented (Table 1) but the authors admitted that the estimates suffered from the very small number of households sampled (3 to 11). Nevertheless, they may provide bases for comparison. Other information presented in the report may be used in determining applicability and technical feasibility of flow-reduction techniques.

68
Commission on Natural Resources Ad Hoc Committee on Water Resources. 1978. Water Conservation Research. Washington, D.C.: National Academy of Sciences.

This report begins by reviewing the events or factors which have led to the current administration's emphasis on resource conservation. It then summarizes 5 consultant's reports which had covered topics such as agricultural water conservation, domestic water conservation, industrial water conservation, steam-electric power water conservation and incentives and institutions for water conservation and discusses them in light of the goals of the Committee on Water Resources. The report concludes that given the limited funds available, the Committee should stress research concerned with incentives for the adoption of water conservation activities, attitudes and perceptions and on institutions and transfer of technology.

The information contained in the report is only generally related to water conservation planning.

69
Comptroller General of the United States. 1978. Municipal and Industrial Water Conservation--The Federal Government Could Do More. Washington, D.C.

This report justifies the need for a national approach to water conservation in terms of economic costs such as energy cost reductions, construction cost reductions, and overall efficiency. Techniques and their effectiveness were outlined. Areas covered were domestic water-saving devices, metering, pricing leakage control, water pressure control, educational campaigns, and industrial conservation.

Recommendations were made to the Water Resources Council to take the lead in the establishment of an interagency task force of Federal and non-Federal agencies. This could then act as a general clearinghouse for water conservation for municipal and industrial water supplies. Further recommendations pertaining to the implementation of water conservation were made to the heads of various Federal agencies which were related to water resources development or use.

In terms of water conservation the first section of this report is important for initial steps of the planning procedure as it presents a review of various water conservation techniques and their effectiveness.

70

Cotter, Donald J., and Fabian Chavez. 1979. Factors Affecting Water Application Rates on Urban Landscapes. Journal of American Society of Horticultural Science 104:189-91.

The authors' purpose was to determine the effects of season and type of landscape on the rate of water applied to maintain mesophytic plants in the arid southwest.

During the study, 40 single-family residential units on metered municipal water systems of Las Cruces, New Mexico, were evaluated. Total water usage during 1971 and 1972 for each residence was obtained from the city utilities records. The mean water application rate to all landscapes was 145.7 and 127.9 cm/ha for 1971 and 1972 respectively, while the expected usage of water from municipal sources should be 102.7 and 95.3 cm/ha. Thus, the actual application rate exceeded these estimates by 42% and 34%, respectively. The authors concluded that the principal reason for excessive water use lay in consumers' lack of knowledge about plant water requirements.

The results of the study can be applied in calculating potential reductions in outdoor water use by residential customers.

71

Crew, M. A., and G. Roberts. 1970. Some Problems of Pricing under Stochastic Conditions: A Case of Seasonal Pricing for Water Supply. Water Resources Research 6:1272-76.

This article presents 2 models of seasonal pricing: a 2-period deterministic model and a 1-period stochastic model. The first gives rules for investment and pricing for perfectly divisible capacity of:

$$LRMC = \frac{P_1Q_1 + P_2Q_2}{Q_1 + Q_2} \quad \text{and} \quad P_2 - P_1 = \frac{\partial TC(k)}{\partial k}$$

where LRMC is the long-run marginal cost

P_1 and Q_1 are the price and quantity in period 1

P_2 and Q_2 are the price and quantity in period 2

TC(k) is the total cost of capacity

and k is the amount of capacity provided.

For the second model, the solution was obtained by setting the price of a level to satisfy the predetermined security constraint. This second model was found to be unsuitable for analytically solving multi-period problems. The above models are relevant in considering the economic efficiency criteria of water supply/conservation plans.

72
Crews, James E., and William E. Trieshman, Jr. 1979. Drought Effects on Metropolitan Washington, D.C. Area. In Proceedings, Conference on Water Conservation Needs and Implementing Strategies, pp. 156-64. New Hampshire: Franklin Pierce College.

The authors described the drought history in the Potomac River Basin and efforts designed to assist in preventing or reducing severe drought impact on water users in the Washington, D.C. area. Three major utilities in the area, the Washington Aqueduct Division (WAD) of the Corps of Engineers, the Washington Suburban Sanitary Commission (WSSC), and the Fairfax County Water Authority (FCWA) signed a low flow allocation agreement which allocates among them the Potomac River's water during time of a drought. However, because during a drought, water supply may be still insufficient, Metropolitan Washington Council of Governments (MWCOG) and water utilities are in the process of adopting comprehensive plans for necessary curtailment of water use and other emergency actions during a water shortage. These plans are designed to obtain maximum demand reduction reaching 60% of normal use.

In general, the paper constitutes an example of increased flexibility in balancing supply and demand when water conservation is introduced as an acceptable alternative to providing additional supply capacity.

73
Curtis, David C., and John C. Schaake, Jr. 1979. The NWS Extended Streamflow Prediction Technique. In Proceedings, Conference on Water Conservation Needs and Implementing Strategies, pp. 182-95. New Hampshire: Franklin Pierce College.

The authors presented the newest technique developed by the National Weather Service for water supply forecasting and for long-range streamflow forecasting in general called the NWS Extended Streamflow Prediction model, or shortly, ESP.

The technique utilized a subset of the collection of hydrologic, hydraulic, and data processing functions known as the National Weather Service River Forecast System (NWSRFS) which included (1) mean areal precipitation (point estimates of precipitation are transformed into areal averages); (2) mean areal temperature; and (3) mean areal evapotranspiration. Three computational elements of ESP were (1) the Sacramento soil moisture accounting model generating five components of flow to the channel (direct and surface runoff, interflow, and primary and supplementary base flow); (2) snow accumulation and oblation model utilizing estimates of air temperature; and (3) channel routing. The data required by the model include (1) hydrological model parameters, (2) initial basin conditions, and (3) representative future time series inputs in the form of areal means of precipitation and temperature over the basin.

Two examples of the use of ESP for water supply forecasts were also presented (San Joaquim Basin, California; Occoquan Reservoir, northern Virginia).

The techniques presented here are of critical importance for estimating the risk of water shortage at each stage of a drought and can also be used in analyzing drought performance of water supply/conservation plans.

74

Danielson, Leon E. 1979. An Analysis of Residential Demand for Water Using Micro Time-Series Data. Water Resources Research 15:763-67.

This study estimates the parameters of a residential water-demand model based on individually metered water-consumption data. A sample of 261 households in Raleigh, North Carolina, was observed cross-sectionally over 68 time periods of approximately 30 days each. The period covered by the data was May 1969 through December 1974.

Separate water-demand models were constructed for total residential, sprinkling, and winter demands. These dependent variables were estimated as a function of temperature, rainfall, house value, water price, and household size. Water price in this study, which included 50% sewerage charge, was interpreted as marginal charge, since nearly all households fell within the first block rate. For total residential demand, price elasticity (in logarithmic demand equation) was estimated to be -0.27. The coefficients for household size, which consistently explained the largest percentage of variation, were estimated to be 0.740. The remaining variables had coefficients of -0.018 for rainfall, 0.316 for average temperature, and 0.334 for house value.

For winter demand price elasticity was -0.305; coefficients for house value and household size were 0.342 and 0.689 respectively. Price elasticity for sprinkling demand was estimated to be -1.38, while the coefficients for rainfall, average temperature, and house value were -0.206, 5.141, and 0.363 respectively.

The demand model for sprinkling water use developed in this study may be applied in predicting unrestricted consumption by this use category.

75

Danielson, R. E., C. M. Feldhake, and W. E. Hart. 1981. Urban Lawn Irrigation and Management Practices for Water Saving with Minimum Effects on Lawn Quality. Colorado Water Resources Research Institute completion report no. 106. Fort Collins: Colorado State University.

This report describes the methods and results of a research project undertaken to establish criteria by which actual evapotranspiration by urban lawns might be reduced with a minimum decrease in turf quality.

The research was conducted during the summers of 1979 and 1980 on the campus of the Colorado State University. The effects of various management practices on maximum water use and the response of turf quality to limited irrigation levels were measured by 48 small "bucket type" weighing lysimeters placed on a 28 by 31 meter area of Kentucky bluegrass.

The study showed that maximum water use (maximum evapotranspiration by the grass when soil water was never limited) was influenced by mowing height, nitrogen fertility, shade level, grass species, and soil properties. Grass maintained at a 5cm mowing height used about 15% more water than grass at 2cm; however, higher grass could better preserve its quality under water stress conditions. Adequately fertilized grass used 10% more water than grass deficient in nitrogen, had minimal reduction in quality when irrigation was decreased to 70% of maximum evapotranspiration, and had a rapid decrease with further irrigation decrease.

These and other results of this study indicate that proper management can minimize the loss of quality in turfgrass. When properly cared for, bluegrass can easily return from its dormant state even after a very severe drought, while regular periods of mild water stress help promote soil aeration and growth of a vigorous root system, increase drought tolerance, and conserve water without reducing quality.

The information contained in this report is necessary for determining the potential of sprinkling water-use reduction as well as for the purpose of public education.

76

Danielson, R. E., W. E. Hart, C. M. Feldhake, and P. M. Haw. 1980. Water Requirements for Urban Lawns in Colorado. Colorado Water Resources Research Institute report. Fort Collins: Colorado State University.

The purpose of this study was to develop lawn-watering guidelines for 17 cities in Colorado based on the data on water requirements of urban lawns, water application practices, and the relation of lawn management and quality to lawn size, lot size, taxbase, and age of development.

The data were collected during 2 seasons of 1977 and 1978 at Fort Collins and at Northglenn.

Lawn irrigation measurements were made at 30 homes in Northglenn and 27 homes in Fort Collins by measuring the outside water use with meters which were attached to all outside faucets and which were read each week. Potential evapotranspiration was measured as water loss from bucket lysimeters which were installed in the lawns. Fifteen lysimeters were placed in each city with 5 in each of 3 lawns.

The results showed that average irrigation application rates were 5.6 millimeters per day at Fort Collins and 316 at Northglenn. These values consisted 135% and 80% of potential evapotranspiration at the two cities, which according to the authors, may reflect the different type of water pricing. Lawn quality ratings based on a scale of 0 to 10 averaged 7.4 for Fort Collins and 6.5 for Northglenn. For the samples of 27 and 30 homes, there was no general relation between lawn quality ratings and home characteristics of lot size, age of home, or assessed valuation of the real property.

Based on the guidelines developed during this study, the water requirements to maintain a lawn of specific quality rating (Q) can be obtained based on the relationship:

$$di = 0.9\ E_{tpj}\ L_m - dr$$

where:

di = required daily irrigation to provide the desired lawn quality rating, mm/day

E_{tpj} = potential evapotranspiration as calculated by the Jensen-Hoise equation, mm/day

dr = average daily long-term rainfall value, mm/day

L_m = necessary water application rate required for desired quality rating (L_m is 1.0, 0.78, and 0.38 for quality ratings 8, 6, and 4, respectively).

The authors reported also on some effects of imposed restrictions for lawn watering. The restrictions in Northglenn during the entire drought year of 1977 resulted in reduced application rates in the study sites to 3.2 mm of water per year. Those lawns received a quality rating of 5.9 while acceptable quality rating by residents was 6.5. In 1978 without restrictions, 4.1 mm/day was applied and the quality rating averaged 7.1 which was considered an acceptable value.

The report contains valuable information which is indispensable in predicting unrestricted water use for sprinkling purposes as well as in the identification of disadvantageous effects of restrictions imposed on this particular water use.

77
Darr, P., S. L. Feldman, and C. Kamen. 1976. The Demand for Urban Water. Leiden, The Netherlands: Martinus Nijhoff Social Sciences Division.

A comprehensive analysis of the structure and level of urban water use in Israel was presented, based on data collected from more than 30 urban areas during the period 1962 to 1972. Aggregate water use for each urban area was correlated with an income surrogate (motorization rate) and the results contrasted with comparable results for the United States. Attempts to correlate water use with price were unsuccessful at this level, due to the complex nature of the water rate structures in use (increasing-block structure). A behavioral analysis was undertaken which attempted to explain variations in water use in terms of such variables as income, persons per dwelling unit, age of the head of the household, education, rooms per dwelling, and various cultural factors including the family's national origin. Survey methods were also used to estimate consumers' willingness to pay for water. A case study of water use in an arid environment (Eliat, on the Red Sea) was also reported, illustrating the use of both macro- and micro-data to obtain a complete description of the determinants of water use. Eliat consumers were questioned, among other things, about their ability to reduce water use in the face of higher prices/shortages.

Water use in Eliat was found to be uncorrelated with many of the socio-economic variables identified elsewhere in Israel; it depended, instead, almost entirely on the technical specifications of water-using appliances (e.g., desert coolers). The implications of these results for water use forecasting and for water rates design are discussed. Both of these elements are relevant to determination of unrestricted and reduced water consumption.

78
Davis, John A., and Taras A. Bursztynsky. 1980. Effects of Water Conservation on Municipal Wastewater Treatment Facilities. Journal of Water Pollution Control Federation 52:730-39.

The authors examined the extent of flow reduction and its effect on the size and cost of wastewater facilities in response to a water conservation program in the San Francisco Bay Area. It was expected that the implementation of the moderate conservation program would reduce the demand for water in the 9-county bay region of 1,404 mgd (forecast) by 160 mgd by the year 2000.

The analysis showed that the effects of water conservation (with savings in the range of 10 to 20%) on existing wastewater facilities will be fairly minor. Variations of flow attributed to conservation were relatively small when compared to those caused by other factors. Flow reduction may even improve their performance and extend the time to reach design capacity. The capital cost of new facilities may be reduced by 2 to 5% as a result of 10 to 20% reduction in wastewater flow.

The report is a useful reference for determining advantageous effects of water conservation resulting from reduced flow of sewage.

79

Deibert, Larry E. 1978. Fiscal Planning and Water Conservation in Madison, Wisconsin. Journal of American Water Works Association 70:2-5.

This article reports on a water conservation campaign in Madison, Wisconsin, introduced in 1975. The campaign, which utilized various publicity techniques, had the primary objective of shifting peak-hour load in order to ease fiscal problems resulting from new additions to supply capacity. A $40,000 program was directed mainly toward the reduction of the 6:00 p.m. lawn-sprinkling load.

The program was evaluated by a survey of 1,000 randomly selected customers prior to the public information campaign which was followed by a second survey of the respondents at the end of the campaign.

The first survey revealed that 46.6% of the respondents watered between 4:00 and 7:00 p.m., whereas only 38.9% watered after 7:00 p.m. and before 8:00 a.m. The campaign called for sprinkling before 10:00 a.m. or after 8:00 p.m. The follow-up survey showed a shift in these numbers to 18.2% and 68.0% respectively.

The author concluded that with this type of continued program success, the additional capital improvements imposing the annual cost of $62,000 could be postponed.

The results of this study are of value for determination of the effectiveness and acceptability of water conservation measures as a result of public education.

80

De Rooy, Jacob. 1974. Price Responsiveness of the Industrial Demand for Water. Water Resources Research 10:403-6.

This article presents the statistical analysis of water use of 30 large chemical manufacturing plants in New Jersey with respect to price. The author reported the price elasticities of water used for cooling, processing, and steam generation of -0.894, -0.745, and -0.741 respectively. Although the reliability of these estimates is questionable because the average price and mixed cross-sectional and time-series data were used in the calculations, this is one of only a few studies estimating price elasticity for industrial water demand. This information is indispensable in evaluating effectiveness of alternative rate structures on this water usage.

81

Duncan, Donald B. 1979. Water Conservation in U.S. Army Corps of Engineers Programs. In Proceedings, Conference on Water Conservation Needs and Implementing Strategies, pp. 80-82. New Hampshire: Franklin Pierce College.

The author outlined a conceptual framework for incorporating water conservation planning into civil works activities of the Corps of Engineers.

An explicit definition of water conservation and its relation to natural resources management are discussed. The author stated that ". . . some of the values involved in determining the appropriate balance between conservation and new water supplies are subjective" adding however that "the entire water resources planning process. . . is accustomed to dealing with the same set of subjective values."

This brief article constitutes a general summary of the state-of-the-art in water conservation planning with an indication of directions in further research.

82

Dunn, Dorothy F., and Thurston E. Larson. 1963. Relationship of Domestic Water Use to Assessed Valuation, with Selected Demographic and Socio-economic Variables. Journal of American Water Works Association 55:441-50.

The authors evaluated a number of possible factors explaining differences in domestic water use for a random sample of 208 single-family dwellings in Kandakee, Illinois, in 1958. A concise literature review was also provided.

In addition to interviews, data on city zoning regulations, county property valuations, and water meter readings were also included in the analysis. The results showed that the average per capita use ranged from 13 to 161 gpcd while maximum month use ranged from 14 to 295 gpcd. Average household water consumption was 148 gpd and maximum 205 gpd or 138% of the average. The study found that the assessed valuation and the respective household water demand for the month of maximum use were highly correlated. The correlation between assessed valuation and income, occupation and education were .46, .50, and .37, respectively. The second most important factor explaining water use was the number of persons in the household. While per capita maximum month use was relatively high for 1-2-3 member households, it was progressively less for household with more persons. Homes with automatic washers had higher assessed valuation, larger family size, and used more water than those who had wringer washers. Similar relations were noted in terms of shower vs. tub-only bathing facilities. Outdoor water use was greater for larger families and valuation.

The study concludes that above average use was found for households with assessed valuation of $10-$13,000 and lower than average for valuation of less than $7,000. Higher valuation households ($14-$17,000) had even greater demands reflecting appliances, education level, income, etc. The authors claimed that individualistic domestic water-use patterns differ "but slightly from the use patterns of the socio-economic group of which they are a part."

The above study represents one of the first micro approaches to water-use analysis which utilized socio-economic variables to explain observed variance in consumption.

83
Dworkin, D. M. 1975. Water Reuse: A Flexible and Efficient Management Alternative for Municipal Water Supply. Water Resources Research 11:607-15.

This paper presents the comparative analysis between a water supply expansion plan and an alternative plan of supply augmentation through integration of renovated effluent into a water supply system. The author has developed a model which stimulates a municipal system using stream flow, a related storage, water use, water reuse capacity, and new source development. The model was used for the simulation of the water supply system in Colorado Springs, Colorado. The role of reuse consists in treating the reclaimed water as a standby source which can increase system yield and allow for planning flexibility by providing (1) a substitute for high levels of assurance required in municipal systems; (2) a method of mobilizing additional supply in the system; and (3) a method of shortening the planning horizon that can replace present long-term projections.

Based on the simulation analysis, it was found that of 2 methods for providing water for Colorado Springs the supply expansion plan was economically less efficient than the alternative plan employing water reuse. The alternative plan was able to supply demands for 50 years at a present cost of $12 million as compared to the $21 million cost of the expansion plan.

This study gives good examples of the advantages that may result from the implementation of renovated water to its full potential for municipal water systems. Techniques presented by the author may be helpful in estimating foregone supply costs.

84
Ecological Analysts, Inc. 1977. Water Supply Study for Montgomery and Prince George's Counties, Maryland. Towson, Maryland.

This study, undertaken for the Washington Suburban Sanitary Commission (WSSC), assessed the adequacy of the existing supply system, determined the requirement for future supply augmentation, and analyzed the trade-off between supply augmentation and demand reduction with a view to determining more satisfactory supply planning criteria. The latter effort is of particular interest not only because of the innovative methods used but because of the broad implications of the resultant recommendations.

A water-use forecasting model was developed for use in the study, based on statistical analysis of water-use data collected for the WSSC service area and for the service area of a neighboring utility, the Fairfax County Water Authority. Multivariate economic demand models were developed for single-family residential and apartment residential use, separating seasonal and nonseasonal use. Because the available data observations covered a period of little or no change in the price of water, the price coefficient could not be estimated. Price was omitted from the models, therefore, and forecasts were conditioned by the assumption of constant real price. Income elasticities of 0.3

and 0.8 were obtained for nonseasonal use by single-family homes and apartments respectively. The income elasticity for seasonal use by single-family homes was found to be 0.7. Single coefficient requirements models were used for 14 other user classes. The forecast was geographically disaggregated, utilizing separate data for each of 63 planning sectors. Alternate forecasts of population and housing characteristics were provided by county planning agencies, yielding alternate water-use forecasts.

A probabilistic analysis of streamflow was undertaken which, when combined with the water-use forecasts, provided a probabilistic forecast of water supply deficits. Explicit drought management plans were drafted, including various measures designed to reduce water use in the event of threatened water supply deficit. These plans were reviewed by political officeholders and recast by them into 3 alternative drought management scenarios, each specifying the frequency with which individual drought management measures would be implemented. A combination of the deficit forecast with a particular drought management scenario gave the supply capacity augmentation which would be required if deficits were to be avoided without exceeding the allowed frequency of implementation of the drought management measures. It was found that the conventional supply planning criteria previously employed would have required raw water storage of 3.4 billion gallons by the year 2005; a drought management scenario considered acceptable by political officeholders would require storage of only 1.32 billion gallons by the same date. In the latter case, no drought management measure, even appeals for voluntary reductions, would be implemented more often than once in 12 years. By increasing the permissible frequency to once in 5 years, the storage requirement is further reduced to 0.74 billion gallons.

This is an excellent reference for determining drought performance of water supply/conservation plans.

85

Ellis, Robert H. 1978. New Considerations for Municipal Water System Planning. Water Resources Bulletin 14:542-53.

The author considered new elements which have recently entered planning for municipal water supply. These new considerations include the Safe Drinking Water Act, coordination with wastewater planning, wastewater reclamation and reuse, water conservation, energy utilization, financial constraints, and changing public attitudes. The potential effects of these new considerations on traditional planning concepts are dependent upon the special needs and size of the community, although they will be experienced by communities of all sizes.

The author concluded that due to new trends in environmental, social, and financial concerns and also because of changing conditions in the community, master plans should be updated at least every 5 years.

The article constitutes a valuable summary of new concerns in planning for municipal water supply.

86
Ellis, Willis, H. 1966. Water Transfer Problems: Laws. In Water Research, ed. Allen V. Kneese and Stephen C. Smith, pp. 233-50. Baltimore: Johns Hopkins University Press.

This paper presents a discussion of the legal problems (and their potential solutions) of transferring water use in western agriculture to other purposes such as municipal or industrial use. The paper states that in the Rio Grande basin in 1975 (projected) 1 acre-foot will return $50 per year if used in agriculture, $200 to $300 per year if used for recreation, and $3,000 to $4,000 per year if used for industry. Other sources were given. The issues discussed by the author relate to water resource planning and management in general.

87
Ertel, M. O., and S. G. Koch. 1977. Public Participation in Water Resources Planning: A Case Study and Literature Review. Amherst, MA: University of Massachusetts, Water Resources Research Center.

The purpose of the study, which concentrates on the northeastern United States, was (1) to determine the effectiveness of 3 Citizen Advisory Groups and to determine their perception of their role in water resource planning; and (2) to bring to light some of the political, ethical, and social issues involved in public participation in water resource planning.

Questionnaires were sent to each advisory group member at time 1 and again at time 2 in order to determine attitudes about this role in planning, on water-related issues, and any changes in these attitudes which occurred over time. A major assumption of the study was that the large turnover rate in advisory group members was unsystematic. Four functions of advisory group members were identified and ranked in order of perceived importance: (1) advice on planning process; (2) informing the public; (3) review of final plan; and (4) support for final plan. The most significant area of opinion convergency at time 2 was on the key issue of structural versus non-structural alternatives. The majority preferred the latter. This preference was explained by the prevailing national interest in non-structural alternatives.

In addition to the empirical study, a theoretical discussion of the various rationale for public participation in policy planning was provided. Public participation (1) fosters a sense of community; (2) enhances self-development of individual citizens; (3) leads to improved policy; (4) facilitates policy implementation; and (5) fosters democracy. These rationale were then assessed critically.

Many important methodological considerations were ommitted in part 1. Part 2, the theoretical treatment of public participation, contains relevant information and questions some facile assumptions. The authors findings may be also related to the determination of public acceptability of water conservation measures.

88
Feldman, S. L. 1975. Peak-Load Pricing through Demand Metering. Journal of the American Water Works Association 67:490-94.

This article presents a discussion of peak-load pricing of municipally supplied water. The article also advocates the use of a pressure sensitive "demand" meter to deal with the peak-load problem on an hourly basis. While the general discussion of peak-load pricing was good, the concepts underlying the new meter seemed weak. First, the design parameter of greatest interest is maximum day use which is only weakly correlated with maximum hour use. Secondly, depending on the location of pumping stations and local service reservoirs pressure may be inversely correlated with system hourly use. Finally, research needs to be done on the willingness of consumers to take the trouble to check their meter for the current price before using water.

Nevertheless, the discussion of peak-load pricing provides some relevant insights into technical feasibility and implementation conditions of this conservation measure.

89
Feldman, S. L. 1977. A Handbook of Water Conservation Devices. Graduate School of Geography no. NSF/RANN Grant APR76-19369. Worcester, MA: Clark University.

This handbook reviews 34 types of devices for reducing residential water use. The major classes of devices reviewed were (1) toilets; (2) flow-limiting devices; (3) alternative plumbing systems; (4) clothes and dish washers; and (5) lawn and garden controls. For each device a general description was given, water savings were estimated, and a list of manufacturers was provided. Although no actual tests on changes in household water use were performed, the data gathered by the author may be used in a preliminary estimation of fraction reduction in water use for each device.

90
Feth, J. H. 1973. Water Facts and Figures for Planners and Managers. Washington: U.S. Geological Survey.

This publication contains a very general discussion of water use in the United States. Presented were some statistics on domestic and commercial-industrial water use which may be helpful in estimating potential for water conservation nationwide.

91
Flack, J. Ernest. Undated. Cutting City Water Demand. Colorado Water Resources Research Institute information series no. 36. Fort Collins: Colorado State University.

This short publication is designed to assist legislators, policymakers, and water resources planners by providing information on the managerial improvement of existing water supplies. The author presented several water conservation methods and possible reductions in "delivery demand"

by metering, water-saving devices, pricing, water-use restrictions, pressure, and system leakage reduction.

This brochure may be a helpful reference in designing materials for public education campaigns and to some extent as a source of information on implementation conditions and measure-effectiveness.

92

Flack, J. Ernest. 1967. Meeting Future Water Requirements through Reallocation. Journal of the American Water Works Association 59:1340-50.

The article discusses the scope of the water problem in the U.S. as of 1967 and examines reallocation as a method of solving the problem. Based on the findings of the Senate Select Committee on National Water Resources and those of Wollman and Garnsey in American Association for the Advancement of Science (1963) pp. 372, it was concluded that unless new sources of water were developed or consumption was drastically reduced, the projected water withdrawals for the west could not be realized in 1980.

Referring to the work done by Howe and Linaweaver and that summarized by Bain, Caves, and Margolis as well as that done by himself, the author concluded that municipal water demand was relatively elastic at low prices but relatively inelastic at high prices. He argues in favor of universal metering. In the section devoted to industrial water use, it was suggested that this sector's demand would be likely to remain small compared to that of irrigation. Further note was made that actual consumptive use by industry was frequently very small compared to intake.

As for consideration of reallocations and transfers, the paper was concerned with the agricultural, recreational, and industrial sectors of the arid West. This section was quite carefully presented. It was concluded that sufficient flexibility should exist in water rights so as to assure that the demands of higher valued uses can be met by obtaining water from transfers as well as from additional storage or imports.

Findings of this analysis have implications for policymaking with regard to water resources in the United States.

93

Flack, J. Ernest. 1971. Urban Water: Multiple-Use Concepts. Journal of the American Water Works Association 63:644-46.

This is a very brief paper presenting an easily readable overview of the development of multiple-purpose management in urban water utilities. Single-purpose private development of water supply evolved to single-purpose public development. From this point it has been increasingly recommended that the management of water supply and sewer systems be combined. In fact, this policy has been implemented in many instances.

This is a summary of guidelines which might be helpful for the utility managers facing such a combination. The discussion is very practical in orientation omitting mention of possible implications.

94

Flack, J. Ernest. 1976. Management Alternatives for Reducing Demand. Paper presented, Conference on Planning Alternatives for Municipal Water Systems.

The author assessed methods of demand reduction in municipalities and cities. He distinguished two general categories of measures which reduce demand: (1) technological (metering, pressure reduction, reduction of unaccounted water, water-saving devices, horticultural practices, land-use controls, growth controls, building and zoning codes); and (2) socio-economic (pricing, demand or peak pricing, seasonal pricing, public education, incentives, rationing, detection of unauthorized uses and control of public uses).

In order to appraise the efficiency of these methods, one must know (1) how well they can be expected to reduce demand; (2) the social and economic benefits; and (3) how to delineate implementation problems. "Implementation of water conservation by a water utility will permit it to (1) reduce its cost of operation and maintenance; (2) postpone system expansion to meet future growth; (3) increase its time horizon for future water supply acquisition and development; (4) better conform to a steady-state or reduced growth rate; and (5) conserve and better utilize its scarce resources, water and energy."

Demand reductions can be implemented by structural, operational, and economic, or social methods. As social means of demand reduction, the author cites (1) public education, ("In-house-use conservation is important, not that it saves that much water, but because it establishes a conservation ethic which carries over to uses that significantly affect peak demand such as lawn irrigation. Using less water and timing uses to avoid peak demand periods can be stressed through public information and education"; and (2) horticulture changes (types of lawns, etc.). The feasibility of these methods must be evaluated from an engineering, economic, and socio-political viewpoint. The structural alternatives "are sufficiently attractive from an economic standpoint that they warrant investigation."

Horticultural changes, pricing, credits, and incentives need to be justified as conservation means by attitudes and responses after their implementation. Their effectiveness is highly problematical. The article plays down importance of resident conservation but raises the point of reducing peak demands.

All issues discussed by the author are generally applicable to water conservation planning.

95
Flack, J. Ernest. 1981. Residential Water Conservation. Journal of the Water Resources Planning and Management Division, ASCE 107:85-95.

This article describes various water conservation measures and evaluates the techniques and information needed for their implementation. The methods of attaining water conservation were classified into 4 broader categories:

1. structural: metering, flow control devices, recycling systems, horticultural changes, etc.;

2. operational: leakage detection and repair, use restrictions, pressure reduction;

3. economic: pricing policy, incentives (such as rebates, tax credits, or other rewards for conserving water), penalties, demand metering (structural device coupled with peak-demand pricing);

4. socio-policial: public education, laws.

The author illustrated a combined effect of 3 water conservation measures, i.e., metering plus devices and doubling the price of water for a hypothetical example of a residential community of 40,000 population with the average household water use of 756 gpd per dwelling unit. Based on the assumed elasticities of demand of -0.26 for domestic and -0.703 for sprinkling use, 50% installation rate of water-saving devices, and additive effects of demand reduction, the overall water consumption would drop by 33%, while utility revenue would increase by 26%. Although these values do not reflect all identifiable costs and benefits of water conservation, they constitute a strong evidence for the effectiveness of water demand management practices.

The article may be helpful for preparing the list of applicable conservation measures and in identifying implementation conditions. The combined effects of the three water conservation measures may serve as an example of incorporating several measures into a water conservation proposal.

96
Flack, J. Ernest, and G. J. Roussos. 1978. Water Consumption under Peak-Responsibility Pricing. Journal of the American Water Works Association 70:121-26.

This article describes how peak responsibility pricing of water might be applied to Denver, Colorado. A numerical example was presented. Two significant problems exist in the analysis. First, no recognition was made of the problem of revenue sufficiency. Secondly, the actual application of the method was presented for calculating the peak and off-peak period price. This is contrary to economic theory.

97

Flack, J. Ernest, and Wade P. Weakley with Duane W. Hill. 1977. Achieving Urban Water Conservation--A Handbook. Fort Collins: Colorado State University, Colorado Water Resources Research Institute.

This book presents an excellent overview of the potential means of reducing residential water use by methods available to water utility managers. Especially valuable are the discussions of the methods of implementation and the assessment of social and political acceptability for each conservation technique. The discussions of return flow implications are also included although these aspects are only for inter-basin transfers.

The conclusion of the book is that savings of from 30 to 40% are possible through the implementation of a combination of socially acceptable and economically feasible conservation techniques. It was recommended that every utility plan of operation include metering, building code modification, public education and leak detection. Demonstration projects for low water-use horticulture and utility programs for the free distribution and assistance in installation of water-saving devices appear to have widespread applicability. Pricing schemes and recycling systems appear to need more study before they can be widely applied in operating utility systems. Water-use restrictions are effective in dealing with short-term shortages. Chapter V by Duane W. Hill describes the use of surveys for studying problems related to water.

The issues discussed in this book may be helpful in determining applicability, technical feasibility, social acceptability, and also implementation conditions of several water conservation measures.

98

Fletcher, Peter W., and William E. Sharpe. 1978. Water Conservation Methods to Meet Pennsylvania's Water Needs. Journal of American Water Works Association 70:200-203.

The authors discussed the possible means of meeting the laws and regulations pertaining to water and wastewater management in Pennsylvania. The article lists several conservation methods available to sewered communities, another set of methods for unsewered communities, and also water-saving appliances, devices, and techniques. Therefore, it is a useful source of information for determination of applicable and technically feasible conservation measures.

99

Ford, Richard K., and Joseph A. Zigler. 1980. An Analysis of Residential Water Demand Schedules in Arkansas. Arkansas Water Resources Research Center publication no. 76. Fayetteville: University of Arkansas.

The objective of this study was to determine the residential demand for water in each of the 5 Arkansas Water Resource Planning Areas.

The sample of 640 individual household interviews used to estimate regression coefficients for a monthly water consumption equation with

respect to a set of 20 independent variables yielded 3 sets of regression equations with alternately average, marginal, and incremental price for water.

The models developed for each area can be applied to forecast unrestricted water use, a necessary step in estimating effectiveness of water conservation measures.

100

Foster, Henry S., Jr., and Bruce R. Beattie. 1979. Urban Residential Demand for Water in the United States. Land Economics 55:43-58.

The purpose of this study was to specify and estimate parameters for a single equation economic model for urban residential water demand. Price, income, rainfall, and number of residents per water meter were chosen as explanatory variables. The model adopted for this study includes price in exponential form and all other variables in power form. Three variations of this model were developed by incorporating dummy variables. This was done for statistical tests of regional and size-of-city differences. The regional breakdown employed in this study divided the United States into 6 regions in terms of drought potential, agricultural production patterns, manufacturing, and monthly precipitation. Data on water quality, price, and number of residents per meter for 218 cities came from A Survey of Operating Data for Water Utilities in 1960 by the American Water Works Association. Income data were taken from the 1960 Census of Population; rainfall and average temperature data were compiled from Climatological Data for the United States, 1960-61.

The resulting estimated equation for the aggregate model was

$$Q = .2492e^{-.1278P}{}_{Y}{}^{.4619}{}_{R}{}^{-.1679}{}_{N}{}^{.4345}$$

where Q = quantity of water demanded by household, i.e., per meter (1,000 cubic feet per year); P = average water price (dollars per 1,000 cubic feet); Y = median household income (dollars per year); R = precipitation (inches) during the defined growing season; and N = average number of residents per meter. This model was intended to permit any city to forecast residential water use, given its values of explanatory variables.

Tests performed with the disaggregate models showed that city size has an insignificant effect on per household residential water use, whereas regional differences have been found more significant. The demand curves were estimated for each region using regional mean values of income, precipitation, and number of residents per meter. These estimates may be used for estimating the effectiveness of alternative pricing in reducing household water demand, as well as unrestricted residential water consumption.

101
Fox, I. K. 1966. Policy Problems in the Field of Water Resources. In Water Research, ed. Allen V. Kneese and Stephen C. Smith, pp. 271-90. Baltimore: Johns Hopkins University Press.

The purpose of the study was to reflect on the ideological factors that affect water resource policy. Two examples of ideology determining policy were found in (1) water abundance and the development of the western United States. Two opposing views were in evidence: economic rationality (water needs are carefully assessed and met through moderate transfers, etc.) and developmental (the assumption that great projects are necessary, a psychological "boom" mentality); and (2) waste disposal and preservation of water quality. The management view (which assumes waste disposal is a legitimate use of a waterway and maintains that the extent of this use should be determined by cost-benefit analysis) opposes the complete abatement view (which assumes that any pollution is bad and therefore should be eradicated).

Fox identified 4 inherent characteristics of water projects which cause policy difficulties: (1) costs may be spread out over large numbers thus disguising the high net cost; (2) benefits aren't always reaped by those who share in the cost; (3) substantively unrelated policies become politically enmeshed; and (4) benefits may be diffuse, making support difficult to mobilize.

Fox advised that the process of policy change itself must be studied both historically and theoretically. The article, although not conceptually sophisticated, focuses on an important area and demonstrates an awareness of the social and psychological issues which are important in determining social acceptability of water conservation measures.

102
Frankel, R. J. 1967. Economics of Artificial Recharge for Municipal Water Supply. Paper, Resources for the Future, Washington, D.C.

This paper analyzes whether or not wastewater reclamation could be economically competitive with other water source systems. Also evaluated were the physical and chemical limitations of artificial recharge using municipal wastewaters, the economic tradeoffs between additional treatment prior to recharge and greater land utilization, and the break-even point for land values as a function of economies of scale. An extensive literature review was made on each of these subjects. The author concluded that "wastewater reclamation through groundwater discharge is the most feasible economic solution to reclamation of municipal wastewaters today." The values presented indicate that recycling municipal wastewaters by artificial recharge can in some cases be less expensive than the conventional system of surface water supply and discharge using secondary wastewater treatment. Accumulation of total dissolved solids will, however, limit the number of times water can be recycled.

The paper, although a brief summary of an apparently much larger study, contains much useful information on the subject, even though much of the cost data is outdated. A table (I) presents a comparison of the estimated

cost of reclaimed sewage effluent and cost of alternative supply for 17 operating facilities in 1967. These may be helpful in determining foregone supply costs as well as disadvantageous effects of water reuse.

103

Frnka, Robert L. 1979. Forecasting the Need for Surface Water Use Conjunctive with Ground Water. Mississippi: Mississippi State University, Water Resources Research Institute.

The objective of this study was to provide a planning model for integrating surface and groundwater supplies in the major municipalities of Mississippi. In order to perform such analyses, the author had to prepare forecasts for municipal water demands in Mississippi for over 40 areas for the years 1980, 1990, and 2000.

Aggregated water requirement models used by the author were log-linear equations derived from other studies which used average annual water use (mgd) and per capita use as dependent variables and population, industrialization index, per capita income, mean temperature, and average rainfall as independent variables, which had to be determined for the future years. The parameters of these equations were estimated based on 82 observations of cross-sectional data in all counties in Mississippi. The author found that based on the available data the intercorrelations between population and per capita income and between mean temperature and rainfall were fairly high. Income and temperature were excluded as redundant factors, therefore. In equations expressing per capita water use the mean temperature was also excluded.

The author's findings, mostly demand forecasting models, may be used in preparing water conservation plans for the investigated areas in Mississippi.

104

Gallagher, David R., John J. Boland, Barry J. LePlastrier, and David T. Howell. 1980. Methods for Forecasting Urban Water Demands. Australian Water Resources Council technical report. Australia: Australian Government Publishing Service.

This report addresses the methods used to forecast water use in the urban areas of Australia. The world literature on factors affecting urban water use was surveyed, and those findings most likely to apply to Australia were summarized. A field survey of the forecasting techniques actually used by the major water utilities of Australia was reported, and the techniques described were contrasted to methods in use elsewhere. It was concluded that improvements in forecasting techniques are warranted and can be readily made. An approach to forecasting is developed, based on disaggregate demand models. This approach is made flexible by incorporating a range of techniques which can be selected according to data availability. In this way, practice can be steadily improved as better data become available in the future. The derivation of demand models is illustrated using data collected for selected residential areas in New South Wales. It is recommended that water utilities begin collecting data which would support the development of disaggregate demand models in the future.

This publication is helpful in selecting an appropriate method for forecasting unrestricted water use.

105

Gallagher, David R., and Raymond W. Robinson. 1977. Influence of Metering, Pricing Policies and Incentives on Water-Use Efficiency. Australian Water Resources Council technical report no. 10. Australia: Australian Government Publishing Service.

The authors hypothesized that pricing is an effective tool in managing urban water supplies. Their investigation covers all aspects of this hypothesis, including description of recent trends in water use, a review of the urban water demand literature, several empirical studies, and analyses of water-supply costs and pricing policies in Australia.

Water-use trends were presented for major Australian cities for a 10-to-15-year period ending in the mid-1970's. These trends were normalized for population, households, or other measures and transformed in various ways to illustrate the difficulty of projecting future water use from trend analysis alone. The economic theory of demand was reviewed in some detail, with application to the urban water sector. The water demand literature was reviewed; many of the empirical findings presented in the literature were reproduced here. Urban water use in Australia is analyzed against this theoretical and empirical background, including some attention to the economic characteristics of the "allotment and excess use" rate structures common in Australia.

Two empirical studies were reported. The first took place in Nowra, New South Wales, a coastal town of 16,000 population. Twenty households chosen at random were interviewed regarding socio-economic and water-use characteristics. Five of these households were segregated as a control group while the remaining respondents participated in a pricing experiment. The results were used to estimate a demand function for household water use in winter. The function explained 65% of the observed variance in water use and included an estimate of price elasticity equal to 0.283.

The second empirical test took place in summer in Wollongong, New South Wales, a coastal city of 200,000 population. An initial sample of 19 households was drawn, and a procedure similar to that employed at Nowra was used. Separate per capita demand functions were estimated for in-house water use and for outside (garden) use. The former explained 29% of observed variance and revealed a price elasticity of -0.288, very close to the winter elasticity in Nowra. The outside per capita demand function explained 45% of observed variance but failed to include price as a significant variable.

The remaining sections of the report analyzed metering and pricing, policies from a welfare economics point of view, arguing for the introduction of marginal cost pricing on the basis of economic efficiency. The characteristics of water supply costs in Australian cities were also described and compared to those reported in studies of United States water utilities. An extensive bibliography was included.

This paper constitutes a valuable reference for consideration of economic aspects of water conservation planning. Many of them are directly related to estimation of effectiveness of pricing in reducing water demand.

106

Gallup Poll. 1973. Water Quality and Public Opinion. Journal of the American Water Works Association 65:513-18.

The poll tried to determine variables relevant to public opinion concerning water quality. A selected summary of a pre-1973 poll is provided. Responses were broken down by sex, race, education, occupation, geographic region, water source, income, and community size. Among the relevant results are:

1. Although some minor inter-group variation existed, the vast majority of Americans were satisfied with both the quantity and quality of water available to them (82% and 70%, respectively);

2. Between 60 and 70% of the public think that water pollution is either somewhat of a threat or a great threat to the water supply. Only a little over 1/3 feel that their water company is meeting this challenge; and

3. Approximately 55% of the respondents said that they would object to drinking recycled sewage. Forty percent said that they would not object.

These findings are to a certain degree relevant to the determination of public acceptability of some water conservation measures.

107

Galowin, Lawrence S. 1979. HUD/NBS Residential Water Conservation Program. In Proceedings, Conference on Water Conservation Needs and Implementing Strategies, pp. 137-38. New Hampshire: Franklin Pierce College.

The author of this paper announced a multi-year project study conducted by the National Bureau of Standards, sponsored by HUD, aimed at the development of the hydraulic requirements for satisfactory performance of water-conserving potable water systems in buildings.

The following were 5 major scopes of the project:

1. development of performance standards, test evaluation procedures, and guidelines for codes of practice;

2. revisions of the "Hunter" model for water supply pipe sizing with regard to expanded acceptance of water consuming appliances in dwellings;

3. development of design procedures for pipe sizing to provide adequate wastewater sweeping velocities;

4. determination of the impact of the flow capacity change on drainage, waste and vent systems;

5. evaluation of the human factor requirements for acceptance of water conservation and implementation strategies.

This ambitious and comprehensive research program will greatly help developers, builders, and planners in the realization of water conservation policies.

108

Gardner, Richard L. 1977. An Analysis of Residential Water Demand and Water Rates in Minnesota. Water Resources Research Center bulletin 96. Minneapolis: University of Minnesota.

The purpose of this bulletin was to examine price elasticity of demand for residential water in Minnesota along with policy implications for rate making.

The author determined a water-demand function based on data on water sales, rate structures and a breakdown into demand sectors obtained through a mail survey of 650 Minnesota municipalities having a public water system, and also based on the 1970 census of population. The variables used in the model included (1) daily per capita residential water consumption; (2) population served; (3) four alternate price measures; (4) per capita income; (5) number of persons per residence; (6) education level; (7) proportion of rented units; (8) number of bathrooms; (9) average minimum water deficiency (evapotranspiration less precipitation); and (10) proportion of youths.

For a sample of 75 towns used to estimate multiple regression and correlation coefficients, variables (2), (3), (4), and (10) significantly helped to explain variance in water consumption. Price elasticities were found to be in the range of -.15 to -.24 and income elasticity .36.

The recommended rate structure changes for Minnesota as proposed by the author include (1) introducing rate structure reflecting marginal cost of service; (2) installment of a seasonal price system; (3) reducing the number of blocks that change over a small quantity; (4) dropping minimum demand charges in favor of a service charge; and (5) introducing a single separate charge for hooking up equal to the marginal cost of this service.

This publication is a useful source of information on pricing as a water conservation measure since it provides a detailed discussion of a few economic concepts which pertain to this issue.

109
Garland, Sidney B., III. 1975. Water Rationing in Okinawa. Journal of the American Water Works Association 67:296-97.

This article describes the turning off of water supply for periods of up to 24 hours for selected zones by the Okinawa Water Utility (IIWS). The utility has successfully prevented outbreaks of water-borne diseases that could result from infiltration when the pressure is low by instructing residents in disinfecting water. No estimates of the effectiveness of this conversion technique were provided by the article.

110
Gerlach, Luther P., and Virginia H. Hine. 1973. Lifeway Leap. Minneapolis: University of Minnesota Press.

The authors' purpose was to explore 4 conceptual tools or ways of interpreting change and to provide a more adaptive base for decision-making. These tools involved revolution versus developmental change, concept of systems, analysis of movements, and an evolutionary perspective on these tools. Developmental change is change that takes place within an ongoing system; one adds to it or improves it rather than replaces key elements (reform). Revolutionary change is change that upsets the workable balance of a system and throws it out of an established equilibrium; it involves fundamental transformation in the structure of society and its basic institutions. The facility for developing ideas is an example of vertical thinking, while the ability to generate new ones is lateral.

The United States has instigated revolutionary change in underdeveloped countries but is hesitant to accept such changes at home. The authors suggest that "the process of social change which we call modernization is similar, from the point of view of those experiencing it, to the process of futurization in which we are engaged. If we can agree that social upheavals, dislocations, and painful conflicts are an inevitable accompaniment of constructive social change elsewhere, then perhaps we can look upon the upheaval, dislocations, and conflicts in our own society in a more positive way and stop expecting constructive change to be necessarily orderly and conflict free."

Five factors crucial to the growth of a movement are: organizational structure; patterns of recruitment; ideology; personal commitment; and opposition. Movements should be viewed as a part of a natural social process.

Revolutionary and developmental change are both part of the evolutionary process. Movement participants by themselves are not the only initiators of evolutionary change. They generate a range of responses and counter-innovations that are also part of the evolutionary process. The process of evolution also operates on the socio-cultural level.

The authors presented an extremely interesting set of concepts and point of view; the analysis could be tied into the conservation movement which could be labeled a radical change (depending on the methods used, etc.). The study provides valuable insights into the workings of a movement and its place in social evolution.

111
Gilbert, Jerome B. 1978. The California Drought--Out of Disaster, Better Water Management. Journal of the American Water Works Association 70:79-81.

This author summarized some of the major benefits that have resulted in the California Drought. The drought brought attention to the need for comprehensive water management, consideration of multiple use projects, efficient delivery, use and recycling. It also demonstrated the need for cooperation among local, State, regional, and Federal agencies in terms of regulations and water transfer. Groundwater management also appeared as an area that requires further emphasis and improvement. The more efficiently the water resource is managed, the less it will cost and the fewer environmental impacts it will have in the future.

The concept of the article, benefits of drought, is an an interesting one. The author points out crucial areas of water management that, if studied and improved, would greatly increase the overall efficiency of water management in California.

112
Gilbert, Jerome B. and Associates. 1977. Water Conservation Reuse and Supply--San Francisco Bay Region. Report prepared for the Association of Bay Area Governments.

This report presents a detailed program for achieving reduced water use in the Bay area. Present water use was divided into agricultural (41%), residential in-house use (22%), residential use outside the house (10%), commercial-industrial use (20%), publicly used water (3.5%), and water lost or unaccounted for (3.5%). Specific plans for conservation are proposed. Estimates were made of the cost and effectiveness of these plans. The incremental cost of conservation plans were compared with incremental cost of supply-augmentation projects. The average cost of the moderate plan for residential use was estimated at $0.04/1000 gal. The maximum residential plan has an average cost of $0.30/1000 gal while agricultural water conservation has an average cost of $0.16/1000 gal. The cost of water developed from new sources ranges from $0.10 to $0.30/1000 gal. Most of the water reuse projects envisioned in the study would be locally cost-effective only if Federal subsidies were provided. Institutional and financial consideration of the plans was also discussed.

The information contained in the report was mostly applicable in the determination of disadvantageous effects and foregone supply costs associated with water conservation.

113
Goicoechea, Ambrose. 1981. Risk and Uncertainty in Water Supply Planning and Management. Paper, Institute for Water Resources, U.S. Army Corps of Engineers, Ft. Belvoir, Virginia, and International Institute for Water Resources, George Washington University, Washington, D.C.

This paper was prepared to serve as a training course for planners. The author gave background information on definitions of risk and uncertainty,

their sources, and their incorporation into water resources planning procedures.

The documents, reports, and case studies which address the risk and uncertainty in water supply and conservation were reviewed with the author's focus on

1. definition of physical boundaries;
2. forecasting water use;
3. assessment of water availability;
4. identification of water supply systems;
5. choice set of alternative system configurations;
6. system reliability;
7. system flexibility;
8. stress capacity of demand area;
9. evaluation, comparison of alternative; and
10. decisionmaking with multiple criteria about system selecting.

All these elements are relevant to several activities involved in water conservation planning, especially in the consideration of supply reliability of water supply/conservation plans.

114

Gottlieb, M. 1963. Urban Domestic Demand for Water: A Kansas Case Study. Land Economics 39:204-10.

This paper presents the economic analysis of municipal water demand based on aggregated water works data. The author's purpose was to isolate the effect of price and income on water consumption in small Kansas towns during the 1950s. The analysis was based on area-wide averages, total consumption divided by either population or the number of customers, and community-wide average household income. The price of water was derived by dividing total water revenue by the total amount of water used.

The author used an estimating function of the form: $\log y = \log a + \log xb + \log zc$, where y = consumption in 1,000 gallons annually; x = average household income, dollars; and z = price in cents per 1,000 gallons. The results of multiple regressions of rate and income levels from cross-sectional data, on per customer water consumption showed price elasticities of -0.68 and -1.23 and income elasticities of 0.45 and 0.58 for years 1972 and 1957 respectively. Two measures of consumption were also correlated, i.e. per capita versus per customer consumption. For 24 cities in 1957 and 20 cities in 1952, the author has obtained the estimating equations: $Y_c = 8.21211 + .25165X$; (R = .9115), and $Y_c = -1.056 + .3165X$; (R = .9663) respectively. Where Y_c is a per capita consumption and X is consumption per connection.

This is one of the first studies which incorporate more than one explanatory variable in modelling demand for water.

115
Graf, Rudolf F., and George J. Whalen. 1977. Programmed Watering: What a Way to Grow. Popular Mechanics 148:92, 93, 114.

The author described in technical terms the way of installing a do-it-yourself programmable system for automatic lawn watering and instructs potential customers about lawn management. It may be useful in preparing an information bulletin for a public education program.

116
Granger, G. A. 1955. Water Conservation through Metering. Journal of the American Water Works Association 17:122-23.

This short article describes the detection of leaks through a single program of universal metering. Unaccounted-for-water was reduced from 60-70% to 6-20%.

117
Grebenstein, Charles R., and Barry C. Field. 1979. Substituting for Water Inputs in U.S. Manufacturing. Water Resources Research 15:228-32.

The general objective of this study was to determine the extent to which conventional inputs, such as capital and labor, may be substituted for the water input in production of U.S. manufacturing.

Partial elasticities of substitution among capital, labor, and water were derived from cross-sectional state data for all SIC 2-digit industries for 1973. The price of water in different states came from two sources: American Water Works Association surveys and the publication of Mantanari and Mattern of 1975. The analysis showed that water and labor inputs were good substitutes but that water and capital were complements. The values for the price elasticity of demand for water were -0.326 for the AWWA price series and -0.801 for the Montanari and Mattern price series.

The econometric approach used in this study may be useful in predicting the total effects of changes in water prices.

118
Griffith, Evan L. 1978. Southern California's Drought Response Program. Journal of the American Water Works Association 70:74-78.

The article summarizes the response of the Metropolitan water district of Southern California to the drought of 1975-77. The district's system of cut backs and reallocation was outlined. By use of industry conservation, a 10% savings by July-August of 1977 was accomplished. (In Los Angeles a mandatory 20% savings was achieved.) The study concludes that the drought brought close cooperation and coordination between agencies and institutions concerned with water resources in Southern California. The public has been awakened to the problems of future water supply and costs.

The study emphasizes the need for cooperation of agencies and planning for future droughts.

119

Grima, Angelo P. 1972. Residential Water Demand: Alternative Choices for Management. Toronto: University of Toronto Press.

This book presents an extensive study, from both theoretical and empirical standpoints, of residential water demand in the Toronto metropolitan area. The water consumption data used in this study werebased on 91 individual observations from metered single unit households for 1967. These water-use data were averaged over a year, the summer period and the winter period, thus producing average water use in gallons per day in a dwelling unit over each period.

These 3 dependent variables were estimated using log-linear equations with 4 independent variables: (1) the assessed value of the residence (a proxy for income), (2) the number of persons per dwelling unit, (3) marginal charge in cents per 1,000 gallons to the consumer beyond the quantity allowed with the minimum bill, and (4) the fixed bill for 1 billing period. The elasticities of demand with respect to the price were found to be -0.93, -1.07, and -0.75, with income elasticities of 0.56, and 0.48 for average annual, summer, and winter water use respectively.

The book, due to its comprehensiveness, may be used as a primer for the analysis of residential water use.

120

Groopman, Abraham. 1968. The Effects of the North-East Water Crisis on the New York Water Supply System. Journal of the American Water Works Association 60:37-47.

This article describes the activities of the New York water system in response to the 1966 drought. Based on water-use data from 1949-50, it judged that intensive appeals for voluntary conservation backed up by restrictions on the nonessential use of water could reduce consumption by 20 to 25%. In April 1965 such a campaign was instituted. Restrictions concentrated on outside uses of water. Appeals were made through the mass media, door-to-door solicitation, sound trucks, handouts of flyers and bumper stickers; and the response was immediate. By the end of May, July and September water use was shown to be reduced by 120, 205, and 270 mgd (respectively) over what would have existed without the campaign. These reductions correspond to 10, 17, and 22% of the water use that would have been expected on those days.

One failing of the article is that the method of computing the "probable" water use in the absence of restrictions was not presented. Also the reduction in water consumption could not be disaggregated by each of the 2 water conservation measures. The article notes that water use remained 75 to 100 mgd less than it was prior to the campaign even 2 years after (mid-1967) the campaign was relaxed.

121

Grunewald, Orlen C., C. T. Haan, David L. Debertin, and D. I. Carey. 1975. Rural Residential Water Demand in Kentucky: An Econometric and Simulation Analysis. University of Kentucky Water Resources Institute research report no. 88. Lexington: University of Kentucky.

This paper examines residential water use in certain rural areas of Kentucky, specifically those provided with public water supply by means of connections to nearby urban areas. Data were collected from 150 such areas. The purpose of the study was to demonstrate the application of econometric demand functions to the determination of optimal pricing policies and reservoir design criteria and to show the interaction between design criteria and optimal rate structures.

Data were collected for 150 rural residential areas, varying in size from 15 to 2064 customers. Water-use data and prices were as of 1972 and were obtained from the records of the Kentucky Public Service Commission. Mean income, mean housing unit value, and mean number of persons per household were as of 1970 and were obtained from U.S. Census reports. Summer evaporation data 1972 were obtained from Climatological Data--Kentucky. The sample was acknowledged to be non-random, as various data points were excluded for reasons including substantial non-metered consumption, substantial non-residential consumption, etc. Both linear and log-linear models are attempted. Average price was used as a surrogate for price, although all water districts sampled apparently used decreasing-block price schedules. Several regression models were presented, irrespective of the significance level of specific terms.

The authors concluded that the model which best represents rural residential water use in Kentucky is the following:

$$Q = 90.92\ P^{-.92}$$

where: Q = residential water use, 1000 gallons/dwelling unit/day

P = aver. price, $/1000 gallons (1972 dollars)

They further concluded that elasticity of residential water consumption is negative, that the demand function is hyperbolic in shape, that other factors (income, persons per dwelling unit, summer evaporation, etc.) have little effect on water use, that the demand is more elastic than has been claimed by other investigators, that an increasing block price schedule is consistent with marginal cost pricing principles and is optimal in this situation, and that pricing policies have a marked effect on reservoir capacity requirements and, hence, cost.

The study suffers from 2 major faults: (1) a failure to recognize the bias in empirical elasticity estimates which results from the use of average price in the regression where actual rate structures are of the decreasing-block form; and (2) a persistent confusion between costs which increase over time and costs which increase with output, and between marginal cost concepts and average cost concepts. In the first case, the authors accepted an estimate of the price elasticity of demand equal to -0.92, which certainly exaggerates, perhaps substantially, the

true elasticity (as a result of the average price bias). In the second instance, confusion between alternate concepts led the authors to believe that increasing-block price schedules embodied marginal cost pricing principles, which they do not, and to conclude that such schedules are in some sense optimal. Also, the existence of a hyperbolic demand function was not proved; it was only shown that the data fit a hyperbolic function more closely than a linear one. The apparent non-significance in other variables properly attributed to a lack of variation in the data set.

Nevertheless, the characterization data for a rural residential area are a useful addition to the literature on water conservation.

122

Guariso, G., D. Maidment, S. Rinaldi, and R. Soncini-Sessa. 1978. Supply-Demand Price Coordination in Water Resource Management. International Institute for Applied System Analysis research report RR-78-11. Laxenburg, Austria.

This work reports on a price coordination method proposed for the solution of a complex demand-supply problem in water resources management. It provides background information on the basic concepts used for the analysis of the coordination of 2 supplies and 2 demands which are next expanded into a general model for determining the optimal interbasin water transfers in the Northwest Water Plan in Mexico.

The algorithm presented in this paper allows one to determine optimum levels of development for both supply and demand units, such as to maximize total benefits from water use in a given region. The results of its application to the Northwest Water Plan in Mexico (a region involving a groundwater supply, 3 surface water supplies, and 4 demand areas) indicated a 6% increase in the total net benefit from crop production. At the same time, it was found that the average price of water would double in the areas from which the water was taken if the water was priced as a market commodity.

The information contained in this report is useful for large-scale water resource planning.

123

Gysi, Marshall. 1971. The Effect of Price on Long-Run Water Supply Benefits and Costs. Water Resources Bulletin 7:521-28.

The author's objective was to apply economic concepts and discreet dynamic programming models to the problems of predicting long-term effects of various pricing policies. More precisely, the model was designed to determine optimal water supply capacity experience patterns for a hypothetical community with a given water pricing policy. The optimum path is the one which maximizes the discounted sum of future producers' and consumers' surpluses.

The policies examined were constant unit rates, decreasing and increasing block rates and summer differential rates. Price was found to be a major determinant of short-run allocation and long-run planning

and conservational pricing policies now than to force future legal restrictions.

The article is a useful reference for the consideration of foregone supply costs and effectiveness of pricing policies in affecting water consumption.

124

Gysi, Marshall, and Daniel P. Loucks. 1971. Some Long-Run Effects of Water Pricing Policies. Water Resources Research 7:1371-82.

The authors contrast the long-run effects of various rate-making policies for urban water utilities. Five types of rate structure were considered: decreasing-block rates, constant rates, flat rates, summer differential rates, and increasing-block rates. A forward moving dynamic programming model was employed to estimate the optimal size and timing of water supply capacity increases that would maximize the sum of consumers' and producers' surpluses. Each rate-making policy led to a different stream of capacity increases and, therefore, costs, producing a different expected present value of surpluses. On the basis of various results obtained from the use of this model, a combination of the summer differential and the increasing block rate structures was identified as the desirable rate-making policy. This conclusion was based on economic benefits predicted, on minimal need for peak-period rationing, and on the authors' judgment that low consumption users should be rewarded with lower average rates.

The results of this study are relevant to the evaluation of effectiveness of conservation-oriented pricing policies.

125

Hancock, J. C. 1979. Water Conservation in Housing. In Proceedings, Conference on Water Conservation Needs and Implementing Strategies, pp. 69-73. New Hampshire: Franklin Pierce College.

This paper constitutes a summary of the draft report of Task Force no. 9 of the President's water policy initiatives on "water conservation in housing assistance programs."

Provided that residential water conservation policy is to be realized at minimal cost and without reducing the quality of life of affected users, the Task Force found that it may be possible to reduce the current 70 gallons per person by as much as 15% within 10 years. Eight actions were recommended for early implementation. Among these were (1) limited flow showerheads, (2) flow aerators on faucets, (3) water leakage surveys, (4) metering of all water distribution pipes, and (5) the modification of government standards. Among general factors affecting residential water-use conservation that are interrelated with other water conservation considerations, the Task Force included (1) the establishment of general conservation ethics, (2) land subsidence, (3) domestic water-use costs, (4) leakage, and (5) sewage plant operations.

The paper, although very brief, is a valuable reference for determination of applicable and technically feasible measures for residential water conservation and to a lesser extent their advantageous and disadvantageous effects. It also contains a list of water-saving devices which could be justifiable for implementation by short-term research, and another list of items for which long-term research is required for proper evaluation.

126

Hanke, S. H. 1970. Demand for Water under Dynamic Conditions. Water Resources Research 6:1253-61.

This article examines the effects of the change from flat rates to commodity (metered) charges for single-family dwelling units in Boulder, Colorado, using time-series data. The study found that (1) "sprinkling demands were reduced by the introduction of meters, with actual sprinkling being greater than the calculated ideal under flat rates and less than ideal under metered rates; (2) sprinkling use not only declined with the introduction of meters but subsequently continued to decline; (3) domestic demands (in-house) were reduced 36% after meter installation; and (4) domestic demands stabilized at these lower levels. The evidence generated by the analysis demonstrates that water users do not return to their old use patterns after meters are installed, and that metering results in a permanent and significant improvement in water efficiency." These findings are well-substantiated in the article and may be used in estimating effectiveness of metering.

127

Hanke, S. H. 1972. Pricing Urban Water. In Public Prices for Public Products, ed. Selma Mushkin. Washington: The Urban Institute.

This paper presents a good general discussion of the use of pricing policy for municipal water supply. Among the pricing policies discussed are uniform, spatially differentiated and peak responsibility. The paper also presents a discussion of the problem encountered in attempts to estimate the effect of price on water use.

Thirty-four estimates of price elasticity were included (Table 12.5). For municipal or total residential water use these estimates ranged from -0.12 (Seidel & Baumann, 1955) to -1.24 (Gottlieb, 1952). Among the conclusions were: (1) that the user fees are universally applicable to municipally supplied water; (2) the "first-rate-of-return" philosophy combined with uniform rates leads to excessive (non-optional) expansion of water supply facilities when compared to the result of peak responsibility pricing of water; and (3) water use is sensitive to changes in price, the sensitivity depends on the type of use and on the user class (domestic, commercial, etc.) The article fails to consider the effect of sewer costs when discussing optional water pricing policy. The facts that water and sewer prices are inherently related (in the absence of separate meters for sewer contributions) and that sewer costs are related to domestic in-house use only and experience late winter-early

spring peak periods which interfere with some of the usefulness of water peak responsibility pricing are ignored.

Generally, the discussion and experimental data reported by the author may be very helpful in evaluating alternative pricing policies.

128

Hanke, Steve H. 1978a. A Method for Integrating Engineering and Economic Planning. Journal of American Water Works Association 70:487-91.

By explaining basic economic principles of supply-demand relations and presenting methods for calculating marginal costs of water, the author of this article encouraged water managers to use marginal cost pricing. The article also contains a summary of price elasticity coefficients obtained in 26 studies of water use. It may be a useful reference for designing conservation-oriented water rates.

129

Hanke, S. H. 1978b. Pricing as a Conservation Tool--An Economist Dream Come True? In Municipal Water Systems: The Challenge for Urban Resources Management, ed. D. Holtz and S. Sebastian. Bloomington: Indiana University Press.

The paper presents a review of the potential rate-making policies for municipally supplied water. Included are increasing-block, decreasing-block, seasonal, and marginal cost policies. A case study of applying marginal cost pricing to Adelaide, South Australia,was presented. The paper concludes:

> "The dominant rate structure in the industry, declining-block rates, is inefficient, discriminatory, and perverse in its income redistributive properties. Although many environmentalists and those in the industry view increasing block rates and innovative, seasonal rates as an economist dream come true, the economist views them as a great night-mare. These new innovations that fly under the banner of conservation encourage an uneconomic use of resources and create many cross-subsidies among consumers."

The article is a useful addition to the literature treating economic implications of alternative policies for pricing urban water.

130

Hanke, Steve H., and John J. Boland. 1971. Water Requirements or Water Demands. Journal of American Water Works Association 11:677-81.

The article seeks to demonstrate that a negative functional relationship exists between the quantity of water demanded and the price paid for each unit; and to demonstrate that pricing policy is a powerful tool that can be used to satisfy a variety of goals of the utility.

In Boulder, Colorado, in 1961, water meters were installed in areas previously on a flat rate basis and prices changed to 35¢/1000 gallons. A total of 3,086 individual, residential connections were sampled. Flat rate aggregated data from 1955-61 with commercial and industrial use were subtracted out. The metered rate was studied from 1962-68 on 220 meter routes. The domestic demand equaled the lowest quarterly demand (winter) and was assumed uniform throughout the year. The study divided the area into northern (low income) and southern routes (affluent). Upon metering, there was a 36% decrease in average residential water use, and it did not tend back to original levels. Lawn sprinkling is the largest and most important component of seasonal use. This also was reduced upon metering.

Interviews were conducted of 180 persons in both areas; most were middle income and well-educated. Of those samples, 51% indicated adoption of conservation practices with the advent of metering and had further intensified those practices. Only 1.7% reported a drop in conservation practices after the first year.

The time series analysis of residential water use in Boulder from March 1955 to June 1968 concluded that the marginal commodity price of water to residential consumers was changed from 0 (flat rate) to 35¢/1000 gal. Sprinkling water use was separated out of domestic (in-home) use. Population, income, and climate were substantially constant throughout the study period. And sprinkling use, corrected for weather conditions, dropped more than 50%.

Findings of this study may be used in estimating the effectiveness of metering and commodity pricings on the reduction in residential water use.

131

Hanke, S. H., and R. K. Davis. 1971. Demand Management through Responsive Pricing. Journal of the American Water Works Association 63:555-60.

This article describes the use of seasonal pricing to reduce the need for new water supply facilities in Washington, D.C. Basic principles of pricing were outlined, and a prospective case study of applying peak responsibility water pricing was performed. "The practical implications of such a move are that the anticipated investments in reservoir storage and system capacity to cope with growth in peak-day (water) demands can be postponed by perhaps more than 10 years." One unfortunate aspect of this analysis is the failure to consider sewer costs which might be increased in winter water use.

132

Hanke, S. H., and J. E. Flack. 1968. Effects of Metering Urban Water. Journal of American Water Works Association 60:1359-66.

This article presents a good summary of the theoretical aspects of metering and a review of the empirical evidence to that date (1968). The article also presents an outline of how a benefit-cost calculation could

be made to assist in deciding whether to install meters. These considerations are important in determining advantageous and disadvantageous effects of this conservation measure.

133
Hanke, Steve H., and Abraham Mahrez. 1979. An Optimal Sampling Procedure for the Collection of Residential Water Use Data. Water Resources Research 15:1343-48.

The authors' purpose was to design an optimal stratified random sample of individual residential water users for the United States. An efficient nationwide collection of residential water-use data was designed to form a basis for the development of water-demand forecasting models and also to determine water system design criteria. These elements are of basic importance in estimating unrestricted water use and effectiveness of potential conservation measures.

Based on statistical sampling theory, the authors have determined an optimal sample for a given hypothetical utility which was stratified by lot size. Subsequently, the optimal number and location of utilities to account for various climatic conditions (as determined by the Koppman classification system) are within the United States. It is the authors' conclusion that an efficient sample would consist of sampling 200 water connections in 5 different strata at 10 different utilities. The choice of the sample of 200 connections would assure a confidence level for the population mean of 95%.

134
Harnett, John S. 1978. Effects of the California Drought on the East Bay Municipal Utility District. Journal of the American Water Works Association 70:69-73.

The author's purpose was to describe the effects of the 1975-77 drought and how the East Bay Municipal Utility District coped with them. The utility serves a population of more than 1 million on an eastern side of San Francisco Bay. The area experienced the driest year ever recorded during the 1976-77 hydrologic year. This followed the previous year which was the third driest on record. By March 1977 the Pardee Reservoir, the only impounding reservoir in the area, was filled to 22% capacity, 112 ft. below the spillway. Because of reduced withdrawal and an additional amount of water from inflows, it was at 36.5% capacity at the end of Fall 1977.

On February 8, 1977, a water-rationing plan was adopted, aimed at an overall reduction in water consumption of 25%. Residential customers were allotted 280 gpd, industrial customers were cut 10%, commercial and public use cut 25%, apartment complexes cut 30%, and non-residential irrigation cut by 50%. The District also adopted specific prohibitions against wasteful usage. By April 1977, further reductions were needed to aim for adjusted overall reduction of 35%. Water rates were increased and an excess use charge was established. Customer response was immediate and usage dropped in February and March. Newsletters and other

publications were used to disseminate information. By June 1977, water was also pumped in from Sacramento to the Jan Joaquin Delta by merging construction of installations.

One result of this study, as the author contends, is that there will be a permanent reduction in per capita consumption mainly because of operation charges by some of the utility's largest customers and home usage charges. The cost of water will not return to predrought rates because of lower consumption and higher costs of operation. The author suggests that in selecting numerous options, all factors should be weighed, the public should be extensively involved, and that the program must be administered fairly and firmly. The program adopted must provide "an appeal procedure" to maintain public support. A non-drought conservation program was highly recommended as it keeps both the customers and the utility aware and ready to deal quickly with a water shortage.

This is an important article. It points out reduction of usage by 35% within just a few months. The article also points out implications of relatively permanent reductions in water usage as a result of technological change during the crisis period, important from a long-term conservation point of view.

135

Harris, Douglas H. 1977. The Human Dimensions of Water-Resources Planning. Human Factors 19:241-51.

The author's purpose was to establish a framework for incorporating human factors in the water resources planning-decision process. This study (1) identifies the factors which constitute the human domain, (2) determines the structure of the domain, (3) measures the relative values of the factors among populations of diverse interests, and (4) evaluates the stability and generalizability of the dimensions and their measured values.

A total of 388 concepts collected from documents in the water resources literature and a panel of 50 people was reduced to 42 factors that defined the human domain. Multi-dimensional scaling was used to determine the relationship among the 42 factors and to identify the smallest number of dimensions which would represent the 42 factors. The resulting dimensions were: (1) quality of drinking water, (2) fair allocation and conservation of water, (3) natural beauty of bodies of water, (4) public involvement in water resources management, and (5) public access to bodies of water. These dimensions were then tested for reliability and generalizability. A value reflecting importance to human well-being was determined for the 42 factors and 5 dimensions. The dimension values established "Quality of Drinking Water" as having the most social importance and "Public Access to Bodies of Water" as having the least social importance, while the other 3 were close together in value.

The research resulted in a framework of human factors that is applicable to various aspects of the water resources planning-decision process.

Applications include:

1. establishment of water resources objectives which relate to human well-being and the quality of human life,

2. provision of a basis for assuring a broad and comprehensive planning effort for water resources allocation and management,

3. incorporation of human factors and values into systems for defining decision alternatives for water management and conservation,

4. establishment of agendas for public participation in planning and for the resolution of conflict among special interests,

5. definition of criteria for water resources decisions, and

6. anticipation and evaluation of the impact of water resources actions.

This article has relevance to the development of the social feasibility of water conservation measures.

136

Headley, T. Charles. 1963. The Relation of Family Income and Use of Water for Residential and Commercial Purposes in the San Francisco-Oakland Metropolitan Area. Land Economics 39:441-49.

The author has analyzed the impact of income levels on water consumption by regression analysis using both cross-sectional and time-series data obtained from utility records and Census of Population, 1950 and 1959. The regressions were performed for 14 cities of varying population (from 3,000 to 775,000) assuming that price, temperature, precipitation, and other socio-economic variables are constant. Separate consideration was given to commercial and residential use categories, although criteria for disaggregation were not specified.

Cross-sectional estimates of residential water-use elasticity with respect to median family income, using a linear demand equation, were 1.49 in 1950 and 1.24 in 1959. In log-linear forms the income elasticities were 1.63 and 1.37 respectively. Time-series analysis yielded an average elasticity for the 14 cities of 0.25. Average elasticity of combined residential-commercial per capita use was 1.09 according to the 1950 cross-sectional regression.

Although this study uses simplified modeling techniques as compared to most recent research, it does give an interesting consideration of economic issues in municipal water supply.

137
Heckroth, Charles W. 1977. Stricter Conservation Sought as Part of Any Water Resource Policy. Water and Wastes Engineering 14:48-50.

The conservation issue paper prepared by the task group from Federal water resource agencies to provide a basis for further discussion and formulation of recommendations to the President was presented by the editor of Water and Wastes Engineering.

Five general water conservation issues were highlighted:

1. insufficient price of water to provide the incentives necessary to promote efficiency and prevent wasteful uses,

2. inadequate consideration of meeting existing water needs by means of comprehensive watershed management practices,

3. reduction in the quantity and quality of water available for stream uses and instream values caused by reuse and recycling,

4. poor regulation and depletion of groundwater supplies, and

5. inefficient use of water in existing water-consuming facilities and production processes.

Options for solving these problems werediscussed to provide a basis for further comment.

The article contains only general information on water conservation.

138
Heggie, G. D. 1957. Effects of Sprinkling Restrictions. Journal of the American Water Works Association 49:267-76.

This article describes the results of various types of sprinkling restrictions in the city of Detroit from 1952-55 designed to reduce the peak hour water use. "Both the voluntary and the imposed restrictions brought about a significant drop in the maximum hour consumption but only a moderate drop in daily consumption." With a 10 a.m. to 9 p.m. sprinkling ban, it was possible to lower the peak hours from 1,074 mgd to below 800 mgd. Use on the peak day was lowered from 665 to 549 mgd. Other less stringent restrictions met with less consumer resistance but also had less effect. A 2 p.m. to 9 p.m. sprinkling ban resulted in a shifting peak (peak hour 900 mgd).

All this information may be helpful in estimating the effectiveness of sprinkling restrictions on aggregate municipal peak water consumption.

139
Herrington, Paul. 1976. The Economics of Water Supply and Demand. Economics 12:67-84.

This article provides an excellent discussion of the theoretical, empirical, and policy aspects of the economics at public water supply, mostly related to the United Kingdom. The author considered, in turn, demand analysis and forecasting, investment decisions and pricing questions, meanwhile intelligently summarizing the current state of economics of water supply and demand. It was concluded that Britain's growing water problems can only be solved satisfactorily by application of well-tried economic principles.

This paper may constitute one of the best economic treatments of water supply problems and other related issues.

140
Hittman Associates, Inc. 1969. Forecasting Municipal Water Requirements: Vol. 1, The MAIN II System, PB 190275. Columbia, Maryland.

This report describes the development of improved methods for forecasting municipal water requirements which led to the elaboration of one of the more successful computer based forecasting models presently available--the MAIN II system. The authors have determined and analyzed the economic and demographic variables of municipal water use (including their future growth based on the data from 50 metropolitan areas throughout the United States.)

The model calculates the values of residential, industrial, commercial, and other water uses for a selected future year. It incorporates several categories of residential water use (metered/unmetered, sewered/septic tanks, houses/apartments), and for each category, water use is calculated by a regression equation that uses economic (home value, price of water), weather, and demographic factors (mostly census Bureau data) as independent variables. Projections were made of these factors rather than the resultant water use. The forecasting system was able to perform detailed estimates for up to 200 water-use categories. The report also contains 3 case studies (Baltimore, Md.; Baton Rouge, La; and Columbia, Md.) in which forecasts of water use were prepared using the MAIN II system.

The MAIN II system may be considered the most appropriate methodology for forecasting unrestricted water use due to its ability to perform estimates for various use categories.

141
Hittman Associates, Inc. 1970. Price, Demand, Costs, and Revenue in Urban Water Utilities. Columbia, Maryland.

This publication constitutes an excellent study of the municipal water industry based on data collected directly from 46 urban water utilities. The primary purpose of this study, sponsored by the United States Department of the Interior, Office of Water Resources Research, was to develop improved rate-making policies for local utilities that would take account

of effects of these policies, including relationships between price, demand, cost, and revenue. The findings of other investigations were reviewed and analyzed, particularly estimates of the price elasticity of municipal water demands.

The authors developed a general economic model of urban water utilities based on the functional expressions for mean, maximum day, and peak hour demand; operating cost; and various classes of revenue which were derived from the data base. The economic model was tested using 2 case studies of Detroit and Roseville, Michigan, to illustrate the effects of a postulated rate increase on water demand, cost, and revenue. The distribution of demand, cost, and revenue among various classes of water users under alternate pricing strategies was also investigated.

The following water-demand functions were reported:

1. Average municipal demand

$$\bar{Q}_{mr} = 0.0042\ N_d^{.9223}{}_{(.0507)} D_p^{-1.389}{}_{(.371)};\ R^2 = 0.935,\ n = 35$$

where

$\bar{Q}_{mr}$ = average municipal retail demand (mgd)

N_d = dwelling units in retail service area (number)

D_p = median number persons per occupied unit (number)

2. Maximum day municipal demand

$$Q_{mx} = 1.55\bar{Q}_m^{1.012}{}_{(0.04)};\ R^2 = 0.947,\ n = 38$$

where

Q_{mx} = maximum day municipal demand (mgd)

Q_m = average municipal demand (mgd)

3. Peak hour municipal demand

$$Q_{mp} = 1.27\ Q_{mx}^{1.039}{}_{(0.28)};\ R^2 = 0.981,\ n = 28$$

where

Q_{mp} = peak hour municipal demand (mgd)

Separate functions for residential and commercial/institutional user categories were developed to express unit water uses (per connection) in terms of such variables as residential marginal price, moisture deficit, and total retail population.

The information contained in this report is of primary importance in developing and evaluating alternative rate structures for both long-term and short-term water conservation.

142

Hoffman, Mark, Robert Glickstein, and Stuart Liroff. 1979. Urban Drought in San Francisco Bay Area: A Study of Institutional and Social Resiliency. Journal of American Water Works Association 71:356-63.

This case study had 4 objectives: (1) to identify the ways of arriving at drought emergency decisions; (2) to identify the policymaking process in selecting coping strategies; (3) to assess the effectiveness, cost equity, and administrative feasibility of different drought policies; and (4) to identify changes in water management practices as a result of the drought experience. The study extracted information from 8 agencies supplying together approximately 1 million acre-ft of water per year in the San Francisco metropolitan community.

The analysis showed that 2 factors have contributed to the unpreparedness of the utilities to supply shortage: (1) the relatively short time frame in which policymakers must reach decisions about the extent of precipitation, and (2) the staff's conviction that dry years are not persistent. Among factors influencing the formulation of drought policies, the most important were equity and public perception of the respective conservation programs. Revenue considerations and administrative convenience played a secondary role.

The strategies chosen by the districts to augment supply (such as emergency surface supplies, dead storage, new wells, leak detection) were generally unsuccessful in producing additional water, and their costs were approaching $\$0.24/m^3$ ($0.91/1000 gal). Interdistrict transfers, although producing considerable increments to supply, were very costly, i.e. up to $\$0.60/m^3$ ($2.27/1000 gal). The most successful management strategies were those of cross-purpose water diversions involving the curtailment or elimination of hydropower generation with direct costs less than $\$0.04/m^3$ ($0.15/1000 gal); however, their indirect costs were substantial.

Demand reduction strategies involved voluntary cutbacks on consumption requested by 3 districts and mandatory rationing imposed by the other 4. The degree to which residential, and to a lesser degree commercial and industrial, consumers were willing to restrict their water use was found to be influenced by the degree to which they believed there was a shortage requiring conservation. Resulting behavioral changes were found to be 3 to 4 times as effective as structural devices in lowering residential consumption. The costs of demand reduction for the 4 districts employing mandatory rationing varied from $\$0.05/m^3$ ($0.19/1000 gal) to $\$0.25/m^3$ (0.95/1000 gal). These include costs to residential consumers which were primarily landscaping losses. A survey of landscapers in one district showed that these losses ranged from 0 to $400 per single-family dwelling unit.

The authors concluded that direct costs to augment supply ranged from 1.75 to 2.3 times the direct costs to reduce demand. However, in order to interpret these numbers properly, it was necessary to take account of cost resulting from lost revenues because of reduced water sales and reduced hydropower. The foregone external opportunity costs caused by reduced water sales were $4.3 million for the East Bay Municipal Utility District and $2.5 million as a loss in power sales by the San Francisco Water District.

All of the above are relevant in the determination of social acceptability and implementation conditions of water conservation programs, as well as their technical and economical feasibility.

143

Hogarty, T. F., and R. J. Macay. 1975. The Impact of Large Temporary Rate Changes on Residential Water Use. Water Resources Research 11: 791-94.

This article presents the results of a time series study of the effect of price on water use of less than 120 individually owned townhouses in Blacksburg, Virginia, over a 2-year period. The estimates of the short-run price elasticity in response to a price increase range from -1.41 to -0.50. The data indicated that the short-run elasticity to a price decrease may be very low or nonexistent.

This article is somewhat confusing concerning long-run and short-run effects. The results are also clouded by the very small data base.

144

Hollman, K. W., and W. J. Primeaux, Jr. 1973. The Effect of Price and Other Selected Variables on Water Consumption. Report no. NTIS #PB-222-264, prepared for the Office of Water Resources Research.

This report presents the results of a regression analysis of data from 402 households in 14 Mississippi towns. Data were obtained by personal interview and from inspection of water utility records. Average price at the mean consumption level for each utility was used. Variables found to be significant at the .05 level include number of persons (per residence), number of bathrooms, number of dishwashers, number of clothes washers, the existence of a swimming pool, irrigable lawn area, average maximum temperature, annual precipitation, education level, and price. When the income related variables were removed, the market value of the house was found to have a significant effect ("income" elasticity 0.24 to 0.26). Price elasticity values ranged from -0.26 to -0.45 depending on the other variables included and on the functional form.

One possible problem with these estimates is that sewer charges are not included. If these charges are based on water use, then the price value is incorrect.

145
Howe, Charles W. 1968. Municipal Water Demands. In Forecasting the Demands for Water, W. R. D. Sewell, B. T. Bower, et al., pp. 43-79. Ottawa, Canada: Policy and Planning Branch, Department of Energy, Mines and Resources.

This article describes an approach for forecasting water demand which is based on the premise that, given economic and technological forecasts must be made in conjunction with an analysis of the costs of water supply and water-pricing policies. Thus, water-demand forecasting should constitute a sequence of the following steps:

1. an economic base study with forecasts of activity levels;
2. a preliminary estimate of water demands using historical coefficients of water use;
3. preliminary water system design and costing;
4. determination of financial and pricing policies for the urban utility;
5. detailed forecasts of demands in the residential, commercial, industrial, and public sectors, based on estimated demand functions and approximate water price structures.

This article discusses the economic base study and the detailed forecasts of demands in the 4 water-use sectors in greater detail. The latter topic is based on the water-demand functions developed by the Johns Hopkins University Study.

146
Howe, C. W. 1971. Savings Recommendations with Regard to Water-System Losses. Journal of the American Water Works Association 63:284-286.

This article examines the data on losses in municipal water systems and estimates the amount of water that could be justifiably saved solely on economic grounds. Fifty-eight percent of the cities surveyed and 79% of industries surveyed lost less than 15% of the total pumpage. A savings function was derived from the data, and it was indicated that present systems use less than the economic amount of leak detection. It was estimated that the amount of water that could be saved by the implementation of economically efficient levels of leak detection and repair was 2.4 million acre-feet, approximately 9% of current municipal system production. Based on the data presented, there was no indication of any bias in the technique used to make this estimate.

The author's estimates provide some insights into applicability of leak detection and repair as a water conservation measure.

147
Howe, Charles W., P. K. Alexander, J. A. Goldberg, S. Sertner, and H. P. Studer. 1980. Drought-Induced Problems and Responses of Small Towns and Rural Water Entities in Colorado: The 1976-1978 Drought. Colorado Water Resources Research Institute completion report no. 95. Fort Collins: Colorado.

The report documents the response of small towns in Colorado to the 1976-78 drought and makes recommendations concerning water rights transfers in response to future droughts. The specific recommendations in the study have limited usefulness for planning the drought responses of small towns outside of Colorado. The study places emphasis on maintaining water system flexibility in terms of water-rights transfers and conjunctive-use management.

A total of 126 towns were mailed questionnaires, and 62 towns responded. Follow-up contacts were made, and the data were tabulated. The average population of the surveyed communities was 3,300.

The study recommends modification of the existing appropriate water-law system concerning priorities between surface and groundwater rights in order to more fully utilize the groundwater supply in a conjunctive-use system.

The results reported by the authors may be helpful in determining implementation conditions and also in designing drought emergency water conservation programs.

148
Howe, Charles W., and F. P. Linaweaver, Jr. 1967. The Impact of Price and Residential Water Demand and Its Relation to System Design and Price Structure. Water Resources Research 3:12-32.

This article presents one of the most extensive and reliable cross-sectional studies of residential water demand, using data collected by the Residential Water-Use Research Project at Johns Hopkins University. The authors analyzed 39 master-metered residential areas in the United States. Continuous recordings of water use were taken for 2- and 3-year periods during the 1960s and aggregated to hourly, daily, seasonal, and annual figures. Indoor and outdoor uses were separated, with the latter divided into eastern and western regions of the nation.

Indoor demand was estimated using a linear equation with the following independent variables: market value and the age of the dwelling unit; number of residents; average water pressure; and the sum of water and sewer charges that vary with water use, evaluated at the block rate applicable to the average domestic use in each study area. The resulting price and income elasticities were -0.231 and -0.319 respectively.

Outdoor use for sprinkling purposes was estimated using a log-linear functional form with irrigable area per dwelling unit, summer potential evapotranspiration, summer precipitation, and marginal price applicable to average summer total rates of use, as explanatory variables. The

results showed a price elasticity of -1.12 for all metered areas and price elasticities of -0.70 for the western region and -1.57 for the eastern region. Maximum-day sprinkling demand functions were developed for 3 types of residential areas, i.e., metered with public sewer (east), metered with public sewer (west), and flat rate with public sewers. The maximum-day demands were found inelastic with respect to price in the west, but relatively elastic in the east.

Findings of this study are relevant to several activities involved in water conservation planning, mostly to estimating effectiveness and implementation conditions of conservation measures.

149
Hudson, W. D. 1964. Reduction of Unaccounted-for Water. Journal of the American Water Works Association 56:143-48.

The article discusses the causes of unaccounted-for water and describes the range of the amount of unaccounted-for water that may arise due to problems pertaining to master meters, domestic meters, industrial and commercial meters, unauthorized uses, underground leakage, leaks from hydrants, and unavoidable leaks. The author recommends the checking, servicing, and replacement of inaccurate meters, minimizing use of unauthorized water usage, leak detection campaigns, and recording water use by hydrants and public trucks. A complete audit of the distribution system should be made if the percentage of unaccounted-for water remains high after most obvious checks have been made.

This technically oriented article discusses the range and causes of unaccounted-for water. Ten-to-fifteen percent of unaccounted-for water is about average for a well-operated system with consumption of approximately 100-125 gpcd. As far as conservation, the article is useful only in the causal factors of unaccounted-for water and what can be done to change this.

150
Hudson, W. D. 1975. Leak Detection in Water Mains. Water and Sewage Works 85:R104-R106.

This article presents a good review of the methods to detect leaks in water utility transmission and distribution systems. Two methods of determining whether there is a need for large-scale leak detection are (1) the minimum use ratio, and (2) the unaccounted-for water ratio. It is stated that a ratio greater than 35% of the minimum night-use rate to the average-use rate indicates further investigation is necessary. Industrial and commercial night use must be taken into account. For fully metered utilities, if the unaccounted water is greater than 15% of the water produced, then intensified leak detection is usually justified.

Seven factors affecting the unaccounted-for water use were given. These included accuracy of master meters measuring total water produced, under-registration of industrial and domestic meters, unauthorized use, use from hydrants, unavoidable leakage, and underground leakage. For

both methods of determining the need for leak detection, consideration must be made for the number of miles of the distributive system and the cost of producing water. The article also provides a good description of three major methods of locating leaks: hydraulic measurements along mains, visual inspection, and audible inspection with mechanical or electrical amplifiers.

The author's findings and recommendations are useful in determining applicability of this conservation measure.

151

Hudson, W. D. 1978a. Increasing Water System Efficiency. In Municipal Water Systems, ed. D. Holtz and S. Sebastian, pp. 211-18. Bloomington: Indiana University Press.

The purpose of this article was to discuss various means of reducing the quantity of water use which is unaccounted-for. Frequent tests of system-level master meters, rotation of home meters every 10 years, and the regular maintenance of repairable equipment are discussed.

152

Hudson, W. D. 1978b. Increasing Water System Efficiency through Control of Unaccounted-for Water. Journal of the American Water Works Association 70:362-65.

The article discusses the use of the metered ratio as a measure of system efficiency and proposes steps to reduce unaccounted-for water. It is stated that in a city with large industrial consumption with a metered ratio of 90%, there can still be much unavoidable leakage and water. Conversely, a system in a city with little industrial use and a ratio of 85 to 90% may be very efficient.

The steps proposed to reduce leakage included (1) check registration of meters, both master and retail; (2) meter all lines to avoid unauthorized use; (3) record hydrant and other municipal uses; (4) examine lines with leakage greater than 4-12 m^3/day/mile; and (5) make periodic check of valves, hydrants, and services for underground leaks.

153

Hughes, Trevor C., and Robert Gross. 1979. Domestic Water Demand in Utah. Logan: Utah State University, Utah Water Research Laboratory, College of Engineering.

The overall objective of this study was to develop Utah residential water-demand functions for average month, peak month, and peak-day per-capita or per-connection water use. These dependent variables are defined using multiple regression cross-sectional analysis performed on pumping records for 14 metered supply systems of varying size. Price of water, outdoor-use index, size of supply system, and number of persons per connection were examined as explanatory variables. The demand functions relating one type of demand to another were presented,

together with recommended design levels for the same time durations. The design levels were calculated by adding to expected values an increment which was based upon standard deviation of the sample.

The study also develops design criteria for the capacity of those water supply components which are related to very short-term flows. This analysis is based on flow measurements (1- to 5-minute-duration flow rates) during the summers of 1977 and 1978 at master meters on 3 Utah systems. The results were analyzed by a frequency analysis approach. It was found that instantaneous demand peaks which can be expected once in about 30 years in Utah are under 2 gpm per connection for lines serving 10 families, and 5 gpm per connection for lines serving 4 connections.

The findings of this study are useful in the evaluation of those conservation measures which are directed toward reduction in peak-load water comsumption.

154

Ibsen, C. A., and J. A. Ballweg. 1969. Public Perception of Water Resource Problems. Blacksburg, VA: Water Resources Research Center, Virginia Polytechnic Institute.

The purpose of this study was to determine the extent to which the public from rural residential southwest Virginia felt that water use was a problem, what action the public thought was appropriate to combat the problem, and what the correlates of these attitudes were.

A random sample of 592 was selected form an area phone book. Of these, 453 cooperated with a 66-question fixed interview over the phone. The interview took 20 minutes. Only 3% said that water use one of the 5 most serious problems in the world. But 34% said they had, at one time or another, considered water as a problem. The younger, better-educated respondents were more likely to see water as a problem. Only 3% of the sample thought that water problems couldn't be solved.

The authors concluded that public support of water policies was more likely if the public were involved in the planning states. Television was the most effective medium for informing the public, and stress should be placed on the benefit to the "common man."

The strength of the study is that it is an empirical study of a somewhat rural population. However, the content of the interview schedule is unspecified, and the reported results are sparse compared to the length of the interview. The conclusions drawn are somewhat simplistic and the recommendations manipulative.

155
James, L. D. 1974. The Challenge to the Social Sciences. In Man and Water, ed. L. D. James, pp. 1-33. Lexington, KY: University of Kentucky Press.

This chapter acts as a general introduction to the rest of the book which consists of a series of articles outlining the place of various social sciences in water-resource planning. The book is an attempt to begin to solve what is termed the "bottleneck" theory of societal development. By this term, the author has referred to the process whereby a society advances by means of certain approaches while neglecting others. But a time comes when the emphasis must shift to other approaches to insure further progress. Thus, in water-resource planning we have come as far as possible without emphasizing social factors. Therefore, the linkages between social and physical sciences must be better understood. In addition to the discovery of these linkages, better means of communication from social theorists to front line administrators must be devised.

The article seems designed more to "set the scene" for the rest of the book than to provide usable information on social aspects of water resource planning itself.

156
James, L. Douglas, and Wade H. Andrews. 1978. Water Conservation Information Dissemination during the 1977 Drought Emergency. Utah Water Research Laboratory Planning Series report P-78-002. Logan: Utah State University.

This study was undertaken to provide for the exchange of drought information among the states affected by 1976-77 drought. The authors collected information on:

A. water-user conservation practices:

    1. domestic use (inside, outside),

    2. industrial,

    3. commercial,

    4. irrigation;

B. water-supplier management practices:

    1. water conservation inducements,

    2. emergency water supply augmentation (groundwater mining, water harvesting, water reuse),

    3. reallocation among uses or users;

C. dealing with special drought problems:

1. livestock and range management,

2. effects on fish and wildlife,

3. fire danger,

4. effects on recreation,

5. energy effects (reduced generation and additional use),

6. effects of resulting changes in water quality including salinity, and

7. wind erosion.

The report contains 667 abstracts and a synthesis of the information obtained on each topic. The latter summarizes the content of the items collected on each of the above topics and discusses the implication of that content for (1) extension programs, (2) government officials, and (3) researchers.

This publication is one of the primary references for designing short-term water conservation programs for drought contingency.

157
Jezler, Harold. 1975. When the Reservoir Almost Went Dry. Journal of the American Water Works Association 67:331-35.

This article describes the activities of the COMASP (water authority for Sao Paulo, Brazil) during a drought. Among these activities was a 2-stage water-use reduction program. The first stage consisted of public appeals with some rotating cutoffs to some zones. No mention was made of fears of infiltration as a result of these cutoffs. After 30 days, these recommendations were made mandatory with specific uses prohibited (no outside use of water) and with specific limitations for total water use by residences. Instructions were given on how to keep water consumption within legal limits. Only in a few (but well-publicized) cases was a 3-day cutoff of water supply imposed on residences. As a result of these efforts, average water use was reduced from 57 to 42 gpd (a 26% reduction). No major serious complaints were noticed.

158
Johnson, H. D., E. G. Brown Jr., and R. R. Robie. 1978. A Pilot Water Conservation Program. California Department of Water Resources bulletin 191.

This bulletin reports on the implementation of home water-saving devices based on pilot projects conducted during the summer and fall of 1977 in 6 California communities. It describes details of water conservation device distribution programs and discusses conclusions regarding

the best methods of distribution, receptiveness of householders to devices, and water and energy savings.

Additional details are contained in 8 separate appendices:

Appendix A: San Diego Metropolitan Area

Appendix B: Santa Cruz County

Appendix C: City of Sanger

Appendix D: El Dorado Irrigation District

Appendix E: City of El Segundo

Appendix F: Community of Oak Park

Appendix G: Device Testing

Appendix H: Device Selection

The report is a valuable source of information necessary for determining applicable and feasible measures for residential water conservation as well as a data source on the effectiveness of advantageous and disadvantageous effects, and the acceptability of these measures.

159

Johnson, H. D., E. G. Brown Jr., and R. R. Robie. 1979. Impact of Severe Drought in Marin County, California. California Department of Water Resources bulletin 206.

This bulletin describes the response of the Marin County citizens to water conservation restrictions imposed during the 1976-77 California drought, evaluates the effectiveness of the water rationing program, and determines the drought-related economic and social costs and losses. In the conclusion, the aftermath of the drought is discussed.

The information provided by authors may be used in determination of social acceptability and effectiveness of this short-term water conservation measure.

160

Johnson, S. 1974. Recent Sociological Contributions to Water Resources Management. In Man and Water, ed. L. D. James, pp. 164-99. Lexington, KY: University Press of Kentucky.

The author discussed how water problems and solutions can be better understood in light of certain sociological principles. Societal values are the key to why people pollute. Some of these values are (1) common land, air, and water belong to all but are the responsibility of no individual (this is referred to as the "tragedy of the commons"); (2) modern industrial societies view the environment in terms of its utility

rather than for its intrinsic qualities. Class societies use physical resources to aid in upward mobility.

Societal values are also crucial to devising acceptable solutions to water resources problems. The simplistic use of economic cost-benefit analysis as the major criterion of program evaluation ignores the fact that major resource programs change far-reaching aspects of a community. Despite the assistance which sociological principles provide in understanding community response to water resource programs, it must be kept in mind that each community has a unique constellation of factors which must be taken into consideration when programs are considered.

The author made a "good case" for considering sociological principles in water resource planning; however, the argument remained at a rather general level.

161
Keller, Charles W. 1976. Analysis of Unaccounted-for Water. Journal of the American Water Works Association 68:159-62.

The article summarizes causes for unaccounted-for water and performs statistical comparisons of water-utility data for unaccounted-for water in reference to major variables such as ownership, type of supply, system size, annual revenue, geographical location, and value of water. The author concluded that distribution losses of less than 10% are excellent, and 10 to 20% reasonable. If greater than 20%, calculations should be checked and then meters should be checked for under registration, and detection of major leaks should also be attempted.

This article is technically oriented and may be helpful in the determination of implementation conditions, leak detection, and repair programs.

162
Kim, Joe R., and Richard H. McCuen. 1979. Factors for Predicting Commercial Water Use. Water Resources Bulletin 15:1073-80.

Of interest in this article is the empirical analysis of urban commercial water use. It was based on data from 64 suburban mall shops in the Washington, D. C. area. Water use in gallons per working day for each shop was provided by the Washington Suburban Sanitary Commission. Temporal variation in water use was not considered, assuming that this use category is not characterized by large daily and seasonal variation.

The results of a multiple correlation analysis and a principal components analysis suggested that the water consumption is a function of the following primary factors: an employee water-use factor, a customer layout factor, and a customer water-facility factor. Gross shop area, number of average daily employees, number of average daily man-hours, number of faucets, number of mop sinks, number of toilets, and number of drinking fountains were rejected due either to high intercorrelation or

to low correlation with water use.

The following linear model was calibrated using a numerical optimization technique:

$$Q = 15.5F + 0.0147A + 0.945L$$

where Q = number of gallons of water consumed per work day, F = the number of drinking fountains, A = gross area in square feet, and L = the length of the display window in feet. This relationship was characterized by a correlation coefficient of 0.883 and a standard error of estimate of 35.6 gpd.

Good presentation of data analysis techniques added to the value of this work as a reference for determining unrestricted water use for the commercial sector.

163

Kingston, William L. 1979. Do-It-Yourself Leak Survey Benefit-Cost Study. Journal of American Water Works Association 71:70-72.

The article presents an operational procedure for benefit-cost analysis of leak survey. The author developed the Do-It-Yourself Leak Survey Benefit-Cost Calculation Fill-in sheet in which the cost of the program is balanced against the following benefit categories:

1. water saved on the system side,
2. water saved on the customer side,
3. deferred construction of new facilities,
4. prevention of property damage,
5. refutation of claims,
6. improved meter reading,
7. improved public relations,
8. savings in leak repair crew time due to more accurate leak location, and
9. postponement of time-of-day power charges in pumped service zones.

All these entries were illustrated and briefly discussed based on the Los Angeles leak survey program.

The procedure presented by the author may be helpful in determining the advantageous and disadvantageous effects of a leak detection and repair program.

164

Klimek, John C. 1970. Forecasting Industrial Water Requirements in Manufacturing. Water Resources Bulletin 8:561-70.

This paper presents the procedures used to obtain estimates of 1964 for water withdrawals for manufacturing and 1990 and 2000 requirements for the Oswego River Basin of New York State, including counties and subareas of 10,000 or more population.

The following equation was used to develop estimates of daily manufacturing group withdrawal in each period of forecast:

$$F(I) = INT(A(I) * B(I) * D(I) * (W(I)-W(I) * P(I) + (W(I) * P(I)/Q(I)))$$

where

F(I) = daily withdrawal by industry group

A(I) = base period employment

B(I) = employment change

D(I) = change in productivity by employee

W(I) = weighted intake per employee

P(I) = percentage of intake subject to reuse

Q(I) = weighted reuse rate

Estimates of intake per employee, manufacturing activity, and water reuse were developed through surveying a selected number (unspecified) of industrial establishments in the region. The survey was designed to obtain information on present and future water-use practices as well as information on existing employment, present rate of operation and expectation in regard to employment, output, and employee productivity trends.

The model presented by the author may be used in determining unrestricted water use by industrial customers of water utilities.

165

Ko, S. C., and L. Duckstein. 1972. Cost-Effectiveness Analysis of Wastewater Reuses. Journal of Sanitary Engineering Division ASCE 98:869-81.

This article presents a study of cost as well as other aspects of 4 plans to reuse secondary treated effluent from the city of Tucson, Arizona. The 4 plans are: (1) exchange with irrigators for groundwater; (2) same as plan 1 except irrigation land is purchased; (3) exchange with copper mining firms for groundwater; and (4) discharge into Rollito Creek for "purification and storage." The report does not show why plan #4 differs from the present solution. Of note in this article

is the authors' confidence that the secondary effluent is suitable for irrigation, although little evidence is given.

166
Kury, Channing. 1977. Prolegomena to Conservation: A Fisheye Review. Natural Resources Journal 17:493-509.

This article reviews and analyzes philosophical assumptions and logics of historically important definitions of "conservation": Aldo Leopold, "The Conservation Ethic" (1933); Walter Firley, "Man, Mind and Land: A Theory of Resources Use" (1960); Ian McHarg, "Design with Nature"; Ciriacy-Wantrup, "Resource Conservation: Economics and Policies" (1967). The author argues that one cannot discuss conservation outside a normative or value hierarchy context, and he defines conservation as "the act of rational behavior in the context of social and natural limitations." He also makes the subsequent point that "conservation actions are conflict-laden in that there are always conflicting values and thus prices to pay for whatever course is taken."

The author's critique of the Ciriacy-Wantrup definition is that it is forced beyond relativistic value to the position of not allowing "irreversible depletion." Thus, Ciriacy-Wantrup reneges on his position that "the evaluation of the utility of conservation (or depletion) is dependent on what the goals of the decisionmaker are. . . ." Instead, certain goals must be forbidden--for instance, the relief of famine by fishing if it would eliminate the species.

The article is of general relevance to water conservation planning.

167
Larkin, Donald G. 1978. The Economics of Water Conservation. Journal of the American Water Works Association 70:470-74.

The author's purpose was to examine the economics of water conservation for the East Bay Municipal Utility District, as exemplified in the recent California drought. An overall cutback of 38% had been reached by the end of 1977, surpassing the goal of 35%. The article summarizes how the overall costs of the utility increased during the drought in terms of operation costs, engineering costs, customer services, public information, and finance. The author pointed out how most water-utility costs are fixed and, thus, if consumption decreases, prices must go up. The decreased consumption will be relatively permanent as consumers have installed water-saving devices and learned water conservation habits. The economic costs to the utility were offset by a 33% rate increase and $6.8 million in grant and loan funds form the Federal Government. The rates will need to be raised again in the near future.

This informative article delineates categorically costs incurred during the drought and how the utility is managing to address this problem. As to conservation, it speculates that the 38% decrease in use may stabilize to a 15 to 20% reduction permanently. The estimates of drought-related changes in utility costs may serve as an indirect disadvantageous effect

of reduction in water use.

168
Larson, Brent O., and H. E. Hudson Jr. 1951. Residential Water Use and Family Income. Journal of the American Water Works Association 43:603-11.

This paper presents an analysis of residential water use with respect to income for 13 Illinois communities based on pumpage and billing records. The author has found that the residential per capita use was poorly correlated with the population of the community served, while a good correlation existed between water use and net effective buying income (averaged for each community).

The study, while important for its time, is not explicit enough to be of much use in water conservation planning.

169
Lattie, J. E., and D. J. Vossbrink. 1977. Water Conservation Education for the Public. Journal of American Water Works Association 69:568-73.

This article presents a large array of means used in the educational process of the general public which was administered by the East Bay Municipal Utility District of California. The program involved a variety of communication tools and was designed to form "a consciousness of water and a conscience about its use."

Although not able to assess the effectiveness of the program, the District has established an exemplary way of public education. The article may serve as a source of information on various techniques used in public education campaigns.

170
Laverty, Gordon L. 1977. East Bay Conserves Water with Surveys, Sonar. Willing Water, AWWA:12-13.

East Bay Municipal Utility District (Oakland, California) reports the use of sonic leak detection equipment in a system-wide survey for water distribution leaks. Leaks were being located and repaired at the rate of 450 per year. After the first 18 months, 50% of the system had been surveyed, and leaks totalling an estimated 4.0 million gallons per day (2% of total production) had been repaired. In addition, many customers had been notified of leaks on their premises.

This information is very useful in estimating the effectiveness of this conservation measure.

171

Laverty, Gordon L. 1979. Leak Detection: Modern Methods, Costs, and Benefits. Journal of American Water Works Association 71:61-63.

This article presents the leak detection program conducted by the East Bay Municipal Utility District (EBMUD), Oakland, California. The program involved 2 two-man crews and 2 pickup trucks equipped with safety devices and sonic instruments. Over a 3-year period the district reduced water losses by 2.5 % (as compared to averaged metered consumption of 208 mgd), at the gross direct cost of the program of about $150,000 per year. Unfortunately, the estimated benefits gained from leak detection were not reported by the author.

The information reported by the author may be used in the evaluation of the effectiveness of a leak detection and repair program.

172

Lee, Clifford T. 1977. Legal Aspects of Water Conservation in California--Background and Issues. Staff Paper no. 3, The Governor's Commission to Review Water Rights Law.

This paper presents a detailed discussion of water rights law and the legal tools presently available to enforce water conservation. The paper concentrates on individually supplied surface water. Unfortunately, this use represents only a very small portion of the total water use in California (11%). The paper notes that little action has been taken to investigate unreasonable use and to pursue judicial action by the State Water Resources Control Board which has such authority. The authority of public agencies to restrict water use during emergencies is also discussed.

The article may be helpful in considering implementation conditions of water conservation measures.

173

Lee, Motoko Y. 1981. Mandatory or Voluntary Water Conservation?: A Case of Twelve Iowa Communities during Drought. Ames: Iowa State University.

The author examined mandatory and voluntary water conservation policies adopted by 12 Iowa communities during the 1977 drought and compared these measures in terms of types of policymaking bodies, rationale behind adopting them, and quantitative evaluations of their effectiveness.

The analysis was based on 56 personal interviews with policymakers of the 12 communities who had participated in water conservation policy-making during the drought, and also on water-consumption data. The results showed that mandatory policies with per capita-based restrictions were most effective in reducing water consumption. Two of the 12 communities achieved substantial reduction with voluntary policies, which is explained by their proximity to communities where extreme shortages existed. The authors concluded that the credibility of water shortage is a key to successful conservation and recommended environmental education of citizens as a necessary policy to accompany long-run water conservation plans.

This information is valuable for determining implementation conditions and social acceptability of proposed water conservation plans.

174

Leone, Robert A., J. Royce Ginn, and An-Loh Lin. 1974. Changing Water Use in Selected Manufacturing Industries. The National Bureau of Economics report no. 74-10, contract no. DACW31-72-C-0044.

This report presents a detailed review of water use in the paper, chemical, petroleum, and primary metals industries. Among the findings were:

1. Between 1954 and 1968, gross water used increased by 70% while intake water increased by 17%. Gross water applied per unit of product decreased by 7%.

2. These changes were due in part to increased water cost as a result of stricter water pollution control laws.

3. The findings suggest that water for industrial processing is unlikely to be a major locational determinant; rather, water for transportation seems to be a more important locational determinant.

An estimation of price elasticities using a micro-economic perspective in the context of the theory of the firm gives demand (cost) elasticities in the range of -0.5 to -1.0.

The data and discussion presented here may be useful in evaluation of conservation measures aimed at industrial water demand.

175

Leopold, L. B., and W. B. Langbein. 1960. A Primer on Water. Washington, D.C.: U.S. Department of the Interior, U.S. Geological Survey.

Among the authors' findings were: "Water engineers have found that families are much more economical in the use of water when their use is individually measured by a meter. Families paying a flat rate use, on the average, two times as much water as those whose use is metered."

"The final class of water consumption in a city is loss or unaccounted-for waste; leaks from water mains and unmeasured leaks from faucets, as well as errors of measurement appear to contribute to this loss. This item is amazingly large and generally even careful construction and management cannot reduce it to less than 20% of total use."

A comprehensive approach to water makes this publication a valuable introductory reading on the subject.

176

Linaweaver, F. P. Jr., John C. Geyer, and Jerome B. Wolff. 1967. Summary Report on the Research Project. Journal of American Water Works Association 59:767-82.

The authors sought to determine water-use patterns and demand rates in residential areas and to determine the major factors influencing residential water use. Forty-one homogeneous residential areas throughout the United States of varying climates were studied from 1963 to 1965.

Because of temporal variability in water use, plant capacity is idle much of the time. "Rates would be more equitable if they reflected the peak demands imposed on the system. . . . Meters barely influence domestic or household use, but have a considerable effect on sprinkling." Domestic use is basically non-consumptive; sprinkling is consumptive. Among the major influencing factors were: (1) number of homes; (2) economic level (r - .76 value of home) of consumer; (3) climate; and (4) metered or flat-rate service. In the west, maximum daily use does not greatly exceed average use. "The water system is designed to meet the expected maximum daily use, is operating reasonably close to capacity throughout much of the sprinkling season. . . . A water system in the east, if designed to meet the expected maximum daily use, will seldom operate at capacity."

In summary, it has been found that residential water demands for any duration depend on the number of consumers, their normal domestic or household use, the average irrigable area of their lawns, the rate of evapotranspiration and the quantity of precipitation. The maximum daily water demand, important in the design of water-system components, can be estimated by calculating a value for potential evapotranspiration. In flat-rate areas, peak demands are more than double because of high sprinkling demands. Domestic use is about the same in metered and flat-rate areas. Domestic use appears to be significantly lower in metered areas utilizing individual septic tanks for sewage disposal. The authors used regression equations and correlation coefficients.

The authors' findings are still relevant and applicable to the evaluation of water conservation measures.

177

Lupsha, Peter A., Schlegel, D. P., and Anderson, R. U. 1975. Rain Dance Doesn't Work Here Anymore, or Water Use and Citizen Attitudes towards Water Use. Albuquerque: University of New Mexico.

The authors' purpose was to discover what typical consumers thought about water and water policies and how they consumed this resource. They studied Albuquerque, New Mexico, an area of rapid growth and low precipitation (8.4"/yr.). One-half of 1% (345 questionnaires) of the residential population in the area was sampled. The sampling was stratified into 5 levels based on value of home. Samples were then clustered into neighborhoods. Eighty-three interviews were also performed.

The following are selected findings reported by the authors:

1. Water use is positively correlated with income, value of home, education level, times of residence, and negatively correlated with increasing household size ("a threshold for use has been passed for washing machines, dishwashers, etc.")

2. Each ethnic group had different consumptions.

3. A total of 85% of respondents said that they were water conscious. "One sees that per capita use at every income level is significantly lower if one has what we have classified as a water conservation attitude. We also note that this has a particularly strong effect on use at the higher income and demand levels."

4. "Attitudes are probably filtered through the reality of self interest and the objective economic conditions of the household's micro-environment. The finding that small users are more likely to be in favor of differential rate structures than large users reinforces this self interest and objective condition conclusion."

5. "Overall, it would appear that the impact of attitudes on demand is a relatively weak and minor aspect of any water-use equation. While attitudes do have an impact, it is small and tends to reflect self interest, which probably has stronger surrogates in economic and appliance variables and micro-environmental factors which are probably better tested by the landscape and sprinkling practice variables."

6. Most residents preferred cheap and unregulated water but were willing to consider a variety of conservation methods if it appeared that the supply was limited. Seventy-one percent of respondents felt green landscaping was nicer than desert landscape.

The authors recommended: (1) a move toward a progressive rate structure; (2) a recognition that excessive water-using appliances do make a large difference in demand; (3) encouragement of desert landscaping; (4) limitation or special assessment taxing of underground sprinkling systems; and (5) examination by the city of its billing system because many errors were found.

The authors have produced an interesting study and use of sociological variables. Their use of statistics, while not extremely powerful, is adequate.

178
Lynne, Gary D., William G. Luppold, and Clyde Kiker. 1978. Water Price Responsiveness of Commercial Establishments. Water Resources Bulletin 14:719-29.

This article presents the results of a cross-section regression analysis of commercial establishments in the Miami SMSA. The results indicated that at the mean marginal water price of the sample ($1.25 per thousand gallons), the price elasticities were -1.33 for department stores (significant to 0.01 level), and -0.14 or -0.30 for motels and hotels (significant to 0.05 and 0.01 levels, respectively), depending on the model used. The price coefficients for eating and drinking establishments and for "other commercial" establishments were not found to be significantly different from 0.

The authors' findings may be helpful in determining the effectiveness of conservation measures directed at this water-use sector.

179
Lyon, Donna K. 1978. Water Conservation in the Las Vegas Valley: Pricing and the Alternative Measures. Water Resources Center, Desert Research Institute publication no. 41056. Nevada: University of Nevada.

The author reviewed literature on various water conservation measures and analyzed the potential for water conservation in the Las Vegas Valley.

Based on price elasticity of -0.335 which was estimated for the Las Vegas area in other studies, modified water-demand forecasts for the years 1980, 1990, and 2000 were developed. For a 150% increase in price, total water demand for the year 2000 was estimated to decrease by 26% from the base estimate. The latter was based on population forecast and per capita water consumption of 400 gal/day.

The report exemplifies the use of price elasticity in the estimation of reduction in the quantity of water demanded, which is relevant for the determination of effectiveness.

180
Maass, A. 1966. Benefit-Cost Analysis: Its Relevance to Public Investment Decisions. In Water Research, ed. Allen V. Kneese and Stephen C. Smith, pp. 311-28. Baltimore: Johns Hopkins University Press.

The purpose of the study was to demonstrate that benefit-cost analysis is an inadvisable means of determining the worth of a water project. Benefit-cost analysis looks only at economic efficiency, as determined by the increase in national product. But many projects have as their purpose something other than economic efficiency--income redistribution for instance. Moreover, the economic efficiency model weights each dollar equally, regardless of who benefits. Standard policies must be devised to arrive at acceptable trade-offs of desirable but mutually exclusive goals. These suggestions together with postulates of other economists

have been taken into consideration in the preparation of the Principles and Standards for Planning Water and Related Land Resources.

181
MacDonald, David V., and Kline P. Barney Jr. 1978. The Effects of Pricing Policies on the Economics of Water Storage. Journal of American Water Works Association 70:245-51.

This article presents an economic analysis of a reservoir project for the city of Oceanside, California. At present, the city uses imported water from the Colorado River. The prime supply agency is considering peaking or summer-use charges that would increase the city's cost of acquiring water. Therefore, the main reason for justifying new supply additions was to reduce peaking on supply systems and thus the total cost of water.

The cost savings to the city, affected by reduced peaking charges, represented approximately 25-75% of the reservoir project cost depending on the peaking rate. The analysis of optimum reservoir size showed that the present worth values for various reservoir capacities did not vary appreciably. Thus, the city is best served with the largest reservoir it can finance.

The above case study shows that water-pricing policies can be an important consideration in determining the need for and cost effectiveness of a reservoir project. It would be very useful, however, to examine water conservation as another alternative to reduce peaking on the supply system.

The analysis presented by the authors is relevant for determination of foregone supply costs.

182
Maddaus, William O., and Donald L. Feuerstein. 1979. Effect of Water Conservation on Water Demands. Journal of the Water Resources Planning and Management Division of ASCE 105:343-51.

This article presents the study of municipal water use and alternative supply for the 9-county San Francisco Bay Area. The authors applied a "requirements" forecasting model disaggregated by spatial location and user class. Average annual water-use projections were developed for 440 zones within the Bay Area (each zone is 1 or more census tracts, using 1975 as the base year).

Water use in each zone was related to 4 explanatory variables: population, housing density, employment, and type of land use. Water uses in 5 different categories--(1) inside residential, (2) outside residential, (3) commercial-industrial, (4) public authority, and (5) unaccounted-for use--were used as dependent variables. The relationships between dwelling unit density and inside residential water use (gpcd), or residential outside unit water use (gpdud), and between

employment density and commercial-industrial unit use (gped) were first determined based on actual water-use data in 1975 obtained from the East Bay Municipal Utility District and applied for the 104 of the 440 zones. The obtained relationships were adjusted for each of the remaining 440 zones according to the actual water-use data from those areas. These relationships were not treated statistically or expressed by mathematical equations; however, graphed data points were indicative of very high correlation. Public authority and unaccounted-for water uses were determined as percentage of appropriate subtotals.

The above relationships were assumed to hold in the future holding that no conservation program was instituted. The water-use projection model considered projected increases in population, dwelling units, employment, and developed acreage in each of 440 zones during 5-year increments.

183
Maidment, David R. 1979. Annotated Bibliography on Water Demands. Water Supply and Management 3:117-29.

A brief introduction describes both the dependence of water-use forecasts on accurate knowledge of the nature of water demands and the factors which determine them. Brief annotations are provided for 67 articles and technical reports analyzing the demand for water in municipalities, agriculture, and industry. These articles and reports represent the work of more than 100 authors in 15 countries.

The bibliography constitutes a useful, informative reference for several tasks of water conservation planning.

184
Maier, Walter J., Jeffrey DeZellar, and Raina M. Miller. 1981. Benefits from Water Conservation Depend on Comprehensive Planning. Water Resources Bulletin 17:672-77.

The authors discussed the effects of water-use reduction on wastewater systems during the 1976-77 drought in California.

The negative effects of flow reductions were (1) accumulation of sediments in sewers, (2) an increase in hydrogen sulfide gas formation causing corrosion of sewer material and odor problems, (3) malfunctioning of treatment facilities resulting from shock loads of grid and other sediments caused by flushing rains following dry periods, and (4) inefficient separation of solids in spite of increased residence time (probably due to flotation). The overall effects were an increase in operating costs and less efficient performance.

The authors suggested that the malfunctioning of wastewater systems could have been avoided if preplanned and properly engineered water conservation were undertaken. The maximum monetary benefits can be obtained for long-term water conservation programs which would coincide

with increased population to be served by utility. It was estimated that for 29 gpcd reduction in water use total per capita savings would amount to $25 per year for energy, $4.3 per year for reduced water use, and $3.0 reduction in sewer charge. In addition to monetary savings, the reduction in discharge of pollutants would produce environmental quality benefits. The authors proposed the rule of thumb assuming that 10% flow reduction results in 10% lower volume of effluent as well as total biochemical oxygen demand and suspended solids. This is so because residual pollutant concentrations in sewage treatment plant effluents are more sensitive to residence time than influent concentrations and remain approximately unchanged within the range of volume and concentration changes resulting from water conservation. However, due to high overhead O & M costs of treatment plant, the total operation cost remains unchanged thus causing unit costs to increase during reduced flows.

This paper contains useful information on advantageous and environmental quality effects of water conservation, although they should be taken with caution since due to technical nature of the analysis, not all cost and benefit categories have been accounted for.

185

Male, W. J., C. E. Willis, F. J. Babin, and C. J. Shillito. 1979. Analysis of the Water Rate Structure as a Management Option for Water Conservation. Water Resources Research Center publication no. 112. Amherst: University of Massachusetts.

The purpose of this study was to assess the potential for residential water conservation by altering the price structure illustrated by a case study of the Town of Amherst, Massachusetts. Two specific objectives of this report were (1) to develop a water-demand model, and (2) to investigate the effects of alternative pricing structures on both the quantity of water demanded and the revenues received by water utility.

The water-demand model was developed by applying cross-sectional multiple regression analysis to 3 different functional forms relating quantity of water demanded per meter per year to (1) average water price, (2) median family income, (3) number of persons per meter, and (4) population density. The data used to estimate model parameters contained 56 observations from 6 states for the years 1965 and 1970. The 3 functional forms were (1) linear model, (2) power function, and (3) model with price exponential form. The latter model allows for price elasticity changes for various price levels.

The analysis yielded a range of price elasticities, with the exponential functional form yielding a median value of -.37. The latter model, which explained 69% of variance, was accepted for application to a case study to estimate the degree of consumer responsiveness to 3 different rate structures. Results showed an estimated reduction of residential demand in Amherst of approximately 15% for a 3-month water short period.

The methodology presented by the authors illustrates very well water-demand relationships derived from economic theory. The effects of price change on water-demand utility revenues may be useful in determining effectiveness of such a measure.

186
Marshall, Hubert. 1966. Politics and Efficiency in Water Development. In Water Research, ed. Allen V. Kneese and Stephen C. Smith, pp. 291-310. Baltimore: Johns Hopkins University Press.

The study constitutes an attempt to determine why so many economically inadvisable water projects are implemented. ("Inadvisable" is defined as grossly inaccurate pre-construction cost-benefit estimates.) The author identified political and economic factors which explain this situation:

1. Congressmen feel stronger loyalty to constituents than to either party or national interests; therefore, policies are often irresponsibly decentralized.

2. The President is loath to use his veto power on water projects because it will erode his congressional power base.

3. Construction agencies wish to flourish.

Also, reasons for why engineering professionals in construction companies can be "unethical" are cited:

1. Professionals share a sense of a cultural ideal regarding the furthering of professional interest (professional socialization);

2. Decisions are corporate, not individual, so ethical considerations are diffused and blunted;

3. A lack of consensus on appropriate criteria for economic evaluation of water projects permits, indeed, facilitates the masking of ethical questions.

The article has general applicability to water conservation planning.

187
McDonald, M. B., J. Tysseling, M. Browde, and L. Brown. 1981. Case Studies in the Development of New Mexico Water Resources Institutions--The Middle Rio Grande Conservancy District and Urban Water Pricing. New Mexico Water Resources Research Institute WRRI report no. 131. Las Cruces: New Mexico.

This report provides a historical description of the Middle Rio Grande Conservancy District and also analyzes water pricing of 4 New Mexico cities: Santa Fe, Albuquerque, Belen, and Los Lunas. The authors presented a history of water rates and water-rate structures and

discussed the social and economic conditions which have influenced these rates. The adaptation to these social and economic pressures on the urban water institutions in these cities via the water pricing mechanism was examined.

This information is relevant to the assessment of implementation conditions for redesigned rate schedules as a conservation measure.

188

McGarry, Robert S., and John M. Brusnighan. 1979. Increasing Water and Sewer Rate Schedules: A Tool for Conservation. Journal of American Water Works Association 71:474-79.

This article describes a conservation-oriented rate structure developed by the Washington Suburban Sanitary Commission. This conservation measure together with a publicity and education program and a revised plumbing code was designed to balance demand and the limited water supply in the Potomac River.

The rate structure was the result of a 2-year study produced by a Citizens' Advisory Committee on WSSC rates and charges. Based on the review of key customer billing information and on the views of all "publics" obtained through 10,000 questionnaires and a series of public meetings, the new rate plan was adopted effective January 1, 1978. The rate structure was based on 100 steps in 10 gal intervals related to average daily consumption (ADC) during each billing period. The rates ranged from $0.36 to $1.05/1000 gal of water consumed and from $0.45 to $1.31/1000 gal of sewer use. The schedule started at a base ADC of 10 gal/day.

The authors stated that the new rate structure has succeeded in reducing average daily and peak consumption by residential customers by 13.8%. Consumption by governmental and large commercial consumers showed a decline of only 0.03%. Overall water consumption for all accounts decreased by 8% for the June 1978 quarter as compared to 1977 consumption.

In addition to the information on the measure effectiveness, this case study provides some insight into the problems of social acceptability as well as implementation conditions.

189

McLeon, Robert J. 1976. Water Conservation--Good. Journal of the American Water Works Association 68:PRR 17.

This editorial contains a discussion of the Washington Suburban Sanitary Commission (WSSC) views on its water conservation program. Water conservation, which here includes information campaigns and modifications of the plumbing code, is judged to have beneficial impacts on both the utility and its customers. The effects of a successful program on utility revenues are not viewed as a long-run problem. The author also provided a definition of a water conservation program: "a cooperative effort with customers to promote and foster the necessary use of water

and to discourage waste of this important community resource."

The article constitutes an important view on water conservation from a utility perspective.

190

McPherson, M. B. 1976a. Conservation in Household Water Use. Paper presented, Conference on Planning Alternatives for Municipal Water Systems.

This article is basically a rehash of a previous article. "The amount of public water supply withdrawals is a relatively small fraction of total metropolitan withdrawals, on the average. Second, domestic use represents a modest fraction of total public water supply withdrawals, on the average. Third, any savings in domestic use through conservation efforts could be difficult to prove because of ambiguities in the amount of 'unaccounted-for' water."

It is the author's opinion that the possibilities for conservation nationwide, in the near term, are greater for reduction in leakage and waste than for household conservation, if for no other reason that the fact that the former is almost solely in the hands of the water works themselves, and the latter depends on the viability of incentives, social and/or economic, for public cooperation. Obviously, pursuit of one objective does not preclude simultaneous pursuit of the other.

The author claimed conservation is not just reduction in quantity withdrawn and handled, but also reduction in peak-demand periods. "While a decision to conserve existing supplies could conceivably be reached voluntarily, it is more likely to be a response to exogenous considerations, in particular, physical or jurisdictional limits for further expansion. Thus the issue of conservation has arisen much more obviously in water-short areas and wherever jurisdictional disputes over the resource have been encountered. Residential water use probably represents close to one-third of total municipal system production.

"Because almost half of in-house water use is for flushing toilets and an approximately equal amount used for bathing, personal uses, laundry and dishes, there are obvious possibilities for recycling the portion that is free from fecal contamination for the flushing of toilets. A first demonstration of this possibility showed that household water usage could be reduced about one-fourth by such recycling. On the average this might mean a community use reduction of less than one-tenth, but the potential would be highest in predominantly domestic-demand communities.

Overall, this paper may be useful as an introductory reference to water conservation planning.

191
McPherson, M. B. 1976b. Household Water Use. New York: American Society of Civil Engineers.

The author gave a summary of quality, quantity, and economic consideration of household water use. He stated that people are concerned about the quality of water, and he cited references and current studies. As to quantity, he discussed waste flow-reduction research and water reuse sources. The study states that "household water usage could be reduced about one-fourth by recycling. . . . A 1971 study by Resources for the Future for the U.S. National Water Committee concluded on the basis of evidence then available that, aside from questions of recycling, water-saving devices could save one-third of in-home use, although an economic incentive for adoption of such devices did not exist."

The author provided a general review of research with regard to economic considerations. He commented that "it is still not clear to what extent metering constrains demand in response to price" because of limited data and the problem of unaccounted-for water.

The author described a study of 12 houses which were metered for a 3-month period in 1972 and recorded every minute (Albany, NY); the study was basically an investigation of water pressure. "Not much short-time interval data from individual households has been collected, little of it has been subjected to pattern analysis, and probably none of it is readily available to researchers in a complete and readily understandable form." The appendix has detailed data of one-minute usage for about 2 weeks of 9 low-income, large-family households outside of Washington, D.C.

The article is very technologically oriented and goes into great detail to describe statistical analysis of pressure changes in plumbing. It is of little value in respect to conservation but is a good source of bibliographic material.

192
McPherson, M. B. 1976c. Household Water Use. Paper no. NTIS #PB-250-879.

This paper presents a general discussion on economic, quality, and quantity aspects of household water use. Variations in household use over short-time intervals (minutes and hours) are analyzed using data from individual households and multi-family dwelling units. These variations are important when considering the effectiveness of conservation measures aimed at reducing peak-load water use.

193

McPherson, M. B. 1978. Conservation in Household Water Use. In Municipal Water Systems, ed. D. Holtz and S. Sebastian, pp. 183-99. Bloomington: Indiana University Press.

The purpose of the study, which dealt with urban residential water uses, was to show the contribution of household water conservation practices relative to the larger water conservation picture. Some of the impediments to implementation of household water conservation were discussed.

Household water conservation practices can have a small but significant influence on total water usage. Despite this potential, several factors operate which decrease the likelihood of implementation of these practices. Among those cited were:

1. Attitudes of water professionals have been anti-conservation. They have felt that the public should have all the water they can pay for.

2. A dearth of water-usage data makes the effectiveness of conservation programs difficult to evaluate.

3. Economic benefits of conservation are interpreted too literally (i.e., sometimes a slight decrease in usage can postpone the necessity of new plant construction).

4. Water input/output often crosses municipal boundaries which makes policy change difficult.

The author placed potential benefits from household conservation in a realistic perspective. He provided plausible arguments for the lack of household conservation, but justification for these arguments was sparse.

194

McPherson, M. B. 1979. Urban Water Balances Considering Conservation. In Proceedings, Conference on Water Conservation Needs and Implementing Strategies, pp. 28-36. New Hampshire: Franklin Pierce College.

The author of this paper presented and illustrated the use of public water/wastewater input-output balance inventories in describing the major factors in water conservation planning for urban areas. It is the author's opinion that there are greater possibilities for reduction in leakage and waste than for household conservation due to the fact that the former can be implemented as a simple managerial practice of water works.

This paper is a very useful reference for educational purposes. Of special value are charts illustrating input-output balance of urban water. The latter will be also helpful in development of potential water conservation measures and in illustrating the summary effects of water conservation proposals.

195
Middlemas, Robin E. 1961. Water Demand Meters Show Results. Public Works:81-114.

This article describes the experience of the Milwaukee Water Works in demand metering of 5 wholesale customers. The maintenance experience with the demand meters manufactured by the Badger Meter Manufacturing Company was good. It was estimated that the meters will have a mechanical life of 10 years with "a minimum of tune-up maintenance adjustment necessary only on an annual basis." The response to the use of demand meters by the wholesale customers was substantial. One suburban village provided additional storage facilities which reduced its peak of average hour ratio to 2 compared to a similar wholesale customer without demand meters which had a value of 4 for the same day. Also described are the results of the $10/ton assessment on "non-conserving" air conditioners and the alternate day sprinkling rules of the Milwaukee Water Works.

196
Middleton, R. N., R. Y. Saunders, and J. J. Warford. 1978. The Costs and Benefits of Water Metering. Journal of the Institution of Water Engineers and Scientists 22:111-22.

The authors examined the theoretical basis for the decision of whether or not to meter individual households. This was illustrated by cost-benefit analysis for several examples of Asian cities.

Assuming that price of water is set equal to the marginal cost of supply, the decision to meter is

$$cR \geqslant M + E + K$$

where c is the marginal cost of supply and disposal; and R is the reduction in total water consumed by the household; while M represents the supplier's metering cost; E, consumer personal inconvenience and expenditure on plumbing repairs; and K is the consumer's foregone consumption benefits. Since it is very difficult to predict both (E + K) component and the value of R, it was suggested that the questions of what reduction in consumption would be sufficient to justify metering and whether such a reduction was likely to occur, should be used in the decision on metering.

In all but one of six Asian cities studied, water metering was economically justified. Since metering can be treated as a water conservation measure, this primary economic test may serve as a check on its economic feasibility. Also certain considerations presented in the article may be helpful in determining advantageous and disadvantageous effects of this conservation measure.

197
Miller, W. H. 1978. Mandatory Water Conservation and Tap Allocations in Denver, Colorado. Journal of the American Water Works Association 70:60-63.

This article discusses the program for water-use reduction in Denver in the summer of 1977. "By limiting outside watering to a maximum of 3 hours every third day, Denver water customers reduced use by 21%." This measure was enforced by department employees who issued 5500 warnings and 238 ten dollar tickets for violations. The number of new taps was also restricted.

This information is important for assessing fraction reduction in water use associated with the restriction on this specific use category.

198
Milne, Murray. 1976. Residential Water Conservation. California Water Resources Center report no. 35. Davis: University of California.

This non-technical report evaluates over 4 dozen commercially available devices for water conservation and presents an exhaustive search of aerospace technology and patent applications. These devices and various implementation methods were evaluated in the context of economic, institutional, socio-cultural and technological constraints. Four scenarios of homeowner-builder conservation were presented.

Among the conclusions were:

1. The technology for water conservation is readily available.

2. "Increasing the prices of water alone will not significantly reduce water consumption; however, changing from one rate structure to another may."

3. Plumbing codes should be revised to require cost-effective lower water using appliances and to allow the use of more advanced systems (such as grey water recycling). The Federal and State Governments should take the lead in water reuse and should purchase conservation equipment, even if it may not be presently cost-effective, to help drive down the cost.

4. Rate structures should be changed to include commodity charges for sewers. Declining block rates should be eliminated and mastermetering should be prohibited in new apartments and condominiums.

5. Water utilities should promote conservation by educational campaigns and demonstration projects.

The study contains an annotated bibliography. The information presented in this report may be hlepful in determining applicability, technical feasibility, implementation conditions, and also effectiveness of water-saving devices.

199
Milne, Murray. 1979. Residential Water Re-Use. California Water Resources Center report no. 46. Davis: University of California.

This publication is a companion to Residential Water Conservation by the same author published in 1977. It was designed to help homeowners, builders, developers, architects, planners, and lawnmakers understand the design and installation of small on-site residential water reuse systems.

Based on this study, the author's conclusion was that these systems are technically feasible and environmentally sound and that they are becoming economically effective due to rapidly increasing costs of water and wastewater services from centralized systems.

The report may be used as a primary reference for determining applicability, technical feasibility, and effectiveness of water-reuse practices in the residential sector of water use.

200
Minton, Gary R., Richard Williams, and Thomas Murdock. 1979. Developing a Conservation Program Tailored to Area Needs. Journal of American Water Works Association 71:286-96.

The purpose of this analysis was to identify the most appropriate water conservation program for the metropolitan Anchorage area in Alaska. The article was based on the study on water supply prepared by the municipality of Anchorage and the U.S. Army Corps of Engineers.

The authors demonstrated potential water savings and marginal cost per unit of water saved for 5 water conservation measures (education, shower restrictions, low flush toilet, metering and pricing, and freeze protection-leak repair), each applied at 3 levels of intensity. Costs and water savings of the minimum, moderate, and maximum programs were determined by the authors. Input data to the evaluation of the effectiveness in flow reduction were reported to come from literature sources describing experience of other areas. Remaining information was obtained from the production record of 3 large water purveyors in the area.

The analysis showed that the moderate program focused only on public education, and pricing could save as much as 7 mgd of water in the year 2000 at a reasonable cost of $0.14/1000 gal. The maximum program could save much more water although it would do so at a cost approaching $1.00/1000 gal. These estimates allowed comparison of conservation programs to the marginal cost of water obtained from a new source.

The article is a useful reference for the determination of effectiveness and disadvantageous effects of conservation measures and in the consideration of other activities of water conservation planning since it describes a complete conservation exercise.

201

Minton, Garry R., Richard Williams, and Thomas Murdock. 1980. Institutional Analysis Criteria for Water Supply Planning. Water Resources Bulletin 16:486-93.

This paper focuses on institutional analysis of municipal water supply conducted in Anchorage, Alaska. This case study illustrates the selection and use of criteria necessary to identify and evaluate alternative institutional arrangements. The analysis was undertaken to determine implementation conditions for alternative water supply plans.

The alternative institutional structures were based on the following criteria (extracted from literature): (1) public acceptability, (2) political feasibility, (3) adequate legal authority, (4) adequate financial resources, (5) fairness and equitability, (6) technical capabilities, (7) stability/reliability/flexibility, (8) conservation suitability, (9) efficiency, and (10) enforcement authority. The conservation suitability criterion included such elements as suitability for implementing conservation measures, ability to enforce areawide emergency conservation, and fostering of uniform application of conservation measures.

Five institutional arrangements, each consisting of a mix of individual government elements, were evaluated according to the above criteria. In sum, an arrangement representing a combination of leading elements of other arrangements (namely municipality, groundwater agency/task force, metropolitan water utility, and independent utilities) was proposed as the most feasible.

This article is a valuable reference for analysis of implementation conditions of all applicable water conservation measures.

202

Mitchell, Robert D. 1957. Water Supply of Saint John's Newfoundland. Journal of the New England Water Works Association 71:173-87.

This article describes, in part, an attempt by the water authority that serves St. John's to reduce water waste that results from defective house plumbing fixtures. In St. John's, the average water use (up to 1951) ranged from 180-292 U.S. gpcd. The author noted that this is high even for an unmetered system such as St. John's. This high usage was attributed mainly to fixture waste and the leakage of service pipes. A house-to-house survey of fixture waste by City Engineers and a leakage survey by the Pitometer Company were undertaken in 1950-51. This effort was rated partially successful. Water use was reduced from 9.0 mgd in 1950 to 7.5 mgd for the first 9 months of 1951; a 17% reduction to 140 gpcd. This decrease occurred even while the number of water users

increased substantially. Metering was not attempted.

This case study showed that significant reduction in household leakage can be achieved in an unmetered system by a combined house-to-house survey and a leak-detection survey. The reported estimates may serve as approximations to the effectiveness of water conservation measures undertaken by the utility.

203

Moran, Edward. 1978. Waterless Toilets--Modern Home Systems Turn Waste into Compost. Popular Science 212:74-76.

This article presents a consumer report on the use of composting toilets. The article describes the operation of composting toilets and gives prices (which range from $700 to $1500 plus installation). It was noted that "all this is not as easy as pulling a flush lever: a composting toilet does require some additional attention. . . Recent developments indicate that despite such nuisances, composters are here to stay and can co-exist with public health standards." These considerations are relevant to determining technical feasibility of this device.

204

Morgan, Douglas W. 1973. Residential Water Demand: The Case from Micro Data. Water Resources Research 9:1065-67.

The author criticized segments of Howe and Linaweaver's article (1967) and attempted to verify the argument that repressed variable dp (persons/dwelling) can be shown to be incorrect by use of micro-data. He argued that Howe and Linaweaver deleted the variable dp from the equation of best fit for metered and public sewer demand and claimed that Howe and Linaweaver's assumption that "the bulk of residential water demand becomes a function of house value and price and is invariant with respect to the number of people residing in the dwelling unit (1065)" is incorrect. Howe and Linaweaver used average area estimates of demand (with 21 observations) and therefore reduced the variance in dp.

The author conducted a first stage opinion survey in Santa Barbara county. It was a random sample of 92 single-family residents, with metered water and public sewer. Information was collected on dp, yearly water use, and value of property. The water price was uniform. Estimates were made of the linear function of variables and log linear for November-December, January-February, and of all 4 months combined. In the results, the value and number of persons (dp) coefficients were positive and significant for all equations. There were very low r^2's, e.g., .19 to .36, which indicated considerable variation. Income elasticities basically were the same as Howe and Linaweaver's for time periods of "probable" in-house demand. The January-February set had highest people elasticity and lowest income elasticity, as well as the lowest r^2's.

The results "indicate an economies of scale with respect to household size holding other variables constant." In an equation with a .57

people elasticity, a 10% increase in household size will produce a 5.7% increase in water use." Transforming the equations to a per capita form, "it is easily seen that as household size dp increases, water use per person declines approaching the asymptotic value of 17.8 hundred cubic feet per year." As the months become drier, value coefficients increase and dp decrease, but still are significant.

The author concluded that the number of persons/dwelling is important and that "area projections based on Howe and Linaweaver's residential domestic demand model could lead to biased per capita use figure unless the people per dwelling unit is similar to their sample mean." However, he also claimed that the wetter months of January and February are more closely related to in-house demand because in November-December the rainfall is only 4.82 inches. This is an assumption which was not proven. In sum, the number of persons/dwelling was found to be a statistically significant variable; as household size increases, however, per capita use decreases.

This critique is relevant to the development of analytical models for forecasting residential water use.

205
Morgan, Douglas W. 1974. A Time Series Demand for Water Using Micro Data and Binary Variables. Water Resources Bulletin 10:697-702.

This study presents the results of an examination of the effects of the imposition of a $3.00 lump sum payment each bimonthly billing period plus an increase of $0.04 per 100 cubic feet of water consumed on 50 single-family residences in Santa Barbara, California. A price elasticity of -0.49 was calculated based on an econometric model.

This result suffers from the use of average rather than marginal price which is contrary to established economic theory. Using marginal price would have resulted in a much higher estimate of the price elasticity. The author's results, similar to results of other researchers, are usually clouded by a lack of information on the consumer perceptions of price change in the short-run period from which the data are usually taken.

206
Morgan, Douglas W. 1979. The Economics of Water Conservation. In Proceedings, Conference on Water Conservation Needs and Implementing Strategies, pp. 59-68. New Hampshire: Franklin Pierce College.

The author developed an economic framework for the allocation of water using the constraints of supply and demand. In doing so, the author incorporated and discussed such elements as (1) specific user group pricing, (2) prices different from marginal costs, (3) seasonal or peak load pricing, and (4) price elasticity.

Water is considered by economists scarce, and thus an "economic good," since it has declining marginal value to the consumer and as a divisible commodity can be allocated over time and space. In accordance with the analysis of demand and supply, conservation policies are those which affect shifts in demand curves while changes in price are referred to as demand management policies. The author stated that ". . . the fact that some conservation measures are effective (in shifting demand curve to the left) means there is evidence of market failure--e.g., a lack of knowledge about water-saving technology or other conservation techniques."

It was recommended that water purveyors get rid of all subsidies and begin to calculate the real resource cost of their water supply. This in turn would require a demand management policy capable of developing rate structure related to marginal cost-pricing. Conservation programs should primarily involve activities necessary for technology transfer thus increasing consumers' ability to "economize" water use.

This paper may be recommended as a primer on economic rationale for water conservation.

207

Morgan, Douglas W. 1980. An Economist's View of Demand Projections Considering Conservation. Water Resources Bulletin 16:941-43.

The purpose of this paper was to clarify and elaborate on the demand model developed by Sonnen and Evenson in "Demand Projections Considering Conservation" (Water Resources Bulletin 15/2, 447-60, also annotated in this volume). The author placed their analyses in terms of an economic demand-supply framework with a clarification of the effects of pure conservation and pure demand management. The latter operates through an increase in the price of water and is measured by price elasticity, while pure conservation effects are classified as factors shifting demand schedules. (See also Morgan, 1979, no. 206.)

208

Morgan, Douglas W., and Peter Pelosi. 1980. The Effects of Water Conservation Kits on Water Use. Journal of American Water Works Association 72:131-33.

The authors reported on the effectiveness of a residential water conservation campaign which was undertaken by the City of Oxnard, California, during August 1977. The campaign involved free distribution of a 3-part water conservation kit. Each kit contained a toilet water dam, a plastic shower-head restrictor, and a packet of vegetable dye tablets to detect leaks from toilet storage tanks. One month after distributing about 3,200 kits, a total of 637 households were interviewed to determine the installation rate, socio-economic characteristics of households, water savings resulting from the installation of these conservation kits, and their cost effectiveness.

The survey showed that 63% of the sample installed the kits while 37% did not. The lowest installation rates occurred in units with lower current water usage, with lower-than-average income, with either single-person or large-family sizes, and for families with adults between the ages of 35 and 44 and over 65.

High water-using households with above average socio-economic characteristics had higher installation rates. An analysis of water use for 12 billing periods showed that installers had, on the average, $0.86m^3$ higher water use than non-installers prior to the distribution of the kits. Water use for installers fell during each of the last 4 billing periods by $2.8m^3$. In general, the water conservation kit reduced actual water usage by a little more than 3% and could pay for itself in 1 year.

The findings of this report may be helpful in determining public acceptability, implementation conditions, and effectiveness of water conservation kits.

209

Morgan, Douglas W., and Jonathon C. Smolen. 1976. Climatic Indicators in the Estimation of Municipal Water Demand. Water Resources Bulletin 12:511-18.

The purpose of this paper was to determine the regression estimator most representative of climatic variation in one common data set of monthly aggregated municipal water use for 33 cities in southern California. A total of 396 cross-sectional observations of average price and income for each water district in 1970 was analyzed. Three alternative climatic indicators were tested: (1) temperature and precipitation, (2) potential evapotranspiration minus precipitation, and (3) monthly binary seasonal variables.

The results of the analysis have shown that both the first and the second models perform much better than the model using seasonal binary variables. In terms of economic responses, the study confirmed that the price elasticity of seasonal water use is higher than other municipal water-demand elasticities. This information is important for determining the effectiveness of price changes on various water-use categories.

210

Morris, John R., and Clive V. Jones. 1980. Water for Denver: An Analysis of the Alternatives. Denver: Environmental Defense Fund, Inc.

This publication contains the results of the comprehensive Denver Water Conservation Study performed by the University of Colorado, Denver. The general purpose of this project was to identify an effective and economically efficient means of meeting Denver's future demand for water with the inclusion of water conservation programs.

The study examines the cost and water yields of the major alternatives that either provide new water supplies or save water. The latter include:

1. installation of water meters,
2. installation of water-saving toilets and showers,
3. reduction in size of lawns,
4. revision of the price structure,
5. water-use restrictions or rationing,
6. in-home water recycling, and
7. commercial scale recycling.

In addition to the assessment of a large array of water conservation measures, the report also contains a brief analysis of environmental costs and financing alternatives of conservation programs.

Based on the specific information obtained from a survey of 889 single-family residential customers, 2 statistical models of household water demand were developed in order to provide a specific basis for the evaluation of water conservation measures. In conclusion, it was found that water conservation is the cheapest alternative to provide water for Denver. It could provide 50% of the water Denver will need over the next 30 years at a cost only one-third as high as the cheapest source of a similar amount of new raw water.

This report constitutes a very useful reference for water conservation planning. It contains information relevant to the determination of effectiveness, disadvantageous effects, foregone supply costs, and environmental effects of several water conservation measures. It may be helpful in the preparation of water conservation proposals.

211

Murray, C. Richard. 1973. Water Use, Consumption and Outlook in the U.S. in 1970. Journal of American Water Works Association 65:302-308.

The author summarized the U.S. Geological Survey's study of water use in the United States for 1970. The article describes by geographic region and by use, the present (1970) water use, water withdrawal, supplies and demands, and sources and consumption data. Among the points considered are:

1. "Public supply withdrawals used for residential purposes in the West cause a greater draft on the supply than they do in the East. . . . Water delivered for domestic and public uses (including water system losses) accounted for 74% (130 gpcd) of the public supply withdrawals in the 9 western regions, but accounted for only 65%

(100 gpcd) of the public supply withdrawals in the more populous eastern regions."

2. "About 86% of the water consumption in the U.S. took place in the 17 western states where only 40% of the country's runoff occurs."

3. "At present, most water problems are problems of resource management rather than inadequate supply; the outlook, however, is that as demands increase, better planning accompanied by increased expenditures for larger supplies of water of acceptable quality will take place."

This article is a good source, both descriptively and graphically of the status of water supply, demand, etc., in the United States in 1970.

212

National Academy of Sciences. 1971. Potential Technological Advances and Their Impact on Anticipated Water Requirements. Washington: National Academy of Sciences.

This report analyzes the impacts on water use of a large number of potential technological changes. In each case the technological and institutional barriers are discussed, and predictions of the time needed for feasibility and for fully operational systems are made. Research priorities are established. The report analyzes developments that will increase and decrease supplies and demands. Economics aspects are not analyzed in detail. It is noted that developments such as recycling and advanced wastewater treatment may have far greater impact than systems to augment fresh water supplies or than other methods of conserving existing supplies.

These considerations may be helpful in determining the feasibility of those water conservation measures which are planned to be implemented in the future.

213

National Water Commission. 1973. Water Policies for the Future: Final Report to the President and to the Congress of the United States. Washington: U.S. Government Printing Office.

This report contains the findings and recommendations of the National Water Commission. Included in Chapter 7 are the areas of (1) "pricing as a means of motivating better use"; (2) water rights and reparian law; (3) reducing water losses; and (4) reuse of municipal and industrial wastewater.

The Commission recommended that water pricing be based on the principle of incremental or marginal cost pricing. This should include the states imposing withdrawal charges on self-supplies but may not be possible because of prior contracts or rights. The problem of failure to price properly is most severe in irrigation which is responsible for 83% of

all water consumption. The Commission advocated free bargaining of water rights as a means of allocating water more efficiently. Establishing the right to sell salvaged water was also recommended. Within the existing system of water rights, it is desirable for Western States to quantify the "duty of water" by crop and region. Similar quantification should be applied to conveyance losses. Uses beyond these amounts should not be included in the water right. Other methods of improving irrigation efficiency include choice of reservoir site, lining of irrigation canals, trickle and sprinkle irrigation, and eradication of streambank vegetation (here environmental effects must be considered).

Improved efficiency in municipal use can be obtained by leak detection, installation of meters, price policy, encouragement of water efficient fixtures (38% and 50% possible savings for household and commercial-business establishments cited) and public relations. The potential for reuse of treated municipal and industrial wastewater is judged encouraging (cost estimates are included). It is recommended that direct reuse for human consumption be deferred. Sewage effluent-irrigation water exchanges hold considerable promise.

In general this report contains a very good general discussion of the above-mentioned aspects of water conservation.

214

National Water Commission. 1976. Forecast and the Role of Alternative Futures. Journal of the Water Resources Planning and Management Division of ASCE 102:363-83.

This staff paper contains a general discussion of forecasting future use and supply of water on the nationwide scale. A review of previous water resource forecasts by the Kerr Commission, the Water Resources Council, and the USGS is presented. Those forecasts have generated widely ranging figures depending on the underlying assumptions. According to the existing need for forecasts useful in policymaking, the Commission has rejected a single "most likely" forecast in favor of separate "alternative futures." This concept recognizes that the amount of water used as well as supply availability is dependent upon policies adopted, future socio-economic phenomena, etc.

The procedure proposed in this article involved 2 steps. First, 3 to 5 "alternative futures" were developed, each of which was described by the set of assumptions encompassing population growth and distribution, food and fiber production, income distribution, national economic efficiency, lifestyle changes, and various means of developing, using, and conserving water resources. In the second step, forecasts of water use for each future were made. This forecasting approach was expected to provide the Commission with a tool for making sensitivity tests of a variety of assumptions.

The procedure proposed by the Commission may be very helpful for policy-making purposes in water conservation planning.

215
National Water Conservation Conference. 1981. Publicly Supplied Potable Water. Colorado: Denver.

This proceedings volume contains 46 abstracts of papers presented at the conference by experts in the field of municipal water management. Although most topics and studies discussed at this meeting are covered by this annotated bibliography, it is advisable to examine all of them since when taken together, they represent very well the status quo in water conservation developments.

216
The National Water Council (Great Britain). 1977. The 1975-1976 Drought. London: National Water Council.

This report details the activities of the British water utilities to deal with the 1975-76 drought (the worst in recorded history since 1727). Of particular interest were the measures used to reduce water use. Generally these began with appeals which became more urgent over time. Public media were very helpful. Appeals combined with hosepipe bans typically achieved 20 to 25% reductions. Savings from pressure reductions were generally less than 10%. Leak-reduction programs saved approximately 5% in some areas. Industries were generally not closed, apparently in response to public sentiment concerning loss of jobs. In some cases rotating cut-offs or complete residential cut-off with standpipes provided was substituted with total savings to over 40%. Because most residences are not metered, rationing or fines for excessive use were not possible.

The council was satisfied with the amount of prior planning. More detailed planning, specifically rules as a function of rain or storage, were not judged to be useful. There are too many social factors that must be taken into account to use hard and fast rules. Implementation planning is very necessary for rotating cut-offs, standpipes and leak detection and pressure reduction. No health problems were encountered. Very few persons placed bricks in the toilet tank (9%) or installed dual flush mechanisms compared to the responses for pleas to cut in bath water, reuse water, flush the lavatory less, and stop watering garden (76-90%). Here advance distribution of water-saving devices would have been helpful. It is noted that the use of prohibitions and mandatory restrictions (hosepipe bans, pressure reductions, etc.) were effective not only in themselves but also in the re-enforcement of the crisis atmosphere necessary for voluntary water-use reductions.

The reductions in water use reported by the Council may be used in estimating the effectiveness of above-mentioned water conservation measures.

217
Nelson, J. O. 1979. Northern California Rationing Lessons. In Proceedings, Conference on Water Conservation Needs and Implementing Strategies, pp. 139-46. New Hampshire: Franklin Pierce College.

The author reported on the effectiveness and acceptability of an emergency rationing of water during the 1976-77 drought in North Marin County Water District in California.

An emergency rationing plan for residential water consumption resulted in the reductions of between 25% and 40%. A serious water shortage and adequate communication with the consumers were considered deciding factors in this response. Reductions in commercial consumption up to 25% were also possible.

Four distinct rationing procedures were used:

1. percentage reduction (compared to normal use in a previous similar billing period;

2. seasonal allotment (a per capita or home allotment--increased in summer and decreased in winter);

3. fixed allotment (per capita or home allotment based on calculated need); and

4. total sprinkler ban.

The latest method was found to be the least successful one. For remaining techniques, rate penalties for exceeding allotments were not needed. In many instances where mandatory rationing was implemented, consumers cut water usage even more than requested.

The information presented in this paper can be used for estimating the effectiveness of water-use restrictions.

218
Nelson, John Olaf. 1977. North Marin's Little Compendium of Water Saving Ideas. Marin County, CA: North Marin County Water District.

This report contains a very detailed description of possible water-saving techniques primarily directed at residential use. Included are extensive lists of water-saving products and lists of distributors. Three case studies in the use of water-saving devices are presented.

Of note is a short section on water-pricing policies. Flat rates and declining commodity rates were rejected as inappropriate. Uniform and seasonal rates were judged better. Inclining commodity rates "have been employed in very few instances and normally only when water shortage conditions exist." Included is an appendix describing the drought management programs of Marin County, California. Also included are recommendations concerning the case of grey and reclaimed water. Grey water for use in toilet flushing should go into the bowl to avoid

contamination of the distribution system if system pressure is lowered. It was recommended not to use grey water for either growing fruits and vegetables or for spray irrigation. Do-it-yourself reuse plumbing was not recommended.

The report may be helpful in determining applicability, technical feasibility, and effectiveness of water-saving devices.

219
New England River Basins Commission. 1980a. Before the Well Runs Dry, A Handbook for Designing a Local Water Conservation Plan. Virginia: U.S. Department of Interior, Geological Survey.

This handbook describes to the water supplier a 7-step procedure for designing a local conservation plan which includes the consideration of social, political, and economic impacts. It was produced jointly by the U.S. Geological Survey and the New England River Basins Commission. The procedure was specifically designed for individual communities. The 7 basic steps involved in designing a water conservation plan are as follows:

1. Identify problem/establish conservation goal,
2. Assess potential of supply management,
3. Analyze cost-effectiveness and impacts of management,
4. Identify actions to minimize adverse impacts,
5. Choose management program(s)/design the specifics of each management program(s),
6. Evaluate and select hardware/software, and
7. Summarize conservation plan.

Each step of the procedure was separated into 3 elements: objective, procedure, and guidelines. The use of the procedure was illustrated by the example of a hypothetical New England community which is using the 7 steps in designing a water conservation program.

The procedure was developed based on information gathered in an earlier phase of study which is published in the technical report "Before the Well Runs Dry, Vol. I: Supporting Research" in June 1980.

220
New England River Basins Commission. 1980b. Before the Well Runs Dry: Literature Survey and Analysis of Water Conservation, Volume I. Virginia: U.S. Department of Interior, Geological Survey.

This volume which summarizes the supporting research for the procedure for designing a water conservation plan (described in Volume II, Designing a Local Water Conservation Plan) presents (1) characteristics and major problems confronting New England Water Suppliers servicing 10,000 or more persons, (2) economic analysis of demand management programs, (3) cost effectiveness analysis of water conservation measures, and (4) extended bibliography listings with 201 sources which are referenced to various elements of cost effectiveness analysis.

The information gathered by the Commission can be very helpful in developing conservation plans based on measure-specific analysis.

221
Nicolson, G. S. 1979. Water Supply System Failures with Conservation. In Proceedings, Conference on Water Conservation Needs and Implementing Strategies, pp. 94-102. New Hampshire: Franklin Pierce College.

The author's purpose was to forecast annual reservoir failures with 2 sets of demands and situations for an existing water supply reservoir system using a computer model capable to simulate streamflow and reservoir operation.

Based on both the historic and synthetic streamflow records and also on water demand from the reservoir that was increasing 1% to 2% annually, and exceeding the long-term safe yield, the computer model was used to analyze the results of water conservation measures during forecasted drought. The results showed that for the considered reservoir system, forecasting and conservation had more impact on reducing failures when the probability of failure is high than when it is low. Failure probabilities of more than 20% and 10% were found for 2 simulation runs which had average demands of 0.85 maf and 0.79 maf, respectively.

The article contains valuable information for determining the performance of alternative water supply/conservation plans for design drought conditions.

222
North Carolina Department of Natural Resources and Community Development. 1980. Proceedings, North Carolina Conference on Water Savings and Water Supply Assistance. North Carolina.

This document represents the official record of the conference which was organized by the North Carolina Department of Natural Resources and Community Development, Office of Water Resources. It contains the papers presented at the meetings as well as the discussion questions.

The conference focused on key issues and approaches which help communities obtain additional water supplies and more effectively use current water resources.

223

Office of Science and Technology Policy. 1978. Scientific and Technological Aspects of Water Resources Policy. Report for the Policy Committee for the Water Resources Policy Study. Washington, D.C.

This paper cites 12 water resource policy issues and discusses the findings, policy recommendations and directions for research in each category. The issues discussed are: climate and water supply, floods and droughts, groundwater, water conservation in irrigation, water quality, erosion and sedimentation, water for energy, methods for increased water supply, future water demands, urban water programs, and a systems approach for water.

As for water conservation in irrigation, 82% of total consumptive use is accounted for by agriculture. Less than half of this water reaches the crops. Much greater efficiency is needed.

The authors recommended a policy change that would reflect the high value of water for energy, industrial, and municipal purposes. As to future demands for water, the authors noted that the water demand was not inflexible. In the future demand, modification will be a viable alternative to supply management. This in turn requires greater sophistication of projection models which will incorporate demand controls as alternatives to investment in greater supplies. Cost-sharing policies should be encouraged.

The future water policies suggested in this report are of high relevance to planning for long-term water conservation.

224

Office of Water Research, U.S. Department of Interior. 1972. Social Aspects of Urban Water Conservation.

The purpose of this study was to examine the effectiveness of various conservation measures implemented during the water shortages of the 1960s and to ascertain the attitudes of the public toward these measures. Data were obtained form on-site visitations with city governments. The response from most cities whose cooperation was requested was not enthusiastic. The danger of drawing conclusions from this unrepresentative sample was not discussed. The report concludes that home consumers will comply with water conservation requests when the need is apparent; it is uncertain whether a rate increase will significantly change home water consumption; opinions on the advisability of voluntary versus mandatory water conservation actions during emergencies varied from city to city; people are poorly informed about water, as little is known of its source, treatment, or price. A list of home conservation methods is appended.

The information contained in this report is helpful in determining applicability, social acceptability, and effectiveness of water conservation measures.

225

Pagorski, Albin D. 1974. Is the Public Ready for Recycled Water? Water and Sewage Works 121:108.

The purpose of the article was to determine public response (degree of acceptability) to hypothetical wastewater recycling for domestic use. The author conducted an empirical survey in Lake Forest, Illinois, in 1971 of 114 people (59% female, 41% male, 59% under 30, 41% over 30).

The results of the study painted a generally positive picture of acceptance; 81% said they would be willing to use recycled water if it met the same quality standards as existing public water supply. As costs went up , acceptance levels fell.

There are some problems with the study. There is no acknowledgement that the results are purely hypothetical, and no distinctions are made with regard to the types of usage (drinking, bathing, washing, etc.).

226

Phillips, W. J. II. 1974. The Direct Reuse of Reclaimed Water: Pros, Cons, and Alternatives. Journal of American Water Works Association 66:231-37.

This article discusses the advantages and disadvantages of direct wastewater reuse. Water recycling events from the past were examined on their effectiveness of purification. Results seemed to be encouraging. Among disadvantages of reuse were such problems as virology and bacteriology. The author stated that the present methods in virus measurement and monitoring were not very efficient or economical. In the author's opinion the question of whether or not recycling should be considered does not have to be settled at this time (i.e., 1974).

This article may be very useful as an introduction to technical problems of direct water use.

227

Planning and Management Consultants, Ltd. 1981a. An Annotated Bibliography on Techniques of Forecasting Demand for Water. Report prepared for the U.S. Army Engineer Institute for Water Resources. Fort Belvoir, Virginia.

The purpose of this volume was to provide field planners with the currently available and relevant literature on forecasting demand of municipal and industrial water. The volume consists of detailed abstracts of 83 journal articles, books, theses, dissertations, or research reports; only those sources considered meritorious and useful are included. The abstracts are classified by forecasting method and content category in a cross-reference table matrix.

This annotated bibliography may be helpful in locating information on empirical coefficients, theoretical models, and practical applications of various forecasting procedures.

228

Planning and Management Consultants, Ltd. 1981b. An Assessment of Municipal and Industrial Water-Use Forecasting Approaches. Report prepared for the U.S. Army Engineer Institute for Water Resources. Fort Belvoir, Virginia.

The purpose of this study was to assess current water-use forecasting practice in the U.S. Army Corps of Engineers and to recommend those additional approaches which best satisfy current requirements.

The report contains a description of the state-of-the-art in forecasting procedures as contrasted to current practice based on the findings of a three-prong investigation: (1) identification of current needs for improved forecasting approaches in light of the current requirements; (2) review and assessment of current forecasting approaches; and (3) recommendation of the most appropriate forecasting approaches which meet the identified needs. Data were obtained from personal interviews with field planners in 6 districts and 3 divisions, from a questionnaire to 35 districts and 11 divisions, and from the analysis of 27 Corps studies that had forecasted demand.

This report is very useful in identifying new and more responsive approaches of disaggregated demand forecasts which are indispensable in predicting the effectiveness of potential water conservation measures.

229

Pope, R. M. Jr., J. M. Stepp, and J. S. Lythe. 1975. Effects of Price Change upon Domestic Use of Water over Time. Water Resources Research Institute report no. 56. South Carolina: Clemson University.

The report contains an excellent literature review and also presents the estimates of price elasticity for residential water use from the analysis of time-series data of approximately 1,000 households from 4 South Carolina cities. For each city, monthly meter readings for each household were obtained for the period 1 year before and 2 years following a price change. Price elasticities were calculated by comparing water use in year 1 with water use in year 2 and by comparing water use in year 1 with water use in year 3. When these percentage changes are divided by percentage changes in price, the result is 8 estimates of a price elasticity (2 for each of the 4 cities). These values ranged from +0.094 to -0.512. Other estimates were presented based on disaggregations by month, income class, number of persons per family and by "lawn irrigation" versus "nonirrigation."

The authors contended that the water users return to old habits after a period of time following the price change. The main support for this contention was the fact that elasticities calculated from water use in year 3 are lower for all 4 cities than the values based on water use in year 2. There were, however, several reasons to distrust this supporting evidence. The time period of 2 years was too short to distinguish between short- and long-run behavior. Weather was not accounted for in this very small sample of years and communities. Sewer charges were not mentioned. Average price was used. The last, but possibly most important, consideration is that nominal not real price was used.

This alone may be sufficient to explain the return to previous water use as real price would decline under inflationary conditions if nominal price remained constant.

The estimates of price elasticity for various use categories may be applied to determine the effects of price change on water use.

230

Powell, F. 1977. PS Tests Bathroom Water-Savers. Popular Science 211:120-22+.

This article involves a "consumer reports" type examination of water-saving devices. Among its findings were:

1. Five different flow control shower heads ($8-20) (flow 2.5-3 gpm) were found to give good performance (subjectively good showers). Washers ($1) (3-5 gpm) also worked well.

2. Flow-reducing faucets were recommended only when replacing faucets for other reasons since most users are volumetric.

3. Toilets with dams in the closet ("Moby Dike," "Little John") (less than $5) (2.5-3.5 gpm) performed better than those without dams and used much less water "cornflake-flushability test").

4. The dual-action flush system tested ("EcoFlush") (no price given) (1.5-2.5 gal for liquid waste) was judged more difficult to install than the dams.

5. Brick-or-bottle-in-the-tanks were judged to significantly reduce effectiveness of flush, were not recommended, and were judged less satisfactory than dams.

The author reported a 30% water-use reduction with 3 toilet dams and 2 shower heads in his own home with no reduction in quality of shower or flushing. The author also reported on a 2-qt. compress-air-water toilet ("Metrophor," $600) and a 0.5 gpm compress-air-water shower head ("Minuse," $260). These are highly reliable measures of reduction in unit water use for the above-mentioned devices.

231

Pratte, Janice, and Warren Litsky. 1979. The Attitudes of Industry and Public Officials on Industrial Use of Reclaimed Municipal Wastewater Effluent in Massachusetts. Water Resources Research Center publication no. 106. Amherst: University of Massachusetts.

The purpose of this study was to determine if wastewater reuse by industry was a suitable water conservation measure in terms of social,

economic, institutional, and technological feasibility.

The study involved interviewing 12 individuals working in public agencies and 26 industrial managers. The latter included only those Massachusetts industrial plants which used at least 100,000 gallons of municipal water per day. The results of the personal interviews guided by a questionnaire showed that economic feasibility will decide about industry's ultimate acceptance of reuse. The public officials were more skeptical and their responses were primarily based on economics and the potential for other water supply sources.

The authors concluded that the concept of reusing municipal wastewater for industrial purposes will be worthy of more attention as water costs increase, sewage treatment plants are upgraded, and alternative supplies are sought.

232
President's Intergovernmental Water Policy Task Force. 1980. Urban Water Systems: Problems and Alternative Approaches to Solutions. Washington, D.C.: Subcommittee on Urban Water Supply.

This report summarizes the results of the work of the subcommittee which was directed at (1) an inventory of existing Federal programs to assist urban water systems rehabilitation or new construction; (2) an evaluation of institutional and financial problems; and (3) an assessment of policy and program changes at the Federal, State, and local level.

The following were the principal findings of the Subcommittee as formulated in the Executive Summary of the report:

1. Urban water system capital expenditures needed over the next 20 years are estimated to total $75-$110 billion. This includes replacement and rehabilitation of distribution and treatment systems at $50-$80 billion, servicing growth at $5-$8 billion, upgrading to improve drinking water quality at $425 million, and new source development at $20-$25 billion.*

2. Rough estimates suggest that as many as two out of ten urban water systems might experience capital investment shortfalls over the next 20 years. An investment shortfall is that portion of the capital investment estimated to be needed which a system is judged unable to finance based on its projected expenditures and on revenue increases up to a doubling of rates. The historical significance of such a ratio of shortfall is unknown.

3. The most probable estimate of urban water system capital investment shortfall over the next 20 years, based on rough order-of-magnitude estimating techniques, is between $10-$13 billion. The shortfall could range

between $5-$26 billion, since estimates are both difficult and uncertain without a city-by-city analysis.

4. Of the total estimated national shortfall, about one-half is attributed to distribution system needs and one-third to new source development needs.

5. Municipally-owned and operated water systems are four times as likely as privately-owned systems to experience shortfalls. Regional public systems are twice as likely to experience shortfalls as private systems. Publicly owned systems currently account for 73% of all urban systems and serve 81% of the population of urban areas.

6. Federal categorical programs which supply assistance specifically for water supply purposes have limited applicability to urban water supply problems. Farmers Home Administration programs are focused on communities smaller than those classed here as urban (over 50,000 population). Federal water resource development agency programs of direct construction, by policy, do not develop projects for single-purpose water supply.

7. Some Federal assistance programs do provide substantial sources of funding assistance which could be directed to water supply. Use of such assistance for water supply purposes depends upon whether State and local governments are able to give such use a high priority relative to other needs for the funds. Economic Development Administration programs, HUD community development programs, and Treasury's General Revenue sharing programs provide very large resources which could be used for water supply purposes. In FY 1977, nearly $10 billion went to State and local governments from these programs; about 2% of these funds appear to have been allocated to water supply purposes. Of the $10 billion total, only $6 billion was available to urban areas (cities over 50,000), of which the amount utilized for urban water supply is unknown.

*All estimates are in 1979 dollars. No adjustments have been made for inflation.

Five possible policy approaches to address the above problems have been identified: (1) status quo or retaining full local responsibility for water supply, (2) modified policies and programs with increased Federal assistance, (3) Federal/State water banks with access to capital investment funds, (4) Federal financial assistance, and (5) removal of existing policies against single-purpose water supply.

233

Primeaux, Walter J., and Kenneth W. Hollman. 1974. Factors Affecting Residential Water Consumption: The Managerial Viewpoint. Water and Sewage Works:R138-44.

This article presents the analysis of residential household water use based on cross-sectional data obtained through surveying 402 single-family households distributed evenly among each of 14 Mississippi cities in 1971. The price charged per gallon and the monthly consumption per each household were obtained from municipal water meter records in each city.

The household water-demand model utilized 13 independent variables: number of persons, number of bathrooms, dishwashers, washing machines, existence of swimming pool, irrigable areas, market value of residence, average maximum temperature, annual precipitation, education, age of head of household, race, and price. The latest variable was taken as the price of 1,000 gallons of water at the mean level of consumption in each municipality. The authors obtained a R^2 of 0.56 for a linear equation when all variables were included; withdrawing the variables of race and age had no significant effect on R^2. The demand model utilizing only 3 independent variables (number of residents, market value, and price) explained 47% of the variance independent variable.

The results reported here are important for developing models for forecasting unrestricted water use.

234

Rees, Judith A. 1969. Industrial Demand for Water: A Study of South East England. London: Weidenfeld and Nicolson, London School of Economics and Political Science.

This book contains an analysis of industrial water use in South East England based on a questionnaire survey of a random sample of 253 manufacturers in the area administered during the spring and summer of 1966.

The author analyzed the uses to which manufacturing industry puts water, the sources from which the demand for water is satisfied, the factors which determine the quantity of water taken by firms in the various industry groups, and also the effect of water availability on industrial location. The results of this analysis were used to analyze possible future trends in industrial demands for water.

The following table summarizes the author's findings concerning estimates of the minimum water requirements of firms (only water purchased from the water supply industry) in various industry groups:

Industry	Equation	Unit use	Level of explanation (R^2)
Chemicals	$Q^2 = a+bT$	tonnage of raw materials	97.3%
Food	$Q^2 = a+bT$	as above	86.7%
Metal Products	$Q^2 = a+bE^2$	number of persons employed	96.0%
Other	$Q^2 = a+bE$	number of persons employed	87.0%

Lower levels of explanation for explanatory equations for purchased water were found for

1. drink industry, $Q = a+b \log P_m$, $R^2 = 36.3\%$, P_m = price paid for gallons for metered supplies of water

2. plastics and rubber, $Q^2 = a+bE+cT$, $R^2 = 41.5\%$

3. paper and products, $\log Q = a+b \log P + c \log QA$, $R^2 = 55.3\%$
   P = price paid for all purchased supplies per 1,000 gallons
   QA = quantity of water privately abstracted by firms

4. nonmetallic minerals, $Q = a+bE$, $R^2 = 67.2\%$

5. engineering (precision plus mechanicals), $\log Q = a+b \log P + c \log QA$, $R^2 = 44.1\%$

The author found that over the past 10 years manufacturers in the study area have expanded their water usage by approximately 2% annually, but many plant managers expected this rate to decrease down to 0.8% during the next 10 years. She also concluded that little evidence exists to suggest that the availability of water facilities will increase in importance in the locational decision of firms.

The data presented in this book may be used to develop the estimates of unrestricted water use in manufacturing.

235

Rees, J. A., and R. Rees. 1972. Water Demand Forecasts and Planning Margins in the South-East England. Regional Studies 6:37-48.

This paper presents estimates for projected water demand for South East England that are considerably lower than previous estimates made by the Water Resources Board (WRB). These differences were attributed to (1) a difference in the functional forms used, (2) the WRB estimates use of local figures which have some implicit level of safety margin, (3) different assumptions concerning the impact of higher prices for private abstraction, and (4) local double counting of projected developments.

Procedures for calculating "planning margins" were presented. These problems suffered from the nature of the regression procedure used. Time (year) was included as a dependent variable even though time cannot be in any sense a causal variable. This feature of the projections makes the procedures inappropriate. The article also fails to explain why the basically linear extrapolation can be expected to be more than the methods used by the WRB.

236
Reid, George W. 1971. Multistructured Municipal Water Demand Model. Water Resources Bulletin 7:1238-45.

The theoretical forecasting approach proposed by the author of this article was based on the application of econometric techniques which would predict the values of explanatory variables required by any demand requirement model. The model was composed of economic, population, reconciliation, and life-style submodels and it is goal oriented. The forecasting process began with the determination of "people needs" which, in turn, were placed in the context of the management of critical resources for beneficial use.

The author admitted that the model was determinative in some aspects and probabilistic or stochastic in others. This must be so, it was stated, since the accuracy of water-demand forecast cannot be better than the present predicting power of macro-economic theory. There is hope that new computer capabilities and econometric techniques will significantly improve in the near future.

This article contains valuable theoretical considerations which may contribute to the development of more powerful forecasting techniques.

237
Rice, I. M., and L. G. Shaw. 1978. Water Conservation--A Practical Approach. Journal of the American Water Works Association 1970:480-82.

This article reports the results of a conservation campaign in Dallas that placed a surcharge on residential customers during peak demand periods in the summer of 1977. The ratio of maximum-day/avg. day demand declined 8% from the average of the last 5 years. Maximum-day pumpage was found to be 12% less than that of the highest maximum pumpage recording in 1974.

The article details encouraging results of the Dallas pricing policy to reduce residential water consumption during periods of peak demand, showing the merits of pricing policies in general. Although of short duration, it is an excellent example of the effectiveness of a pricing policy.

238
Ridge, Richard. 1972. The Impact of Public Water Utility Pricing on Industrial Demand and Reuse. Report no. NTIS PB 214-393. Philadelphia: Water Resources System Engineering Lab, General Electric Company.

The relationship of water price to water use and reuse was examined for five specific industries: paper mills, paperboard mills, poultry dressing, malt brewing, and fluid milk processing. Data were obtained by mailing questionnaires to representative firms in each of the 5 industries. Of 380 questionnaires sent, 90 useable responses were received, ranging from 11 to 34 per industry. The rate structure of the water utility serving each firm was also obtained and used to determine the marginal price of water to the firm. Water-use rates were regressed

on marginal price and other explanatory variables, giving demand functions for publicly supplied water in each of the 5 industries. Statistically significant estimates of the price elasticity of demand were given for 2 of the 5 industries: malt liquor, -0.3; and fluid milk processing, -0.6. Of the firms surveyed, 35% reported having recently limited water intake due to higher intake cost. Typical water-reuse measures were reviewed and found to be well within the range of feasibility as adjustments to higher water prices.

Findings of this study are useful for estimating the effectiveness of conservation-oriented pricing schedules with respect to the considered industries.

239

Riley, John G., and Charles R. Scherer. 1979. Optimal Water Pricing and Storage with Cyclical Supply and Demand. Water Resources Research 15:233-39.

This paper constitutes a general economic analysis focused on the optimal pricing of a commodity when demand fluctuates in a periodic fashion. Specifically, the authors' purpose was to integrate the literatures of peak-load pricing and optimal water reservoir planning and operation.

By using a Lagrangian analytical framework, the authors maximized net willingness to pay, subject to 3 capacity constraints and 1 flow constraint. The problem of investment-operating-pricing was considered using continuously varying price-sensitive demand. Results of this analysis indicated that the optimal rate structure was well approximated by a policy in which the price of water is adjusted at only a few points in the cycle. Also it was shown that the introduction of storage to the system permits such allocation of available supply, and that prices in all seasons may be held above marginal operating costs, thereby bearing part of the capacity costs.

Findings of this analysis are relevant in the development of implementation plans for a water conservation program.

240

Robie, Ronald B. 1978. California's Program for Dealing with Drought. Journal of the American Water Works Association 70:64-68.

This article reports on the measures taken in California to reduce water use in 1977. "With an urgent and perceived need cutbacks in municipal water use of up to 50% are possible. . . . Based on current experience this (mandatory conservation including rationing) is usually required for cutbacks exceeding approximately 20 to 25%. . . . Farmers can get by on less water but not to the same degree as urban users." In many cases short-term groundwater mining greatly lessened potential agricultural losses because of reduced surface supplies. Other events and new contingency plans arising from the drought are also described.

The reported estimates may be used to determine the effectiveness of water conservation measures which were undertaken during the event. These estimates may be used in the preparation of drought contingency plan.

241

Robie, Ronald B. 1980. The Impact of Federal Water Policy on State Planning: A Cautionary Example. Journal of American Water Works Association 72:70-73.

The author of this article reviews California's experience in conflicting Federal-State water policies. He suggests that "long-term water policy reform would be more successful if the Federal government accepted State water system laws and cooperated with the states to ensure that the reforms are workable and that the affected local and State agencies are involved in their planning." With respect to the President's new water conservation policy, the author states that the Bureau of Reclamation has repeatedly ignored water conservation and wastewater reclamation in planning the proposed project.

The discussion presented in this article relates to determining implementation conditions of water conservation.

242

Romm, Jerri K. 1977. Water Supply, Land Use, and Urban Growth. Journal of the Water Resources Management Division of ASCE:271-84.

The general thesis of this article is that land-use projections are more reliable than population projections for the determination of future water requirements. This approach was adopted to water supply planning by the Santa Clara Valley Water District in California. It was suggested that the analysis of residential, industrial, and agricultural land-use combinations possible with available water supply be first performed, and next, a set of community goals be established to best fit available supply.

Although the above implies that water supply is the primary determinant of growth, a highly controversial proposition, the program designed by the district to project future water use seems to be of real value. It projects spatial distribution of annual water demand for a 25-year period in Santa Clara Valley County. The forecasting process consists of 2 components: (1) taking stock of all anticipated land-use changes for each year to the year 2000, based on parcel-by-parcel inventory by water service area, and (2) assessment of unit water uses associated with each new land use. There are 13 categories of possible land use with further disaggregation of residential use into 5 density classes. The model uses a density-consumption relationship for residential water-use projections and water use per employee in the case of commercial consumption. Agricultural use is projected on the basis of water use per acre for individual crops.

The article does not contain any of the functional forms or coefficients of the proposed model. These data were reported to be included in "Master Plan: Expansion of In-County Water Distribution System" prepared by the District in the December of 1975. The approach proposed by the author may prove very useful for preparation spatially disaggregated water-use forecasts.

243
Rondon, Joanne. 1980. Landscaping for Water Conservation in a Semiarid Environment. Handbook prepared for the City of Aurora, Colorado.

This publication is a water conservation handbook that provides the residents of semiarid regions with factual information on how to create an aesthetically pleasing low water use landscape. The handbook was designed for use by the residential homeowner. A wide range of information covering topics from water-conserving plant species to complete landscape design is presented. The handbook is well written and documented and can serve as a design aid and reference for the professional as well as the homeowner.

The theme of the handbook was based on the following 2 premises:

1. Landscapes are part of the overall land-use function and should be planned in relation to their environment;

2. Thoughtful landscapes can be designed that both save water and add value to the home. The book is separated into 5 sections: (a) landscape planning, (b) alternative grasses, (c) plants, (d) soils, and (e) watering.

This informative publication may be used for preparing educational campaigns aimed at reducing outdoor water use, since it identifies various potential measures which decrease water consumption for this purpose.

244
Russell, Clifford S. 1979. Water Deficit Planning. In Proceedings, Southeast Regional Conference on Water Conservation and Alternative Water Supplies, pp. 209-19. Georgia: Georgia Institute of Technology.

The author's purpose was to set out a planning framework for drought contingency programs with discussion of data requirements and limitations of such procedure.

Three broad decisions that constitute water deficit planning were as follows:

1. deciding on levels of expected annual deficits (hence expected annual losses) in the long run, by balancing the costs of alternative system investment paths against the implied expected damages from drought. . . ;

2. deciding when in the course of a particular period of rainfall shortage to introduce water-use restrictions (or other water-conserving measures) and thus to create a water shortage for consumers; a symetric decision must of course be made about removing any measure once imposed;

3. deciding on the actual measures which will be taken to reduce water use below normal demand by various amounts.

Discussing the data needed to back up these decisions, the author found that the most serious information gap resulted from (1) limited possibility of weather prediction over a long enough period of time to provide some basis for restriction decisions, (2) our limited ability to predict the responses of water use to price in the long- and short-run and thus future water demands, and (3) data inadequacies for estimating damages from water-use restrictions.

This paper constitutes an excellent treatment of the subject of drought contingency planning with its all implications for long-run water conservation.

245

Russell, C. S., Arey, D. G., and R. W. Kates. 1970. Drought and Water Supply. Baltimore: Johns Hopkins University Press.

The book presents, in part, a description of the activities of 39 communities which suffered shortages in Massachusetts during the 1966 drought. By far the most common activity was to place restrictions on water use and appeals for conservation. Thirty-four of the 39 communities restricted lawn sprinkling; of these 34, 10 banned all outside use. Thirteen of the 39 communities placed mandatory restrictions on industries (primarily recirculation) and 9 other "requested" or recommended recirculation. Nineteen communities also placed some restrictions on some public sector uses. Also reported was a study by Hudson and Roberts which indicated that 64 of 75 communities in Illinois that suffered shortages in 1953-55 placed restrictions on water use. Other methods of curtailing water use for short periods of time were not widely used in Massachusetts in 1966. Only 3 communities increased metering activities or increased leak-detection programs. No communities increased price in response to the drought. It was noted that if the shortage were 10% or less, restrictions on industrial use were not likely to be imposed. No problems with enforcement were evident.

This book contains one of the best treatments of the problem of optimization in providing adequate urban water supplies with emphasis on drought performance of various supply systems.

246
Sabadell, J. E. 1979. Conservation Between and Beyond Droughts. In Proceedings, Conference on Water Conservation Needs and Implementation Strategies, pp. 196-200. New Hampshire: Franklin Pierce College.

In this paper, the author summarized the persistence of water conservation effects in various sectors after the California Drought 1976-77.

The highest reductions in water use were achieved in the urban residential sector, and although consumers are returning to pre-drought consumption behavior, the residential water consumption is returning to normal levels more slowly than consumption in commercial, industrial, and agricultural activities. Based on his analysis, the author drew the following conclusions:

1. The inevitability of droughts should be recognized and should be an integral part of planning;

2. The manipulation of nature conditions is limited by ecological impacts, and by economic, social, and political factors;

3. Many systems are operating at their carrying capacity and have no resilience; and

4. There is too little concern about future droughts once a crisis period has passed.

The author's findings are relevant to the preparation of drought contingency plans.

247
Schaake, John C. Jr., and David C. Major. 1972. Model for Estimating Regional Water Needs. Water Resources Research 8:755-59.

This article describes (in general terms) a Fortran IV computer program used for estimating future demands or requirements for water in the 50 sub-basins of the North Atlantic Region (NAR) of the United States. The water-flow requirements (water demands) were disintegrated by geographic area, economic sector, and water quality type. There were also 9 categories of water use, including totals and some intentionally overlapping classes. The model utilizes projections of regional product, population, personal income, and water withdrawal coefficients within each region, and it produced estimates, by bench mark years, of water demands disaggregated by the above categories.

One of the 6 subroutines of the program generated estimates of future municipal and industrial water demands based on population served and per capita income for each sub-basin. It used a regression equation derived from a time-series analysis of the data for Connecticut. Explanatory variables were population served and per capita income (the measures of these variables were not specified). Another subroutine estimated future total gross water use by economic sector through multiplying the dollar gross output estimates by the appropriate water-

use coefficients. The dollar output was derived from an input-output table for the NAR.

A detailed description of the model and data requirements can be found in Appendix T of the United States Army Corps of Engineers North Atlantic Region Study Report.

248

Schaefer, Richard K. 1979. Economics and Water Conservation. Water and Sewage Works 126, no. 6:82, 84, 86; and no. 8:28-30.

This two-part overview article summarizes various economic incentives for water conservation. The author presented in tabular form (1) costs and relative savings of several water-conserving devices, (2) potential water savings with $10 worth of conservation devices, and (3) potential community savings from water conservation. Data and analysis of water-use patterns, physical and social alternatives for causing water-use changes, and specific ways in which elasticity and rate structure can influence water usage were considered.

In addition to its value as a comprehensive summary of water conservation issues, the article also contains information valuable for determining applicability of conservation measures.

249

Schnizinger, Roland, and Henry Fagin. 1979. Emergencies in Water Delivery. California Water Resources Center contribution no. 117. Davis: University of California.

The purpose of this study was to evaluate the need for emergency preparedness, implementation methods, and disaster management procedures for water supply systems. The analysis involved a review of water needs in residential, institutional, industrial, and agricultural use sectors, and an examination of the nature of disaster with particular attention to public response and vulnerability of water systems.

The authors performed vulnerability analysis and evaluated emergency water allocation and system restoration policies for general models as well as for a particular geographical area in the San Diego region. The emergency operations which were investigated include: (1) recognition of an emergency; (2) communication and coordination; (3) allocation mechanisms; (4) the effects of rate structures; (5) restoration policies; and (6) mutual assistance. The site specific nature of emergencies is illustrated by selected case studies of emergency situations including earthquakes, the Trenton Water Crisis of 1975, and three recent droughts in the United States and England.

This publication is a valuable reference for the preparation of contingency plans for individual water systems in the case of disrupted supply. Also, many topics discussed by the authors are relevant to determining drought performance of water supply/conservation plans.

250
Schufle, J. A. 1968. How Can We Live with a Permanent Water Shortage. Water Resources Bulletin 4:46-49.

The purpose of the paper was to question the assumption that the arid Southwest should use its limited water resources to expand agriculture and industry. The author decried plans for the importation of vast amounts of water to the Southwest in pursuit of agricultural and industrial development. He suggested that such growth may be untenable in such an arid environment and may, therefore, trigger chain reactions of undesirable results--not the least of which would be destruction of the beauty of the area. The author's opinion was that water used for recreational purposes might be economically more beneficial to the area than water used for either agriculture or industry.

The strength of the paper lies in the fact that it crystallizes and questions the assumption that development is synonymous with social well-being. However, the somewhat simplistic treatment of the subject detracts from the effectiveness of the argument.

251
Sewell, W. R. Derrick, and Leonard Bouche. 1974. Peak Load Pricing and Urban Water Management: Victoria, B. C., A Case Study. Natural Resources Journal 14:384-400.

This article presents a brief discussion of the theory of marginal cost pricing which is next applied to peak-load pricing in municipal water supply. The authors illustrated these pricing rules based on a simulation program developed for the Great Victoria Water District, Victoria, B. C. Prior to this, they develop separate demand functions for average annual, peak (June-August), off-peak, and mid-peak (May and September) water uses. Prices, income, average summer temperature, and average summer rainfall were used as independent variables. Mid-peak and peak prices for water were obtained by allocating the capacity costs between mid-peak and a peak period according to their relative contribution to the total period (30% for mid-peak and 70% for peak demand).

The demand model was defined quantitatively on time-series data for the years 1954-70. The results showed that the demand for water for residential purposes was moderately inelastic (elasticities from -.318 to -.568) when considered on an overall annual basis. The simulation analysis showed that the application of seasonal prices over the period 1967-70 would stimulate a reduction in peak demands ranging from -7.3 to -5.4 percent, and in an 18% increase in off-peak demand.

The article also contains a summary review of 12 urban water-demand studies carried out before 1974. The authors' findings may be very useful for determining the effectiveness of conservation-oriented pricing schedules designed to reduce peak-load water use.

252
Sewell, W. R. D., and B. T. Bower et al. 1968. Forecasting the Demand for Water. Ottawa, Canada: Policy and Planning Branch, Dept. of Energy, Mines and Resources.

This volume presents a series of discussions on methodologies for forecasting water demands. Authors of the discussions included C. W. Howe, R. W. Judy, G. M. Brown, Jr., R. E. Capel, D. W. Ross, P. H. Pearse, W. M. Baker, A. C. R. Albany, in addition to B. T. Bower and W. R. D. Sewell. The water demands treated are municipal, industrial, agricultural, recreational, and "in-stream" or flow-demands. In each case, a general discussion of the water use and problems of forecasting that water use was presented. A general description of one or more potential methodologies was then outlined. The general conclusions of most papers were that (1) current methods of forecasting water demand are too simplistic and (2) while more complex or more sophisticated methodologies will improve accuracy, there will still be considerable error especially for long-term forecasts.

Since planning for water conservation requires disaggregated water forecasts depending on the coverage of each water conservation measure being considered, the discussion of these methodologies may be very helpful in selecting those which are the most appropriate.

253
Sharpe, William E. 1976. Water Conservation with Water Saving Devices. Paper presented, New Jersey Conference on Water Conservation, Rutgers University, New Brunswick.

This article is a state-of-the-art summary of the existing water conservation devices, their applications, and their success rate. It discusses waste-flow reductions, energy consumption reduction, and effects on sewage treatment and collection. After outlining the available technologies, the author proceeded to outline the steps toward implementation of an effective water conservation program by using a variety of examples both hypothetical and existing.

The article is comprehensive, concise, and an excellent overview of water conservation alternatives and their applications. It may be used in determining applicability, technical feasibility, implementation conditions, and effectiveness of the conservation devices considered by the authors.

254
Sharpe, William E. 1978a. Domestic Water Conservation Research Plan. Report prepared for the Office of Water Research and Technology.

The major factors contributing to the recent emphasis on water conservation were first outlined, followed by a state-of-the-art assessment of current water conservation technology along with recommended research needs for each area. After outlining a 4-year research plan, the author concluded that potential savings would be impressive but that the "vitally needed conservation program may be doomed to failure" because

of a general lack of basic research.

This is one of the most comprehensive surveys of the current status of water conservation technology available, and as such, the report is of primary usefulness for determining applicability and technical feasibility of various conservation practices in the domestic water-use sector.

255
Sharpe, William E. 1978b. Municipal Water Conservation Alternatives. Water Resources Bulletin 14:1080-87.

Municipal water conservation alternatives (measures) were categorized as public education, pricing and metering, and water conservation devices. The author commented on the rationale for water conservation programs by municipal water utilities and noted that the desires to reduce sewage flows, or to reduce energy consumption, have played a major role in the programs examined.

Public education was considered helpful and necessary to insure speedy and effective adoption of water-conserving fixtures and appliances. The use of pricing policies alone was not considered an effective strategy in achieving national water conservation goals. Water conservation on utility revenues was discussed, and the use of marginal cost pricing policies was advocated as a means of avoiding revenue erosion caused by water conservation. Constraints on the adoption of water conservation methods were stated to be the lack of suitable, unbiased data on the performance of water-conserving fixtures, and on the effectiveness of various devices or combinations of devices in reducing water demand. Availability of devices through customer plumbing fixture outlets was also noted as a constraint, as was concern over rate increases resulting from reductions in water use.

The author does not present empirical data, and the conclusions are based on review of the literature and the author's own experience in the field.

256
Sharpe, William E. 1978c. Residential Water Conservation with Water Conservation Devices. In the Water Conservation Challenge, pp. 32-37. Bloomington, MN: The Upper Mississippi River Basin Commission.

The author summarized 3 basic topics pertaining to water conservation. In addressing methods for meeting the municipal water conservation challenge, he discussed pricing, metering, and water conservation devices. Water conservation case histories were then described including those of the WSSC and Gettysburg and Springettsbury, Pennsylvania. The article closed with a discussion of the potential impacts of water conservation on consumers.

The issues discussed by the author are relevant to several steps in planning water conservation, mostly to the determination of disadvantageous effects of water conservation measures.

257
Sharpe, William E. 1978d. Water and Energy Conservation with Bathing Shower Flow Controls. Journal of the American Water Works Association 70:93-97.

This article documents a controlled experiment in 2 dormitories at Pennsylvania State University. Reduction in shower water use in comparison to control periods and control dormitories ranged from 37.5 to 62%, with the low flow shower heads. Very low flow rates (2.0-2.5 gpm) were judged satisfactory on the basis of lack of complaints. Other studies have shown that shower time does not increase significantly with lowered flow rates. Flow control devices at the University proved very economical with a complete payback period of 28 days when the costs of hot water were used. The overall reduction in water use from shower head flow controls depends, of course, on the percentage of water use for showering. Estimates from other studies ranged from 7.2 to 30%. Caution on retrofitting was recommended because of possible unique characteristics.

The percentage of estimates of percent reduction in water use may be helpful for estimating the effectiveness of the investigated device.

258
Sharpe, William E. 1978e. Why Consider Water Conservation? Journal of the American Water Works Association 70:475-79.

The article summarizes recent State and Federal legislation, national plumbing codes, local plumbing codes and ordinances, agency regulations, and appliance manufacturers promotions as they pertain to the fact that water managers will most probably be forced to consider water conservation in their future plans. Emphasis was placed on the interrelationship between water usage and sewage both in terms of quantity and pricing. Benefits of a conservation campaign may prolong hydraulic life of sewage plants, as well as water storage and treatment facilities. Conservation would also aid in the deferrment of capital expenditures. Inflation creates a more serious problem in the pricing of water than price charges due to conservation measures. Customers utilizing conservation measures would save money in the long run however.

This excellent article is a good summary of legislation and its impact on water conservation. The article points out the benefits of conservation, tempered by current economic trends.

259
Sharpe, W. E., and P. W. Fletcher, eds. 1975. Proceedings, Conference on Water Conservation and Sewage Flow Reduction with Water-Saving Devices. Institute for Research on Land and Water Resources information report no. 74. Pennsylvania State University.

This report contains the following 20 papers:

Grear, M. J. Residential Water Conservation: The Suburban Maryland Experience, 1970-75.--This paper describes the experience of the Washington Suburban Sanitary Commission's water conservation program and outlines research needs. It was noted that little is currently known of the effects of public education programs and utility-sponsored distribution of water-saving devices. It was estimated that a reduction in water use of 6 to 13 mgd was obtained by the utility at a cost of $500,000 for its conservation program.

Sharpe, W. E. Residential and Commercial Water Conservation and Wasteflow Reduction with Water-Saving Devices.--This paper presents a brief literature review along with recommendations for research. It was noted that the impact of water-saving devices is not well known. "Conflicting results have been reported even in the small amount of existing data."

Coelen, S. P. Water Price-Quantity Relationships and their Effect on Water Conservation.--This article notes that although meters can be expected to reduce water use, the cost of metering may outweigh the benefits gained. The benefits of metering would depend on the pricing of the utility and upon the rate of growth of the community.

Chan, M. L., and S. Heare. The Cost-Effectiveness of Pricing Schemes and Water-Saving Devices.--This paper presents the results of 2 computer models. The first (PAM-Policy Analysis Model) was designed to evaluate water-pricing policies. The second (EEAM-Engineering Economy Analysis Model) was designed to estimate the cost-effectiveness of 8 water-saving devices. There were 2 major problems with the PAM computer model: (1) Sewer contributions were to be a constant 120 gpcd; and (2) Under the increasing and decreasing block rate schedules, all consumers are assumed to face the same marginal price. These assumptions seriously clouded the results of the model. Using the EEAM it was estimated that immediate replacement of existing devices by flow-limiting shower heads, dual cycle toilets, shallow-trap toilets, or toilet inserts is cost-effective for individual households. Faucet aerators were cost-effective for individual households. Faucet aerators were cost-effective only from a total water utility/household standpoint under current pricing policies. Thermostatic mixing valves, vacuum flush toilets, and recycling for flushing are not currently cost-effective (i.e. have a net positive economic cost).

Bishop, W. J. Field Experiences in Water-Saving Programs of the Washington Suburban Sanitary Commission (WSSC).--This paper outlines the results of specific tests of water-saving devices conducted by the WSSC. It was noted that large differences can exist between the predicted physical performance of water-saving devices and actual

performance. For some of the WSSC test areas water use actually increased after the installation of water-saving devices by the utility (although these may not have been significant increases). The size of water-use reductions depended heavily on whether the devices were maintained by the utility or by landlords and households. Specific recommendations for implementing and evaluating water-saving programs were made.

Cole, C. A. Impact of Home Water Saving Devices on Collection Systems and Waste Treatment.--This article finds that the transporting capacity of sewers and house connections would not be substantially changed by reducing the amount of water used per flush from 5.25 to 2.0 gallons. It was also noted that this lower quantity of water per flush would increase sewage treatment plant efficiency of removal of BOD and suspended solids and/or increase the economic life of the treatment plant.

Bennet, E. R. Impact of Flow Reduction on On-Lot Sewage Systems.--This paper estimates the benefits of flow-reducing devices on operation parameters and costs of on-lot sewage disposal systems. Water-use patterns in 6 homes were used as the basis for this study. Gross sewage disposal cost savings from a 40% water-use reduction were estimated. The values obtained were $25/yr., $80/yr., and $170/yr., for septic tanks with leaching fields, septic tanks with imported fill and leaching field, and septic tanks with evapo-transpiration beds, respectively. Aerobic systems would be expected to cost less, but operational problems associated with surge flows would be less severe.

Baker, L. K., H. E. Bailey, and R. A. Sierka. Household Water Conservation Effects on Water Energy and Wastewater Management.--This paper analyzes the impacts of very low water-using appliances (0.5 gal/flush toilet, 0.5 gal/min shower and a front loading clothes washer). These devices were estimated to reduce water 65% and lower non-space heating and cooling requirement 30%. Conversion from conventional hardware and secondary treatment of sewage to these devices and an AWT system (ultrafiltration and reverse osmosis) was estimated to result in a 33% reduction in total system costs. No field tests were conducted.

Muller, J. G. The Potential for Energy Saving through Reduction in Hot Water Consumption.--This paper concludes that the oil equivalent of roughly 0.5 million barrels per day (BPD) would be cut from an estimated 1.1 million BPD used currently in residential water heating. This could be accomplished through a program of replacement of water heaters, cold water laundering, flow restriction devices and other measures. Flow restriction accounts for about one fifth of the energy saving. It was noted that little is known about the current use of residential hot water.

Moses, H. L. Research on Water Saving Devices at Virginia Polytechnic and State University.--This paper discusses flow characteristics of water-saving shower heads and faucets. Noise, flow control, compatibility with available plumbing fixtures, cavitation and

instability problems were investigated. It was concluded that currently available devices are "entirely satisfactory."

McLaughlin, E. R. "A Recycle System for Conservation of Water in Residences.--This paper presents the results of a pilot project which installed a recycle system ("gray water" used for toilet flushing) in one residence. The system worked well and saved 23% of the water previously used. At current water and sewer rates (total cost of $0.86/1000 gal), the system cannot be justified economically.

Smith, Khervin. The Testing of a Clivus-Multrum (Sewage) System in a Limited Use Campground.--A test of the Clivus-Multrum Sewage System at Hawk Mountain Sanctuary indicated that the system did not function as stated in the manufacturer's literature. Odors and condensation were problems. Potential problems with other no-water systems were discussed.

Hoxie, D. C., and W. C. Toppan. Maine's Experiences with Reduced-Water Waste Disposal Systems.--This paper presents a general discussion of household waste waters and potential systems for separating toilet waste from other household wastes. Problems with low permeability rates for soils were discussed.

Konen, T. P. An Investigation of the Performance and the Effects of Reduced Volume Water Closets on Sanitary Drainage. Sewers and Sewage Treatment Plants.-- Engineering tests were conducted on 2 syphon jet and 1 washdown toilets with flush volumes of 16, 11, and 6 liters, respectively. It was concluded that the washdown performed more poorly and may have acceptance problems. Drainage was not a problem except in horizontal lines which are not good practice in any case. A very brief discussion concluded that there will be no effect on sewage plants.

Montgomery, C. E. Water Savings with the Save-It Water Saver.--This paper describes a toilet tank insert that reduces flush volume to 2 - 2½ gal.

Sittler, E. L. Future Research in Water Savings.--This paper describes several water-saving devices, with special emphasis on a new thermostatic mixing system at the hot water tank.

Schaefer, R. K. Socioeconomic Considerations for Domestic Water Conservation.--This paper presents a general discussion on the problems of providing incentives for consumers to install water conservation devices.

Wertz, R. J. A Plumbingware Manufacturer's Viewpoint on Water Saving Devices.--The design history and characteristics of various water-saving devices were presented. Problems with retrofitting toilets were discussed.

DeArment, W. E. Impact of Conservation on Water Industry.--Water conservation programs that could be instituted by water utilities were discussed. These included metering leak detection, elimination of declining block rates, sprinkling bans, reducing back-wash water in treatment plants, and cross connection control plans.

260

Sharpe, W. E., and P. W. Fletcher. 1977. The Impact of Water-Saving Device Installation Programs on Resource Conservation. Institute for Research on Land and Water Resources research publication no. 98.

The authors evaluated the effectiveness of water conservation programs carried out by the Washington Suburban Sanitary Commission which involved the installation of water-saving devices and changes in the plumbing code. In addition, a comparison was made of costs for on-lot sewage disposal facilities with and without minimum water-use fixtures.

The results of the effectiveness tests for bathing shower flow controls in collect dormitories showed possible savings in water use up to 60% with commercially available devices. Other findings presented in the report are those relevant to applicability, technical feasibility, and advantageous and disadvantageous effects of water-saving devices.

261

Sheer, Daniel. 1980. Analyzing the Risk of Drought: the Occoquan Experience. Journal of American Water Works Association 72:246-53.

The author's purpose was to develop practical risk analysis techniques to determine the possibility of extreme water shortages and to evaluate the policies necessary for reducing those risks to acceptable levels. The techniques were developed based on the case study of the Fairfax County Water Authority which had to cope with expected water shortage during the 1977 Drought.

Two independent techniques were developed: (1) the USGS risk analysis technique which can assess the likelihood of storage deficiencies based on historical streamflow records; and (2) a more precise technique, developed by the National Weather Service, which incorporates snowmelt, long range weather forecasts, and soil moisture conditions.

It is the author's conclusion that both techniques are useful in predicting streamflow and thus the expected availability of water supply during persisting dry weather conditions. The techniques described in this article are of primary importance for developing drought contingency plans.

262

Shelton, Theodore B., and Joseph J. Soporowski, eds. 1976. Conference Proceedings, Water Conservation with Water-Saving Devices. Extension bulletin 421. New Jersey: Rutgers University.

This publication contains the proceedings materials of the New Jersey Conference on Water Conservation with Water-Saving Devices which was held on November 30, 1976. Six papers included in this volume discuss need and methods for water conservation in New Jersey by the use of water-saving devices and their impacts on the water supply and drainage systems both within buildings as well as in external installations. This information is relevant to determination of disadvantageous effects of such devices.

263

Shuval, Hiller I., ed. 1977. Water Renovation and Reuse. New York: Academic Press.

This book contains 15 papers on the technical aspects of water reuse and on water reuse practices around the world. Included are (1) "Advanced Wastewater Treatment Technology in Water Reuse," by F. M. Middleton; (2) "Health Considerations in Water Renovation and Reuse," by H. I. Shuval; (3) "The Use of Wastewater for Agricultural Irrigation," by Josef Noy and Akiva Feineussen; (4) "Water Reuse in Industry," by L. K. Cecil; (5) "Reuse of Water for Municipal Purposes," by G. J. Stander; (6) "Pressure-Driven Membrane Processes and Wastewater Renovation," by George Belfrot; (7) "Alternative Water Reuse Systems: A Cost-Effectiveness Approach," by Lucien Duckstein and Chester C. Kiscel. Also included are papers on water reuse practices in California, the Federal Republic of Germany, India, Israel, Japan, South Africa, The United Kingdom, and at the Environmental Protection Agency's pilot plant in Washington, D. C.

The book constitutes a useful reference to those steps in water conservation planning which involve evaluation of water reuse as a conservation measure.

264

Sims, J. H., and Baumann, D. D. 1978. Psychological Acceptance of Renovated Wastewater: Professional and Public. In Planning for Water Reuse, ed. D. D. Baumann and D. Dworkin, pp. 75-90. Chicago: Maaroufa Press.

The purpose of the study was to demonstrate unconscious psychological determinism in career choice, in professional attitudes toward renovated wastewater, and in public response to renovated wastewater. Three studies were summarized, 2 of which used the Thematic Apperception Test on professional groups (public health officials, water engineers, business executives, career civil service executives); the third used in the Sentence Completion Test on a lay sample.

Among the results were:

1. Careers (that is, professions) and persons carry out a mutual selection process at entrance to and during the professional socialization (training) process which results in producing a professional who not only is defined by particular professional knowledge and skills but also by particular attitudes, ways of seeing, biases, etc. of which he is largely unaware.

2. Hence the attitudes of water engineers and public health officials toward the use of renovated wastewater reflect not only their professional considerations but their "professional" prejudices. These biases are detailed.

3. Public attitudes toward renovated wastewater use are found to be related to education and knowledge; possible psychological determinants investigated were found to be unrelated. The authors warn that the instruments are suspect and that the research with the public is hypothetical in nature. The authors argue persuasively that psychological factors of which we are not aware influence our attitudes toward water and water use.

This is one of the rare studies that has data pertaining to public acceptability of renovated water, even though the authors themselves acknowledge that their data are weak.

265

Smith, D. W. 1979. Water Reclamation and Reuse. Journal of Water Pollution Control Federation 51:1250-76.

This literature review focused on technical and, to some extent, economical issues of water reclamation. Containing 294 references mostly from the years 1977 and 1978, the review was divided into 8 sections which were presented under the following headings: general, water resources planning, agriculture and irrigation, groundwater recharge, industrial reuse, domestic reuse, health considerations, and technology developments. Each publication was characterized by means of 2 or 3 sentences. The author refers to only one study on public acceptance of the use of renovated water, conducted by Olson and Pratte, published in Great Britain in 1978; and one report of the California State Water Resources Control Board on policy and action plan for water reclamation published in 1978.

There are 54 references listed under the heading "Domestic Reuse" which deal with the latest technological achievements as well as with economic and operational issues. This publication may be useful in identifying information needed for determining technical feasibility, social acceptability, and effectiveness of water reuse.

266

Smith, Stephen W., and Wynn R. Walber. 1975. Annotated Bibliography on Trickle Irrigation. Colorado Water Resources Research Institute information series no. 16. Fort Collins: Colorado.

The publication provides the user with a set of cross-indexed references on trickle irrigation that include design methods, hydraulics, crop response, salinity, water filtration, fertilization, irrigation scheduling, emitter design and clogging and wetting patterns. Although the bibliography emphasized primarily agricultural applications, much of the information is directly applicable to urban landscape irrigation. Each of the references is annotated, and a key word index is included.

267

Smith, Vernon L. 1977. Water Deeds: A Proposed Solution to the Water Valuation Problem. Arizona Review 26:7-10.

This article considers the implementation of marketable water rights as a water conservation measure for Tuscon, Arizona. The present price charged by the city water company covers only the cost of drilling wells, pumping, distributing and managing the water system and does not reflect resource scarcity, i.e. the price of the water itself. The proposed deed system is designed to form in markets a price for unrecovered groundwater in the Tuscon Basin.

The author proposed giving each property owner in the area 2 supplementary water deeds in addition to his present real property deed. This property right system would start with a base reference period or year during which each individual i used some amount of water x_i. For example, in 1975 the total of all the x_i's was 224.6 thousand acre feet. Based on the estimate of a naturally stored stock of some 30-million acre feet of recoverable water in the aquifer under the Tuscon Basin, and on the annual flow of about 74.6 thousand acre feet of net new water from a natural collection system, the two deeds would be as follows:

First deed,

$$r_i = 74.6 \ (x_i/224.6)$$

conveys to i the right to draw r_i acre feet per year.

Second deed,

$$R_i = 30 * (x_i/224.6)$$

conveys to i the right to draw any proportion of R_i of water in thousand acre feet.

The author stated that this property right would be a more effective and equitable water conservation measure than voluntary programs since the latter "are inequitable in the sense that those who cooperate provide a subsidy of more available water for those who do not."

268

Snodgrass, Robert W., and Duane Hill. 1977. Achieving Urban Water Conservation: Testing Community Acceptance. Colorado Water Resources Research Institute completion report no. 81. Fort Collins: Colorado State University.

The study demonstrates the usefulness of "survey research" in delineating viable water conservation programs in forms of public acceptance. The survey technique, a Q-Sort Factor Analytical Design, is useful for determining which conservation practices are acceptable in a community.

The Q-Sort Factor Analytical Design was used to test community acceptance of various water conservation measures in Lafayette and Louisville, Colorado. Using census and questionnaire data, the authors performed a factor analysis resulting in reduction of all variables into 3 major components: (1) socio-economic information factor (education, income, age, sex, occupation); (2) community identification factor (length of residency, "attachment" to community; level of participation in the community affaris); and (3) attitudinal factor (attitudes toward state population growth rate, industrial growth, pollution, etc.). These generalized factors defined "zones" of acceptance where various conservation measures fit logically into one or another zone (not necessarily geographical zones).

For these 2 Colorado communities, legal restrictions on water use and restrictions on growth and development were the most acceptable policies. Economic and landscape irrigation techniques were the next most acceptable. The study method can be used in determining the social acceptability and implementation conditions of water conservation measures in any community.

269

Sonnen, Michael B., and Donald E. Evenson. 1977. A Model for Estimating Water Demands. Walnut Creek, Calif.: Water Resources Engineers, Inc.

This report describes an application of computer program developed by Water Resources Engineers, Inc., for predicting urban and agricultural water demands. The model was based on a number of usage, geographic, weather and economic variables. It was described in greater detail in the publication "Demand Projections Considering Conservation" (Water Resources Bulletin 15, no. 2, April 1979).

This publication contains an actual computer output of the program when applied to forecast water demand for the Kaneohe Bay (Hawaii) area. Based on population and land-use information for the base year 1976 and the projected values of these variables for the year 2000, water demands for these 2 years and for 5 intervening years (1978, 1980, 1985, and 1995) were calculated. Water demands for each month by land-use category for the years 1976 and 2000 in 3 sectors of the Kaneohe Bay were also calculated.

The authors have also performed simple sensitivity analyses of the basic demand function by differentiating it with respect to each variable and showing how to convert the results to the units of percentage change in total demand for 1% change in the value of each input variable.

270

Sonnen, Michael B., and Donald E. Evenson. 1979. Demand Projections Considering Conservation. Water Resources Bulletin 15:447-60.

This article describes a water-demand model which is disaggregated to 40 land-use categories in any of 35 census tracts in each of 10 larger areas of the Island of Oahu, Hawaii. The model was developed by Water Resources Engineers, Inc., for the United States Army Corps of Engineers, Pacific Ocean Division, in 1977.

The model calculates a total average monthly water use using the following functional form:

$$Q = [UI \times WR \times UF \times (I-CI) + 27{,}152.4(UO-G) \times A \times EA \times (1-CO)]$$

$$\times \frac{PR+OP+E(PR-OP)}{PR+OP-E(PR-OP)} (1-SL)$$

where UI = the number of units using water in a given land-use category (homes, people, 1,000s of square feet, hotel rooms, or acres); UF = the average use rate (pgd per dweeling unit); WR = seasonality factor for indoor usage (ratio of water use in each month to water use in average month), CI = anticipated average annual indoor conservation fraction in future year. In the second part of the equation describing outdoor use, the expression (UO-G) measures monthly requirement for irrigation water in inches (total requirement minus precipitation) in each month; A = the gross area in acres; EA = the fraction of irrigable acreage; and CO = the outdoor conservation percentage in future years. The third expression takes account of price effect on water use, where PR = current price of water; OP = an older price of water, in a previous year in the stimulated prediction period; and E = the elasticity of demand with respect to price. Finally, the last expression excludes the fraction of total water demanded that is supplied locally.

Although this model seems to be straightforward, it requires an unusually large amount of data, including price elasticities for each land-use category. The authors admitted the difficulty and argued that choosing the numerical conservation target to be achieved is more meaningful and yields more predictable results than price or price elasticity manipulations.

The proposed forecasting procedure and its discussion are of primary usefulness in estimating the effectiveness of water conservation measures.

271

Sterling, M. J. H., and D. J. Antcliffe. 1974. A Technique for the Prediction of Water Demand from Past Consumption Data. Journal of the Institution of Water Engineers 28:413-20.

This article presents a mathematical description of time-series data on water consumption; utilizing it to predict the average monthly consumption of water in a mixed rural and industrial water-use area. Actual consumption data, used to illustrate the methodology, consisted of total daily water consumption averaged over each month from 1963-68. The authors applied both linear regression analysis and spectral expansion by orthogonal functions as prediction methods. (The latter estimator is capable of following seasonal variation in water use.) Comparison of projected and actual total water-use patterns by month in 1968, based on the 1963-67 data, revealed a mean error of $\pm$1.2% (averaged over 12 months with a maximum of 3.3%) for one month ahead rising to approximately $\pm$1.8% for 12 months ahead.

The technique proposed by the authors may be applied to rapid estimation of total unrestricted water consumption for periods of drought when only limited amounts are delivered to the customers.

272

Stone, Brian G. 1978. Suppression of Water Use by Physical Methods. Journal of American Water Works Association 70:483-86.

This article presents various physical techniques for long-term water conservation and peak-demand suppression (either maximum-day or the peak-hour demand). The author summarized in tabular form the literature estimates of water-use reduction for several water-saving devices, which generally can reduce long-term residential water use by 6-12%.

Among phsycial methods to suppress maximum-day peak demand, the following were found as effective: (1) meters, (2) pressure regulation, (3) flow restrictions, (4) service diameters, (5) house meters and timers, (6) moisture sensors, and (7) landscape design. The potential amount of suppression for these methods and costs of administering them were also identified from literature sources. The author suggested greater concentration on peak-demand suppression methods since their potential for savings in capital investment seems even greater than that of conservation practices.

The article is a useful reference for identification of applicable water conservation measures, as well as their effectiveness.

273

Sweazy, R. M. 1979. The Federal Overview--Bureau of Water Conservation. In Proceedings, Conference on Water Conservation Needs and Implementing Strategies, pp. 245-500. New Hampshire: Franklin Pierce College.

The author considered the need for establishing a new or modified Federal government bureau to prepare and enforce detailed universally

applicable water conservation regulations.

The author's opinion was that although water conservation when properly implemented is highly desirable, the new bureau is not desirable. It is sufficient for a defined Federal policy to include only consideration of supply and demand both subjected to cost-benefit analysis. The existing Federal agencies such as the Corps of Engineers, the Bureau of Reclamation, and the Soil Conservation Service are adequate to handle future water policy objectives, while states should set their own water policy with minimum Federal encroachment.

Also, any Federal Government water conservation policy should recognize State priority in water management and only aid states by (1) providing incentives to sound conservation and eliminating disincentives, especially for Federally financed project; and (2) providing an information and assistance clearinghouse to promote water conservation using the Water Resource Council for that purpose.

This paper is relevant for determining implementation conditions of water conservation measures.

274

Tate, Donald M. 1977. Water Use and Demand Forecasting in Canada: A Review. Ottawa, Canada: Department of Fisheries and the Environment, Inland Water Directorate.

This report reviews the state-of-the-art of water-demand forecasting and water-use studies in Canada. The author provided an outline of the concepts in forecasting which included (1) the alternative futures framework, (2) the spatial disaggregation of forecasts, and (3) the usefulness of the system approach to the subject. Some general points concerning these procedures, such as the need for practicality in formulating new methods, the rœle of water pricing, economic interrelationships, and the role of technological change, were also considered.

The review of several water management projects in Canada showed that the most frequent approach was based on per capita water-use coefficients (requirements appraoch). The use of input-output methods or the alternative futures approach was attempted; however, these methods were not widely accepted. The author concluded that the newest approach being taken to water-demand forecasting in Canada was based on systems analysis. It analyzed basic data on population and industrial production under alternative growth assumptions and disaggregated these data to river basins and further to local regions. Next, these data were used as inputs to detailed sector-by-sector forecasts at the local level including municipal, industrial (manufacturing, mining, agriculture, energy generation, and navigation), and recreational water demands.

The last part of the paper outlined models proposed for general use in Canada. Municipal water demand for all Canadian municipalities over 1,000 persons was to be analyzed by separate consideration of residential, commercial, industrial, and institutional sectors. Municipalities under

1,000 persons were to be dealt with using coefficients of total water pumped per capita. Inputs to the individual community models would be derived from the population/agriculture component of the national/regional model and other data required only for the municipal mode.

The extensive analysis of water-demand forecasting in this report was dictated by the fact that it was prepared as part of a multicountry review of this subject by the International Institute for Applied Systems Analysis.

This publication may serve as an informative reference to water-demand forecasting methodology.

275

Taylor, R. S. 1979. Effects of Water Conservation Measures on Water Demands. In Proceedings, Conference on Water Conservation Needs and Implementing Strategies, pp. 202-30. New Hampshire: Franklin Pierce College.

This paper briefly summarizes the evaluation of the impacts of different levels of water shortages on different classes of users and the ability of conservation to minimize these shortages. The evaluation was conducted for the Metropolitan Washington Area (MWA) by the Baltimore District, Corps of Engineers.

The evaluation involved 8 subregional areas and several alternative conservation "scenarios" with future water demands to demonstrate the relative effectiveness of conservation techniques. The projections of future water demand utilized current water-use levels, projected population, employment, and housing and were disaggregated into 5 major user categories from 1980 to 2030 in 10-year increments.

The study also analyzed short-term responses to an expected water shortage as well as economic losses and social impacts related to the event. All these are relevant in determining advantageous and disadvantageous effects of water conservation as well as for supply reliability considerations of water supply/conservation plans.

276

Thompson, A. G., V. E. Smith, and W. R. Colvin. 1976. Development of Commercial Institutional Parameter Units for the Main II System of Water Demand Forecasting. Water Resources Research Institute report no. PB 263 493. Laramie: University of Wyoming.

The primary objective of this report was to provide a method of estimating commercial/institutional parameters for the MAIN II (Municipal And Industrial Needs) water forecasting computer model where data are not available. This modification was based on data collected from 20 cities west of the Mississippi River ranging in size from 2,500 to 300,000 in population. Data on commercial/institutional water use included 28 categories and their associated parameter units.

The authors incorporated a subroutine in the MAIN II model which estimates missing data on commercial/institutional values using linear relationships between population and category parameter units. The modified program was applied to 3 test cities (Billings, Mont.; Twin Falls, Idaho; and Kimball, Nebr.), and it produced estimates of 1975 water use within 10% of the actual usage.

The method developed in this study is very useful for predicting disaggregated unrestricted water use with the MAIN II forecasting system.

277

Thompson, Russell G., and H. Peyton Young. 1973. Forecasting Water Use for Policy Making: A Review. Water Resources Research 9:792-99.

This article presents a linear method of approximating derived demand functions for water in agricultural and industrial production. The authors reviewed the basis for estimating withdrawal, consumptive, and disposal demand functions which relate water use to its price and to prices of all other inputs. Demand functions were derived from other studies which indicated that, for example, withdrawals by electric generating stations for once-through cooling would be lowered 90% if a price of 0.5¢/1000 gallons were imposed. This use accounts for nearly 25% of all freshwater withdrawals in the U.S.

Two important applications of these demand functions are: (1) alternative projections of water use, and (2) a basis for evaluating proposed investments in water resource development which should be justified by the economical value of the water provided.

278

Turnovsky, Stephen J. 1969. The Demand for Water: Some Empirical Evidence on Consumers Response to a Commodity Uncertain in Supply. Water Resources Research 5:350-61.

This paper estimates some demand functions for domestic and industrial water based on cross-sectional data from 19 Massachusetts towns for the years 1962 and 1965. These years mark respectively the beginning and the end of the 1960s New England drought. The author attempted to take account of the uncertainty of water supply which was present during the drought period.

It was found that per capita domestic consumption (actual and planned) was significantly dependent on price (elasticities from -0.049 to -0.406), average housing space in a town, and supply uncertainty as measured by supply variance. For industrial demand only price and "uncertainty" were significant (price elasticities: -0.473 to 0.839).

The interesting feature of this article is the original measure of supply uncertainty and its associations with water consumption. The author's findings may be helpful in the preliminary evaluation of aggregate reductions in water use.

279

Turvey, Ralph. 1976. Analyzing the Marginal Cost of Water Supply. Land Economics 52:158-68.

The author's purpose was to explain the concept and also to expose the analysis of the marginal cost of supplying water.

The approach presented here defined the marginal cost as a dynamic, time-related concept which measures the effect of slowing down or speeding up the expansion on the total costs of the system expansion. This principle was illustrated on the schemes to increase total yield and to enlarge the distribution system of Bristol Waterworks Company in London through the description of future cost consequences of additional water consumption and of additional connections.

This article is a relevant reference in identifying marginal supply costs which are essential for a proper examination of water rates and marginal pricing policy for long-term water conservation.

280

U. S. Army Corps of Engineers. 1976. Water Conservation Measures for the New York Metropolitan Area. Northeast U. S. Water Supply Study: Special Studies Branch.

This volume presents a detailed description of an implementation program for water conservation measures for New York City and the metropolitan area (MYMA). Included were universal metering, leak detection in the distribution system, industrial recirculation, changes in the plumbing codes to require installation of shallow traps or siphone jet toilets, 3 gpm shower heads and 2.5 gpm faucets, an educational campaign and drought contingency measures. A review of the literature indicated a price elasticity of -0.15 seemed applicable to the New York City domestic water use. Table 1-1 contains a summary of the estimated yields, costs to the public treasury, critical assumptions and uncertainties of the various elements of the conservation plan.

The data presented in this study may be helpful in determining applicability, implementation conditions, and effectiveness of the investigated water conservation measures.

281

U. S. Army Corps of Engineers. 1978. Large Array of Water Conservation Strategies for Pima County, Arizona. Pima Association of Governments 208 Project: Element 6, Tasks 6350 and 6360, Conservation Strategies and Program Development.

The purpose of this study was to identify and discuss a range of possible methods to reduce the amount of water lost from the water systems in Pima County, Arizona. In order to trace all water loss or consumption points, the several systems of the region were described through the identification of each of the components from supply, through use, to disposal.

This report contains useful information for determination of applicable water conservation measures.

282

U. S. Environmental Protection Agency. 1978. Proceedings, National Conference on Water Conservation and Municipal Wastewater Flow Reduction, EPA/430/9-79-015. Washington, D.C.

This document presented at the conference contains 30 proceedings papers which are divided into 6 major topic areas: (1) federal legislative background, (2) regulation of the water resource, (3) water conservation technology, (4) education and public participation, (5) water and wastewater management issues, and (6) case studies of water resource management.

The papers which are relevant to water conservation planning have been annotated and are included in this bibliography.

283

U. S. Environmental Protection Agency. 1980. Residential Water Conservation: An Annotated Bibliography. Washington, D.C.: Office of Water Program Operations (WH-595).

This publication contains 155 short annotations of articles, booklets, and reports which are the result of a literature search done for the preparation of the Department of Housing and Urban Development book on implementing residential water conservation measures.

In addition to the annotations, the report summarizes the data obtained from the references and groups them under 9 separate topics: (1) conservation projects, (2) cost savings, (3) energy requirements, (4) energy/water savings, (5) sewerless wastewater disposal devices, (6) regional issues, (7) residential water use, (8) water rates, and (9) water-saving tips. These summaries make the bibliography especially useful for planning water conservation programs. Certain information on the effectiveness and advantageous effects of particular water conservation measures can be easily obtained from this report.

284

U. S. Environmental Protection Agency. 1981. Flow Reduction: Methods, Analysis Procedures, Examples. Office of Water Program Operations. Washington, D.C.

The purpose of this publication was to provide community leaders and planners with the overall guidance in carrying out wastewater flow-reduction analysis. This volume constitutes the first part in a 3-volume series and provides background information on flow reduction, case examples of communities which have implemented such programs, and descriptions of various flow-reduction measures along with the assessment of their cost effectiveness. A step-by-step methodology provided by this

guide involves the following sequence of major tasks in the analysis:

A. Is flow-reduction analysis required?

B. Establish without-flow-reduction condition.

C-1. Develop first-cut program.

C-2. Modify program or develop alternatives.

D. Determine costs and benefits.

E. Have all reasonable alternatives been considered?

F. Conduct public participation meeting.

G. Select flow-reduction program.

H. Incorporate into facilities plan.

Each task was organized according to the sequence of operational elements: (1) statement of purpose, (2) data and information needs, (3) "What to do?", (4) example, and (5) major observations.

Of the 2 additional volumes, the first (Part III) demonstrates the flow-reduction methodology as applied to 2 communities, and the second (Part IV) constitutes a package of flow-reduction public information material which can be adopted for direct use in a community's program.

A series of tables with exemplary calculations of water and energy savings for 6 different types of water-saving devices included in the Appendix C of this manual may be used for the determination of effectiveness and the advantageous effects for several types of water-saving devices.

285

U. S. General Accounting Office. 1977. California Drought of 1976 and 1977--Extent of Damage and Government Response.

This report reviews the effects of the 1976-77 California drought and the laws passed by the Congress and the State Legislature in response. Activities of some local irrigation districts and municipal water utilities were discussed. The report recommends the State plan be re-examined in light of the large expenditures ($4.3 billion Federal, $3.4 billion State) and the strong possibility that even these expenditures will not be sufficient to stop the need for overdrafting of groundwater. The report questions the advisability of the projected 1 million acre-feet increase in irrigation.

This publication contains relevant information for planning and management of water resources in California.

286
U. S. Water Resources Council. 1978. The Nation's Water Resources 1975-2000. Second National Water Assessment Report. Washington, D.C.: U. S. Government Printing Office.

This final report of the Second National Water Assessment provides a comprehensive information base for the water resources of the United States. The report consists of 4 separate volumes which can assist Federal, State, local, and other program managers in establishing and implementing water resources policies and programs. The contents of each volume are as follows:

Volume 1, Summary, gives an overview of the Nation's water supply, water use, and critical water problems for the near future, and summarizes significant concerns.

Volume 2, Water Quantity, Quality, and Related Land Considerations, consists of one publication of five parts: Part I, Introduction; Part II, Water Management Problem Profiles; Part III, Water Uses; Part IV, Water Supply and Water Quality Considerations; Part V, Synopses of the Water Resources Regions. The last part covers existing conditions and future requirements for each of 21 water resource regions.

Volume 3, Analytical Data, consists of 6 separate parts--a summary volume and five appendices. The summary volume describes methods and procedures used to collect, analyze, and describe the data used in the assessment. The appendices contain data for regions and subregions as follows: Appendix I, Social, Economic, and Environmental Data; Appendix II, Annual Water Supply and Use Analysis; Appendix III, Monthly Water Supply and Use Analysis; Appendix IV, Dry Conditions Water Supply and Use Analysis; and Appendix V, Streamflow Conditions.

Volume 4, Water Resources Regional Reports, consists of separately published reports for each of the 21 regions. Synopses of these reports are given in Volume 2, Part V.

The information contained in the report may be used in identifying needs and potential for water conservation in the 21 regions and 106 subregions for which aggregated data are provided.

287
U. S. Water Resources Council. 1980. State Water Conservation Planning Guide. Washington, D.C.

This guide was designed to help states develop comprehensive water conservation programs and prepare applications for water conservation planning grants. It provides information on Federal, State, regional, and local policies and activities concerned with water resources management and also describes an 8-step procedure for integration of water conservation activities into the State water resources plans. Each step of this procedure was described by a set of outputs which

should result after the step is performed:

Step 1: planning objectives, planning area boundaries, planning period, target areas;

Step 2: plan outline, scope of work, budget, planning criteria;

Step 3: revised scope, schedule of activities, work assignments, inter-agency agreements;

Step 4: existing and future water conditions, water-use laws, regulations and agencies;

Step 5: cost, benefits, and impacts of practices, cost-effectiveness analysis;

Step 6: draft recommendations and implementation actions at State, regional, and local level;

Step 7: input from water users, other agencies, and public;

Step 8: final plan with recommended implementing policies, legislation, regulations, and other activities.

The guide also contains a detailed bibliography of references which can be used to provide information for all phases of the water conservation procedure. These references were grouped under the following subject headings:

(1) water use: general, urban, industrial, agricultural;

(2) water conservation planning: Federal, State, regional, local;

(3) water conservation practices: residential, industrial, agricultural;

(4) pricing and revenue planning: urban agricultural, industrial;

(5) institutional/legal;

(6) public participation;

(7) public education;

(8) energy assessment;

(9) wastewater reuse: residential, industrial, agricultural;

(10) emergency/contingency planning: general, urban, agricultural;

(11) water conservation impacts.

This publication also contains information useful in the analysis of implementation conditions of several water conservation measures.

288

Upper Mississippi River Basin Commission. 1978. Proceedings, Symposium on the Water Conservation Challenge. Bloomington, Minnesota.

This is an outstanding collection of brief papers presented at the Symposium on the Water Conservation Challenge on May 10, 1978, in Bloomington. The scope of the Symposium ranged from local to national in character with papers reflecting the various levels of focus. The report was broken into 3 segments. The first investigates the Federal, State, and local viewpoints toward water conservation as it examines the conservation potential for the U.S. in general, the Upper Mississippi River Basin, and selected local areas across the country. The second segment investigates measures for water conservation such as the need for a good water-use data base, residential water conservation and devices, municipal water conservation and a discussion on the extent of government control of non-point source pollution. The final section addresses applications and implications of water conservation for industry, stream electric generation management, farm water management, institutional, residential and commercial water management.

In sum the scope of the Symposium was comprehensive and the papers collected are concise and contain valuable information for several activities involved in water conservation planning.

289

Wade, David A. 1978. Residential Water Conservation and Community Growth. In Proceedings, National Conference on Water Conservation and Municipal Wastewater Flow Reduction, EPA/430/7-79-015, pp. 177-206. Washington, D.C.: U. S. Environmental Protection Agency.

This paper analyzes possible effects of water conservation on community growth potential by examining the relationships of land-use mixes to community growth and water demand. The general parameters of water supply and demand, key issues relating the management of water supply and community growth, and approaches being undertaken to correlate the management of water and growth policy were discussed.

It was concluded that since water conservation can have a significant impact on community growth through lifting water supply limitations, any conservation program should be integrated with planning policies and program implementation for community growth, land use, and water management.

The aspects of water conservation considered by the author may be important in the general analysis of water resource planning policies. It should be noted that the above intepretation of water conservation is very peculiar, since it implies implementation of water conservation programs regardless of needs for and benefits of such actions.

290

WAPORA, Inc. 1978. Water Use and Conservation at Federal Facilities in the Washington, D. C. Metropolitan Area. Report to the U. S. Environmental Protection Agency, Region III, Philadelphia, PA.

This report describes water-use practices at Federal government installations in the Washington, D. C. metropolitan area. Federal activities account for 15% of all water use in the District of Columbia, 13.7% in the county of Arlington (Virginia), and smaller percentages in other jurisdictions. Significant difficulties were experienced in obtaining reliable water-use data for Federal installations, due to the record-keeping practices of the water purveyors, and the fact that 40% of Federal office space in the region consists of leased (often partly leased) premises. Where suitable data were not available, a regression model was used to estimate water use as a function of employees and floor space.

It was found that water conservation receives little attention in the management of Federal buildings. Building managers were described as viewing water as a free commodity. This attitude was reinforced in the District of Columbia by the practices of reading meters infrequently and irregularly, and not providing building managers with copies of water bills. Devices and practices with potential for reducing water use at Federal facilities were reviewed, including the use of pricing practices. Various recommendations were listed for increasing the awareness of building managers with respect to the cost of water and the possibilities for reducing its use. It was concluded that the existing data base is insufficient to support estimates of the likely effectiveness of water conservation programs.

The above considerations are important in the analysis of implementation conditions of water conservation measures.

291

Warford, J. J. 1968. Water Supply. In Public Enterprise, ed. R. Turvey, pp. 212-36. Middlesex, England: Penguin Books.

Projections of future water "requirements," where water use is taken to be a function of population, housing and appliance stocks, and industrial development, were contrasted to projections of future water "demand," which is an explicit function of, among other variables, price. "Requirements" forecasts were satisfactory only where supply was perfectly elastic (constant marginal and average costs), and demand was perfectly inelastic. Both conditions were described as unlikely. Since water use is responsive to price, properly set prices served the function of efficiently rationing existing supplies as well as providing needed information for optimal investment in future supplies. Particular attention was drawn to the situation in Great Britain, where residential water uses are characteristically unmetered, effectively setting price equal to zero. The use of meters (and, therefore, prices) was contrasted to other methods of balancing the cost of supply increments against the benefits obtained. Other water-use reduction methods discussed included pressure reductions, industrial recirculation, and rotating cut-offs of

supply to residential areas. These considerations are important for water conservation planning in general.

292

Wasserman, Kurt L. 1978. Water Conservation through Wastewater Reuse. In Proceedings, National Conference on Water Conservation and Municipal Wastewater Flow Reduction, EPA/430/9-79-015, pp. 208-25. Chicago.

This paper discusses the role and constraints of water reuse in the management of California's water resources. Creating new lower-cost water supplies, conserving energy and natural resources, and also enhancing water quality were considered the key benefits to be gained from water reuse. Among serious concerns of reuse, the author considered economic constraints, institutional barriers, legal hassles over water rights, and problems of health risk and public reluctance.

The information provided by the author is relevant to the determination of applicability, technical feasibility, and public acceptance of reusing wastewater as a means of water conservation.

293

Water Resource Policy Study Group. 1977. Water Resource Policy Study. Washington: Policy Group for Water Policy Review.

Of particular interest was the "Water Conservation Task Group Report." Water conservation was defined as "saving water at one place and time to make it available for more beneficial uses." The report outlines the quantities withdrawn and consumed by various users and gives the estimated potential percentage reductions that could be obtained.

Three policy questions were addressed: (1) What should be the role of the Federal Government in water conservation? (2) What changes in Federal policies and programs can promote rate structures (prices) that encourage water conservation? (3) How can comprehensive water resources planning be improved to implement water conservation? Various options for each of these policy questions were presented and discussed.

The discussion may be helpful in establishing planning criteria for long-term water conservation.

294

Watkins, A. M. 1970. Sanivac--Revolutionary Vacuum Toilet. Popular Science 197:97+.

This article describes the "Sanivac" toilet system developed by Joel Lelyendhal. The system uses 3.5 cubic feet of air and a bit more than a quart of water per flush. Because the system requires only 2-inch PVC plastic pipe to convey the sewage rather than the normal 3-4 inch sewer pipe, the article claims this more than offsets the cost of the system. "The present Sanivac system can economically handle virtually any kind

of housing or other building with a minimum of 30 to 40 people. A new version specifically designed for individual one-family homes is under development and should be out in 18 months," according to Dick Gregory, Vice President of the Sanivac Division, National Homes Corporation. In the "Sanivac" system human wastes go into a collecting tank which is automatically emptied in a catch basin or periodically pumped out.

The description of the device is of limited usefulness for planning purposes since it fails to provide sound estimates of its effectiveness.

295

Watkins, George A. 1972. A Sociological Perspective of Water Consumers in Southern Florida Households. Gainsville: Florida Water Resources Research Center, University of Florida.

According to the author, due to increased water demands there are many existing programs for water usage. It is important to assess the feelings of a population before water management changes are made. This will help bridge the gap between administrative solutions and hesitations on the part of the consumers.

The author provided a general review of the literature in the field. His purpose was two-fold: (1) to verify the relationships between water consumption in residential areas and socio-economic variables, e.g., verify Linaweaver, Spauling and others; and (2) to develop a scale to measure attitudes toward water conservation as developed by Watkins (1968).

The study area consisted of Homestead, Florida, and areas of northwest Palm Beach. In correlating the scores on a Water Concern Scale with socio-economic factors, only education and income level of family head were significant. The conclusion was that the more urban lifestyle of Palm Beach had more appliances, income, and higher consumption. Palm Beach people didn't know their water suppliers, and the majority of all people hadn't thought about cutting water consumption, and if so would do it in sprinkling then leaks. If a shortage would relegate responsibility to water plant, most never expect a shortage; and the majority were against reclaimed water.

The results of this study are relevant to the evaluation of public acceptability of water conservation measures.

296

Weeks, C. R., and T. A. McMahon. 1974. Urban Water Use in Australia. In Civil Engineering Transactions, pp. 58-66. Australia: The Institution of Engineers.

This article presents results of a survey of urban water use in Australia, based on data collected during the late 1960s. Factors influencing per capita municipal use were examined, including population size, presence of metering, water quality, and climate. Forecasts were prepared for 11 Australian cities using a simple trend extrapolation approach. Monthly

water use was forecast from multi-variate regression models which include monthly rainfall, mean maximum monthly temperature, number of raindays, and pan evaporation as explanatory factors.

An investigation of household water use was reported, based on data collected for five small study areas in Victoria. Per capita use was expressed as a function of number of persons per housing unit, and both seasonal variations and peak-day use levels were investigated. A survey of water use by major industrial firms in Melbourne was also reported. Water-use coefficients, based on units of production, were calculated for 29 industrial categories. Australian results were contrasted to corresponding data reported for the United States and the United Kingdom.

The Regression models for forecasting monthly water use in this study may be applied to forecasting short-term unrestricted water use.

297

Whipple, William, Jr. 1979. Summary of Conference. In Proceedings, Conference on Water Conservation Needs and Implementing Strategies, pp. 10-14. New Hampshire: Franklin Pierce College.

The author highlighted several important issues of water conservation including: (1) semantics and politics, (2) conservation as a water resource planning objective, (3) dual aspects of water conservation, (4) criteria and incentives, and (5) Federal action and overall policy.

He argued that the definition of water conservation that includes only beneficial reductions in water demand or beneficial reductions in waste or usage of water ". . . has a valid objective, that is not to make conservation an end in itself." However, he also says that "in the interest of clarity, and practicality, . . .such a definition appears unnecessary." Two kinds of conservation distinguished by the author were: (1) the attempts to achieve permanent changes in the handling and using of water, which can be evaluated according to the Principles and Standards, and (2) the contingency program for periods of drought or low flow which require "governmental sanctions of some sort."

This brief statement constitutes an excellent introduction to planning for water conservation.

298

White, A. V., A. N. DiNatale, J. Greenberg, and J. E. Flack. 1980. Municipal Water Use in Northern Colorado: Development of Efficiency-of-Use-Criterion. Colorado Water Resources Research Institute completion report no. 105. Colorado: Colorado State University.

The purpose of this study was to develop a set of recommendations for the development of implementable water conservation programs in small towns in Northern Colorado. Twenty-five towns were surveyed in order to obtain data on residential water use, and the attitudes and perceptions of water officials with regard to water conservation were identified.

In addition, a random sample of 105 water customers in each of 7 cities was surveyed to assess the consumers' attitudes toward the same subjects.

Based on this comparison, the authors recommended that technically feasible and socially acceptable potential water conservation measures for long-term water supply should include (1) universal metering, (2) development of new supplies and water rights, (3) requirements for low-flow devices and native vegetation in new housing areas, (4) increasing block pricing, (5) public education, (6) reuse of water for non-drinking purposes, and (7) possible restriction of growth. Short-term conservation programs, i.e. drought contingency plans, were recommended to include (1) public education of drought and its consequences, (2) installation of water-saving devices, (3) implementation of restrictions and allotments, and (4) surcharges on prices for metered services.

Meeting the demand of these municipalities for water with the above means which ensure a minimum effort, expense, or waste is referred to by the authors as an "efficiency-of-use criterion."

This report constitutes a useful reference for determining applicability, technical feasbility, social acceptability, and implementation conditions for a large array of water conservation measures.

299

White House Drought Study Group. 1977. March 1977 Drought Appraisal. Reprinted by the U. S. Army Engineers Institute for Water Resources.

This report describes the 1976-77 drought in California, Oregon, Washington, Idaho, and Nevada, and presents possible measures for drought management both in the short- and long-term. It was noted that in 1977, production on irrigated lands is expected to be 75% of normal. It was estimated that a comprehensive long-term conservation program in agriculture could achieve annual savings of 6 to 8 million acre-feet of consumption and 40 to 50 million acre-feet of withdrawals and that a 20% reduction in residential use could be achieved by the installation of water-saving devices. Short-term measures could reduce the average use per person by 50%. Tables of water conservation measures (agricultural and municipal) and a large number of tables, matrices, and maps describing the drought were presented.

The contents of this report may be helpful in developing drought contingency plans.

300

Whitford, Peter W. 1970. Forecasting Demand for Urban Water. Stanford University Report EEP-36. California.

The author's purpose was to develop and demonstrate a model for forecasting residential water use. The model incorporates an uncertainty factor that takes account of various future water management policies that could be adopted. Four case studies (Baltimore, Kanasa City, Phoenix,

and Seattle) were used to illustrate the model application in forecasting water use in the year 2000.

The reported alternative forecasts of future water use resulted from various assumptions concerning the outcomes of the following 6 factors that may affect water use:

1. regulations on the water use of appliances,
2. the type of pricing policy that is adopted,
3. policy on public education (water conservation),
4. the housing patterns in the future,
5. the cost of supply, and
6. changes in the technology of use.

Two or 3 outcomes were considered for each of these factors, and probabilities of occurrence were subjectively assigned to each outcome, allowing a probability distribution of a given future water use to be drawn. This was done by multiplying conditional probabilities assigned to each policy outcome and ascribing it to an appropriate level of water use.

For each case study the cumulative probability distribution curves described the probability of any given per capita water demand in the year 2000. A "base" line estimate was determined based on water utility data such as population served, the average annual and seasonal consumption of water (disaggregated into residential, commercial, industrial, and other), and the water rates.

The author's model may be adopted to the analysis of drought performance of water supply/conservation plans in order to assess the risk of water deficit for assumed probability distribution of future water use.

301

Whitford, Peter W. 1972. Residential Water Demand Forecasting. Water Resources Research 8:829-39.

This article provides an excellent discussion of the problem of water-demand forecasting and describes a methodology for forecasting urban residential water use which incorporates the development of "alternative futures." The "futures" are projected based on the 2 or 3 outcomes of each of the following factors that may influence future water use:

1. regulations on the water use by appliances,
2. types of policy pricing adapted,
3. policy on public education,

4. future housing patterns,

5. cost of supply, and

6. changes in the technology or use.

Thus, the forecasting method incorporated potential water conservation programs into estimates.

It should be noted that the author was primarily concerned with factors or variables which are not significant or which do not exist at present. The proposed model may be treated as a tool for generating a probability distribution of the future water demand, once a single-number base line forecast is found by using standard methods.

The proposed model was demonstrated by forecasting water demand for the cities of Phoenix and Baltimore for the year 2000. Data on present water use, obtained from water utilities, included such items as population served, the average annual and seasonal consumption of water (disaggregated into residential, commercial, industrial, public and other), and the water rates. The base line estimate for Baltimore was obtained by projecting the 1985 forecast of Hittman Associates (using MAIN II system) to the year 2000. The base line forecast for Phoenix was estimated by comparing the rate of growth of per capita residential demand with that of Baltimore.

Whitford's model should prove very useful for policymaking purposes since it incorporates the concept of alternative futures.

302

Wilson, George E., and Jerry Y. Huang. 1977. Water Conservation: Dramatic Changes Taking Place. Food Engineering 49:79-81.

This article presents 3 major water conservation measures which have been undertaken in the food processing industry: (1) increasing water-use consciousness, (2) cooling water conservation, and (3) counter-current reuse of process flume water. The authors reported that full-scale water conservation practices have been demonstrated to reduce net water requirements to less than 10% of those observed prior to the 1972 enactment of the Water Pollution Control Act (PL 92-500).

This information may be useful in determining effectiveness of these three industrial water conservation measures.

303

Wolf, Ray. 1977. Greywater in the Garden. Organic Gardening and Farming 24:83-86.

This article discusses methods for reuse of greywater as household irrigation water. It was noted that it is generally illegal to do so but that this has been overlooked by authorities during the drought in the Far West. Such use of greywater can be done safely. "Because

of salts in greywater, do not use it on acid-loving plants. Avoid using greywater on plants that are eaten raw like lettuce and carrots." The article was primarily on do-it-yourself plumbing.

The article identifies a potential water conservation measure which may conserve water normally used for outdoor purposes.

304

Wolff, Jerome B., F. P. Linaweaver Jr., and John C. Geyer. 1966. Commercial Water Use. ASCE Urban Water Resources Research Program technical memorandum no. 27. New York: American Society of Civil Engineers. (reprint of 1966 report by Department of Environmental Engineering Science, The Johns Hopkins University)

This report presents the results of an intensive study of water use for 186 commercial and institutional establishments in the Baltimore, Maryland, metropolitan area. Water-use data were obtained from quarterly meter readings, from more frequent special readings, and from recorders attached to water meters. Data were collected for various periods in 1964 and 1965. Both average water-use levels and peak-use rates were investigated, including the development of water-use hydrographs for selected establishments.

A major contribution of this study was the development of unit use coefficients suitable for estimating average-day water use for 18 categories of commercial and institutional users, ranging from primary and secondary schools to department stores. In each case, water use was expressed as a function of some appropriate parameter, such as number of students in the case of schools, or square feet of sales area in the case of department stores. Coefficients were also presented for maximum-day water use and peak-hour water use (on a noncoincident basis) for each category. The information provided by the authors may be very helpful in determining unrestricted water use in commercial sector.

305

Wong, S. T. 1972. A Model on Municipal Water Demand: A Case Study on Northeastern Illinois. Land Economics 48:34-44.

This article presents regressions of municipal residential water consumption on price, income, and average summer temperature for Chicago and outside communities. The analysis was performed on data obtained from the Department of Water and Sewers, City of Chicago, and other local agencies. The data characteristics were not discussed in detail.

The results of time-series regressions (1951-61) on the Chicago area showed partial R's of income and average summer temperature of 0.74 and 0.77 respectively. Price was found insignificant (elasticity -0.02) for Chicago, whereas it was significant at the 5% level for the outside communities (elasticity -0.28). For those communities, average summer temperature had the most significant effect. The author suggested that a partial flat-rate pricing policy and otherwise very low price of water

were responsible for the insignificant effect of price on water use in Chicago. A log-linear functional form was used.

Four cross-sectional regressions of residential per capita water use on price and income were performed for 103 communities (stratified into 4 community site groups), giving price elasticities ranging from -0.82 to -0.26 and income elasticities of 0.48 and 1.03. These values were compared with the results of 17 previous studies of these variables.

The author's findings are relevant to the determination of unrestricted water use in the evaluation of effectiveness of water conservation measures.

306

Yarborough, Keith A. 1956. Analysis of Seasonal Water Consumption in Danville, Illinois. Journal of the American Water Works Association 48:479-84.

The author's purpose was to determine seasonal water consumption in Danville based on house meter records for the summer quarter (June 15-September 15) and winter quarter (December 15-March 15) for the period 1950-55.

Although the conclusions of this study were very general, it is important to note that the author attempted to take account of potentially important variables explaining water use. Climatological factors (or weather conditions) and assessed-property evaluation were considered for each of 5 water-use zones.

307

Young, R. A. 1973. Price Elasticity of Demand for Water: A Case Study of Tucson, Arizona. Water Resources Research 9:1068-72.

This article presents estimates of the short-run price elasticity of aggregate water use for Tucson, Arizona, from the series date for a single utility. The estimates were -0.60 for the period 1946-64 and -0.41* for the period 1965-71 (*not significantly different from zero at the .05 level). Both estimates suffer from the use of very small data bases (19 and 7 data points). More importantly, the use of 2 separate periods was apparently based on an ex-post analysis of the results. A re-analysis of the complete data set (Carver, Ph.D. Thesis, 1978) indicated a short-run price elasticity of -0.2 (significant 0.10 level). Nevertheless, the authors attempted to estimate that short-term effects of price on water use are of value for designing drought contingency plans.

308

Young, R. A., and S. L. Gray. 1972. Economic Value of Water: Concepts and Empirical Estimates. Department of Economics report no. NTIS PB 210-356. Fort Collins: Colorado State University.

The authors observed that the practice of allocating water among competing uses by means of administered prices and various non-market procedures results in the absence of reliable market measures of value. Instead, values for various uses of water must be inputted from limited market transactions, from theoretical demand functions, from measurements of residual value, or from information regarding alternative costs. A framework for establishing values for water, suitable for use in public or private sector development and allocation decisions, was presented. Specific attention was given to valuation problems arising within the agricultural, industrial, and municipal use sectors, as well as to valuation problems associated with the use of water for waste assimilation, recreation, navigation, and hydroelectric generation. In each case, the literature was surveyed, and empirical estimates of value, where available, were given. These were supplemented by several original derivations of value measures, based on data obtained by the authors. Where value measures were available by region, regional differences in value are characterized as minor.

The article provides information which is of general importance to water conservation planning.

JOURNALS

CONFERENCE PROCEEDINGS

RESEARCH REPORTS

BOOKS AND OTHER PUBLICATIONS

AUTHOR INDEX
by Page Number

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