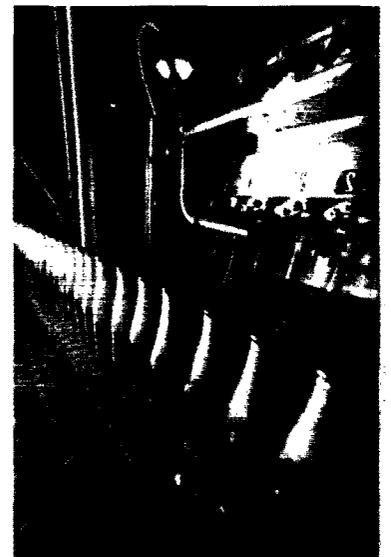
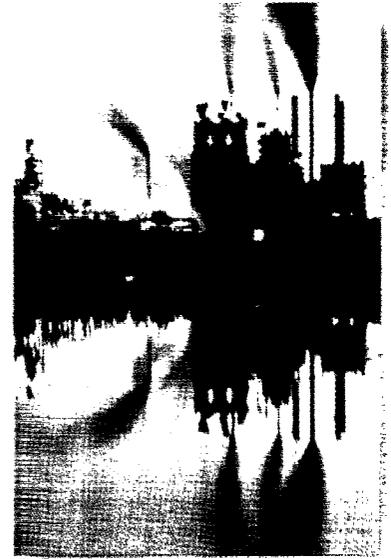


Guidelines for Preparing Cost-Effectiveness Analyses of Urban Water Conservation Best Management Practices



**September
1996**



Sponsored by

California Urban Water Conservation Council

D - 0 4 6 1 3 9

D-046139

**GUIDELINES TO CONDUCT COST-EFFECTIVENESS ANALYSIS OF
BEST MANAGEMENT PRACTICES FOR URBAN WATER CONSERVATION**

**Prepared for
The California Urban Water Conservation Council**

by

David M. Pekelney, Ph.D.

A & N Technical Services, Inc. and
UCLA School of Public Health

Thomas W. Chesnutt, Ph.D.

A & N Technical Services, Inc.

W. Michael Hanemann, Ph.D.

University of California, Berkeley

California Urban Water Conservation Council

455 Capitol Mall, Ste. 705

Sacramento, CA 95814

Phone: (916) 552-5885

Fax: (916) 552-2931

email: CUWCC @ aol.com

September 1996

PREFACE

The California Urban Water Conservation Council (CUWCC) and signatory organizations face the challenge of deciding which Best Management Practices (BMPs) to implement. The Memorandum of Understanding Regarding Urban Water Conservation in California (MOU) states that cost-effectiveness is a fundamental criterion for making such decisions. There is no single correct way to apply cost-effectiveness analysis (CEA), and there is valid controversy on several key issues needed for CEA of BMPs—water savings, discount rates, project life spans, and appropriate cost accounting. Differences in method and assumptions can make large differences in results of a CEA. Hence, to implement the MOU, guidelines are needed to conduct and evaluate CEA studies.

The objectives of this document are to:

- Develop guidelines to conduct consistent CEAs of BMPs and Potential Best Management Practices (PBMPs) based on sound economic principles;
- Encourage the analysis of costs and benefits from total society, supplier, and customer perspectives;
- List data requirements and methods for collecting data needed to evaluate the BMPs and PBMPs listed in this document;
- Promote the consistent use of discount rates, BMP project life spans, and methods of addressing environmental benefits and costs; and
- Present examples that illustrate the application of these CEA guidelines.

In short, these guidelines are written to help the Council and its signatory organizations develop reliable estimates of the costs and benefits of BMPs. Since suppliers may face differing circumstances, the guidelines do not prescribe a single method or set of parameter values to conduct CEAs. Instead, these guidelines suggest ways to choose methods and parameter values, and to set reasonable bounds. These guidelines do not attempt to resolve long-running debates surrounding the theory and practice of cost-effectiveness analysis. Rather, they provide defensible criteria for conducting and evaluating CEAs.

This document should prove useful to water utility managers, cost-effectiveness analysts, and consultants by demonstrating how they can use quantitative tools to calculate costs and benefits and to provide results that may improve conservation decision-making.

ACKNOWLEDGMENTS

This project was supported by and prepared for the California Urban Water Conservation Council. The CUWCC would especially like to thank the Metropolitan Water District of Southern California and the City of Santa Monica for financial support of this project as well as the California Department of Water Resources for document production and distribution.

CUWCC and A & N Technical Services appreciate the time and energy contributed by the members of the Project Advisory Committee:

Dick Bennett	East Bay Municipal Utility District
Roberta Borgonovo	League of Women Voters
Deborah Braver	California Department of Water Resources
Steve Cowdin	California Department of Water Resources
James Fryer	Marin MWD
David Fullerton	Natural Heritage Institute
Byron Buck	California Urban Water Agencies
David Mitchell	M.Cubed
Tom Panella	UC Berkeley, School of Public Policy
Bob Penny	California Public Utilities Commission
Craig Perkins	City of Santa Monica
John Wiedmann	MWD of Southern California

The City of Santa Monica and Contra Costa Water District have generously provided information about their conservation programs. We especially thank David Mitchell, the project manager, for his guidance and suggestions.

These guidelines draw upon and cite previous work found in the cost-effectiveness literature. We have paraphrased or adapted some language from other government guidelines in the public domain (e.g., Office of Management and Budget 1992a and 1992b). Although we have built upon this previous work, we are responsible for any remaining errors.

A GUIDE TO THESE GUIDELINES

WHO SHOULD USE THESE GUIDELINES . . . AND WHEN?

The Memorandum of Understanding Regarding Urban Water Conservation in California (MOU) established water conservation as a standard policy for many of California's urban water suppliers. To follow the MOU, *suppliers agree to implement a list of water conservation Best Management Practices (BMPs)*. To monitor and implement the terms of this agreement, the MOU established the California Urban Water Conservation Council (CUWCC or the "Council").

Based on cost-effectiveness, as well as other criteria, the Council determines whether or not a BMP is on the implementation list. Also, it exempts water suppliers from implementing a listed BMP as long as they annually substantiate that the BMP is not cost-effective. This document, developed for the Council, contains guidelines to conduct these cost-effectiveness analyses. *These guidelines are designed to be used by the Council when determining the BMP implementation list and by water suppliers when substantiating a BMP exemption.* For agencies undertaking design of conservation programs, the guidelines will also be useful as a tool to assess program cost-effectiveness and to assist prioritization.

WHAT IS COST-EFFECTIVENESS ANALYSIS?

Cost-Effectiveness Analysis (CEA) is a systematic method of comparing the costs and benefits of alternative courses of action. For example, BMPs with benefits greater than costs are attractive; those with costs greater than benefits are not. CEA is a formalized, consistent, and detailed version of weighing the "pros and cons" of a decision. The MOU considers a BMP **Cost-Effective** when its benefits are greater than its costs. The table below provides a rudimentary example of CEA for an ultra low flush (ULF) toilet program:

Simple Example of CEA

Cost per ULF Toilet		Benefits per ULF Toilet	
Toilet Rebate	\$75	Water Savings	.67 acre-feet
Administration	+ \$40	Costs per acre-foot	x \$500
Supplier Costs	\$115	Supplier Benefits	\$335

The table shows costs to the supplier include the cost of the toilet rebate plus administration. Benefits to the supplier include the water savings over the life of the ULF toilet times the avoided costs of water supply. Since benefits outweigh costs, the ULF toilet is cost-effective to the supplier.

Although this example illustrates some of the basics, CEAs must consider much more complex issues in the MOU process: How to sum costs and benefits to the **Total Society** or to the Customer (not just the supplier)? How to include the **Environmental Benefits** of conservation? How to estimate the **Value of Conserved Water**? How to **Discount** costs or benefits that occur in different years? This document addresses these kinds of issues.

HOW TO USE THESE GUIDELINES?

Chapter 1: The MOU Process and the Role of CEA

Use Chapter 1 to provide detailed background on the MOU and its specific provisions that call for CEA. Also use Chapter 1 as an introduction to the MOU process and the role of the Council.¹

Chapter 2: General Guidelines for BMP Cost-Effectiveness Analysis

Refer to Chapter 2 for general guidelines for cost-effectiveness analysis that apply to all BMP conservation measures. The guidelines describe four steps for conducting CEA:

- 1) Identify Costs and Benefits
- 2) Measure and Value Costs and Benefits
- 3) Discount Costs and Benefits
- 4) Analyze Uncertainty.

Step 1 emphasizes the identification of all costs and benefits of a BMP, even if some cannot be quantified. The guidelines define different **Perspectives of Analysis** so that costs and benefits can be identified for suppliers, total society, and for customers. Step 1 also defines useful **Categories of Costs and Benefits**.

Step 2 provides detailed guidance on measuring and valuing costs and benefits. It emphasizes measuring the **Incremental Savings** due to the BMP, to distinguish the BMP's water savings from that which would have occurred anyhow, such as through natural replacement of water saving devices. Step 2 also shows how to value the saved water in dollars. The value of saved water usually includes **Avoided Water Supply Costs** and **Avoided Environmental Costs**. In addition, Step 2 includes guidance for dealing with external environmental benefits of conservation (avoided environmental costs), which are often difficult to value in dollar terms.

Step 3 adds up total costs and benefits using a **Discount Rate** to convert costs and benefits into present value terms.

Step 4 analyzes **Uncertainty** produced by the imprecision of underlying data, variability of costs or benefits, and inevitable rough assumptions. All analyses should explicitly state the underlying **Assumptions** used to arrive at estimates of costs and benefits, the rationale behind them, and description of their strengths and weaknesses.

Chapter 3: CEA Guidelines for Specific BMPs AND PBMPs

Refer to Chapter 3 for additional CEA guidelines that apply to specific BMPs. Chapter 3 includes a table of device life spans that form a starting point for a CEA.

¹Chapter 1 contains the most relevant sections of the MOU. For additional information, consult "Memorandum of Understanding Regarding Urban Water Conservation in California," California Urban Water Conservation Council, Last Amended March 9, 1994.



Chapter 4: Illustrative Examples – ULF Toilets and Large Landscape Audits

Read Chapter 4 to see how CEAs can evaluate two important BMPs: ultra-low-flush toilet replacements and large landscape audits. Chapter 4 illustrates CEA of BMP 16, using the example of Santa Monica's BAYSAVER program, and BMP 5, using the example of Contra Costa Water District's large landscape audit program. These illustrations follow the guidelines defined in Chapters 2 and 3.

Chapter 5: Conclusions

Read Chapter 5 for a summary of the principles that underlie these guidelines. This document does not present the guidelines as a "cookbook" recipe to conduct CEAs. Rather, CEA requires professional judgment to produce high quality results. The guidelines in Chapters 2 and 3 provide guidance in making these judgments and in highlighting their implications. The guidelines can also be used as a "checklist" before, during, and after the analysis to ensure that CEAs address the important issues defined by the MOU.

Appendices

Consult the appendices for more in-depth information. Appendix A contains a primer on methods used to value external environmental costs and benefits. Appendix B is a glossary of economic terms used in this document. Appendix C contains a calculation "short cut" for computing streams of benefits over time.

GETTING STARTED -- SOME FREQUENTLY ASKED QUESTIONS

The prospect of performing a cost-effectiveness analysis can be rather daunting, particularly if you have never done one before. To help get you started, here are some frequently asked questions about using these guidelines and doing cost-effectiveness analysis.

Is cost-effectiveness analysis required for every BMP?

CEA is a useful tool for planning or evaluating any conservation program. However, the MOU does not require you to do a cost-effectiveness analysis every time you implement a BMP. A cost-effectiveness analysis is required, however, to exempt your agency from implementing the BMP. In other words, it is incumbent upon your agency to show that a particular BMP is not cost-effective and therefore should not be implemented.

Do I have to use these guidelines to do an analysis?

These guidelines are just that -- guidelines. You do not have to use them, per se. But you do need to make sure that your analysis is consistent with their recommendations. The CUWCC will use these guidelines as a reference when reviewing your agency's BMP exemptions.

There are economic terms used in these guidelines I just don't understand. Where can I get an explanation?

These guidelines try to be as jargon-free as possible. However, it is simply not possible to discuss cost-effectiveness methods without referring to economic concepts that may be unfamiliar to people that have not had basic economics. If you are brand new to cost-effectiveness analysis, or if you need a refresher, it might be worthwhile to familiarize yourself with the glossary of terms contained in Appendix B before launching into the guidelines.



What other sources can I consult about cost-effectiveness analysis?

Cost-effectiveness analysis is a very well developed branch of economics. There are numerous textbooks, articles, and reports on the subject. In developing your analysis, you may wish to consult one or more of the following:

Zerbe, R., and D. Dively. *Benefit-Cost Analysis in Theory and Practice*. New York: Harper Collins College Publishers, 1994.

Stokey, E., and R. Zeckhauser. *A Primer for Policy Analysis*. New York: Norton Publishers, 1978.

Planning and Management Consultants, Ltd., "Evaluating Urban Water Conservation Programs: A Procedures Manual." Denver, CO: AWWA, 1993.

American Water Works Association, "Water Conservation Guidebook for Small and Medium Sized Utilities," August 1993.

The Bay Institute of San Francisco, "Proceedings of a Workshop on Economic Non-Market Evaluation of Losses to Fish, Wildlife and Other Environmental Resources," May 1987.

In addition, if you have particular questions regarding an analysis you are conducting, you can contact CUWCC's main office. They will be able to put you in contact with somebody that can address your questions.

How do I know what cost and benefit data to collect for a given BMP?

Chapter 3 of these guidelines reviews potential program costs and benefits for selected BMPs and PBMPs. Use this chapter to begin developing your data collection game plan. Remember that data requirements will to some extent depend on the specifics of your program.

Where can I get some examples of cost-effectiveness analysis of water conservation programs?

Chapter 4 of these guidelines provides two examples: (1) an evaluation of a ULFT replacement program; and (2) an evaluation of a large landscape water audit program. These examples illustrate the principles and methods put forth by these guidelines. In addition, you can find numerous "real world" program evaluations documented in the American Water Works Association's Conserv Proceedings, and the proceedings of the American Water Resources Association's 1995 Spring Symposium, "Water in the 21st Century: Conservation, Demand, and Supply."

I'm all thumbs when it comes to math and spreadsheets. Who can do this for me?

If you are a large agency, you may have in-house staff that routinely does this sort of analysis. Check with your planning and financial departments for staff availability. There are also a number of consulting companies in California that specialize in this area. The CUWCC can provide you with a list of consultants specializing in water conservation program evaluation and cost-effectiveness/cost-benefit analysis. However you decide to proceed, don't remove yourself entirely from the analysis. At the very least, familiarize yourself with the guidelines so that you may critically review the analysis when it is completed.

How long will an analysis take?

The time required to do an analysis depends on the complexity of the program and the availability of information. If the basic data you need to estimate costs and benefits is easily available, and you have done cost-effectiveness analysis before, then the analysis could be done in a matter of days. Otherwise, the analysis could take substantially longer. Try not to reinvent the wheel. Before you begin, check with other agencies with similar programs to see if they've done cost-effectiveness evaluations. Their studies may provide a good template or useful data on program costs or benefits.

How much should my agency spend on cost-effectiveness analysis?

The cost of a good cost-effectiveness analysis will depend on the complexity of the program and the availability of information. Some analyses will be very inexpensive. Others may require a more significant investment. There is a point, however, where it will not be cost-effective to pursue a cost-effectiveness analysis further. How much to spend depends on the information that will be produced by the analysis, and the decision-making consequences of having versus not having that information. Your agency should consider the value of the information it hopes to produce through the analysis, and then invest accordingly.

TABLE OF CONTENTS

PREFACE	ii
ACKNOWLEDGMENTS	iii
A GUIDE TO THESE GUIDELINES	iv
TABLE OF CONTENTS	x
TABLES	xii
FIGURES	xiv
CHAPTER 1 THE MOU PROCESS AND THE ROLE OF CEA	1-1
1.1 A New Approach to Water Resource Management	1-1
1.2 Basic Concept of CEA	1-4
1.3 BMP Exemption Process	1-4
1.4 CEA and MOU Modification	1-5
1.5 CEA Guidelines Development	1-8
CHAPTER 2 GENERAL GUIDELINES FOR BMP COST EFFECTIVENESS ANALYSIS	2-1
2.1 Introduction	2-1
2.2 Step 1: Identify Costs and Benefits	2-2
2.3 Step 2: Measure and Value Costs and Benefits	2-6
2.4 Step 3: Discount Costs and Benefits	2-13
2.5 Step 4: Analyze Uncertainty	2-15
2.6 Conclusion	2-16
CHAPTER 3 CEA GUIDELINES FOR SPECIFIC BMPs AND PBMPs	3-1
3.1 Introduction	3-1
3.2 Device Life Spans	3-1
3.3 BMP 1: Interior and Exterior Water Audits and Incentive Programs for Single Family Residential and Multi-Family Residential Customers	3-3
3.4 BMP 2: Plumbing, New and Retrofit	3-5
3.5 BMP 3: Distribution System Water Audits, Leak Detection, and Repair	3-7
3.6 BMP 5: Large Landscape Water Audits and Incentives	3-9



TABLE OF CONTENTS (Continued)

3.7	BMP 9: Commercial, Industrial and Institutional Water Conservation	3-12
3.8	BMP 10: New Commercial and Industrial Water Use Review	3-14
3.9	BMP 15: Financial Incentives	3-16
3.10	BMP 16: Ultra Low Flow Toilet Replacements	3-18
3.11	PBMP 3: Replacement of Existing Water Using Appliances (Except Toilets and Showerheads Whose Replacements are Incorporated as Best Management Practices) and Irrigation Devices	3-20
3.12	PBMP 4: Retrofit Existing Car Washes	3-22
3.13	PBMP 5: Graywater Use	3-24
CHAPTER 4 ILLUSTRATIVE EXAMPLES: ULF TOILET REPLACEMENTS AND LARGE LANDSCAPE AUDITS		
		4-1
4.1	ULF Toilet Program	4-1
4.2	Identify Costs and Benefits	4-1
4.3	Measure and Value Costs and Benefits	4-2
4.4	Discount Costs and Benefits	4-6
4.5	Analyze Uncertainty	4-10
4.6	Summary of ULF Toilet Cost-Effectiveness	4-12
4.7	Large Landscape Audits	4-12
4.8	Identify Costs and Benefits	4-13
4.9	Measure and Value Costs and Benefits	4-14
4.10	Discount Costs and Benefits	4-16
4.11	Analyze Uncertainty	4-19
4.12	Summary of Large Landscape Audit Cost-Effectiveness	4-20
4.13	Conclusions	4-20
CHAPTER 5 CONCLUSIONS		
		5-1
REFERENCES		
		R-1
APPENDIX A: VALUING ENVIRONMENTAL EXTERNALITIES		
		A-1
APPENDIX B: GLOSSARY		
		B-1
APPENDIX C: PRESENT VALUE CALCULATION SHORTCUT		
		C-1

TABLES

Table 1.1 – Memorandum of Understanding Regarding Urban Water Conservation in California	1-2
Table 1.2 – BMPs and PBMPs	1-3
Table 1.3 – MOU Identified Costs and Benefits	1-7
Table 2.1 – Costs and Benefits from Different Perspectives	2-3
Table 2.2 – Sample Supply Costs	2-10
Table 2.3 – Typical External Environmental Benefits of Conservation	2-13
Table 2.4 – Interest Rates on Treasury Notes and Bonds of Specified Maturities	2-14
Table 3.1 – Device Life Spans: Indoor Residential and Commercial	3-2
Table 3.2 – Device Life Spans: Landscape	3-2
Table 3.3 – BMP 1 Costs and Benefits	3-4
Table 3.4 – BMP 2 Costs and Benefits	3-6
Table 3.5 – BMP 3 Costs and Benefits	3-8
Table 3.6 – BMP 5 Costs and Benefits	3-11
Table 3.7 – BMP 9 Costs and Benefits	3-13
Table 3.8 – BMP 10 Costs and Benefits	3-15
Table 3.9 – BMP 15 Costs and Benefits	3-17
Table 3.10 – BMP 16 Costs and Benefits	3-19
Table 3.11 – PBMP 3 Costs and Benefits	3-21
Table 3.12 – PBMP 4 Costs and Benefits	3-23
Table 3.13 – PBMP 5 Costs and Benefits	3-25
Table 4.1 – Identify Costs and Benefits	4-2
Table 4.2 – Program Costs	4-3
Table 4.3 – ULF Toilet Water Savings	4-4
Table 4.4 – Supplier Perspective: Present Value of Costs and Benefits (Single Family ULF Toilet Rebate)	4-7
Table 4.5 – Supplier Perspective: Present Value of Costs and Benefits	4-8

TABLES *(Continued)*

Table 4.6 – Participating Customer Perspective: Present Value of Costs and Benefits4-8
Table 4.7 – Total Society Perspective: Present Value of Costs and Benefits4-9
Table 4.8 – Results Summary: Single Family ULFT Rebate4-12
Table 4.9 – Identify Costs and Benefits4-13
Table 4.10 – Program Costs4-14
Table 4.11 – Program Savings4-15
Table 4.12 – Supplier Perspective: Present Value of Costs and Benefits4-17
Table 4.13 – Participating Customer Perspective: Present Value of Costs and Benefits4-18
Table 4.14 – Total Society Perspective: Present Value of Costs and Benefits4-18
Table 4.15 – Sensitivity to Water Savings and Persistence4-19
Table 4.16 – Results Summary: Large Landscape Audit Program4-20

FIGURES

Figure 1.1 – CEA Decision Flow Chart	1-6
Figure 2.1 – Streams of Costs and Benefits	2-1
Figure 4.1 – Sensitivity Analysis	4-11
Figure 4.2 – Sensitivity of NPV to Discount Rate	4-11

THE MOU PROCESS AND THE ROLE OF CEA

1.1 A New APPROACH TO WATER
RESOURCE MANAGEMENT

Memorandum of Understanding. The signing in September 1991 of the Memorandum of Understanding Regarding Urban Water Conservation in California (MOU) set in motion a major change in California's water resource management. The MOU established as standard policy the implementation of a broad array of conservation measures by many of the state's urban water suppliers. Once a transient strategy to cope with drought, water conservation became a permanent component of the long term water management planning process. Table 1.1 lists the recitals contained in the MOU.

Cost-Effectiveness Analysis. The MOU stipulates cost-effectiveness analysis (CEA) as one of the primary mechanisms for determining which water conservation measures should be implemented. The MOU lists 16 Best Management Practices (BMPs, see Table 1.2), all of which signatory water suppliers agree to make good faith effort to implement *unless they are shown not to be cost-effective*. The MOU also lists Potential Best Management Practices (PBMPs), which suppliers have no commitment to implement until and unless the PBMPs are promoted to BMPs based on CEA and other factors.

Guidelines for Computing Costs and Benefits. To monitor and implement the terms of the agreement, the MOU established the California

Urban Water Conservation Council (CUWCC or "Council"). Comprised of all signatory organizations, the Council currently consists of almost 200 water suppliers, public advocacy groups, and interested parties. Its responsibilities include developing guidelines to compute costs and benefits, which in turn can be used to determine the cost-effectiveness of BMPs. In addition, these guidelines will assist the Council in (1) determining the appropriate composition of the BMP implementation list, (2) reviewing exemptions submitted by suppliers who claim that certain BMPs are not locally cost-effective, (3) recommending procedures for assessing the effectiveness and reliability of urban water conservation measures, and (4) making annual progress reports on BMP implementation to its signatories and to the State Water Resources Control Board.

Purpose of this Document. This document provides guidelines for conducting CEAs that will support the Council's activities. Since water suppliers may face differing circumstances, these guidelines do not take a "cookbook" approach to conducting CEAs. Instead, this document seeks to provide guidance that promotes consistent decision making across a broad spectrum of circumstances.



Table 1.1

Memorandum of Understanding Regarding Urban Water Conservation in California

Recitals

1. The signatories to this MOU recognize that California's economy, quality of life and environment depend in large part upon the water resources of the State. The signatories also recognize the need to provide reliable urban water supplies and to protect the environment. Increasing demands for urban, agricultural and environmental water uses call for conservation and the elimination of waste as important elements in the overall management of water resources. Many organizations and groups in California have an interest in urban water conservation, and this MOU is intended to gain much needed consensus on a complex issue.
2. The urban water conservation practices included in this MOU (referred to as "Best Management Practices" or "BMPs") are intended to reduce long-term urban demands from what they would have been without implementation of these practices and are in addition to programs which may be instituted during occasional water supply shortages.
3. The combination of BMPs and urban growth, unless properly accounted for in water management planning, could make reductions in urban demands during short-term emergencies such as droughts or earthquakes more difficult to achieve. However, notwithstanding such difficulties, the signatory water suppliers will carry out the urban water conservation BMP process as described in this MOU.
4. The signatories recognize that means other than urban water conservation may be needed to provide long-term reliability for urban water suppliers and long-term protection of the environment. However, the signatories may have differing views on what additional measures might be appropriate to provide for these needs. Accordingly, the MOU is not intended to address these issues.
5. A major benefit of the MOU is to conserve water which could be used for the protection of streams, wetlands and estuaries, and/or urban water supply reliability. This MOU leaves to other forums the issue of how conserved water will be used.
6. It is the intent of this MOU that individual signatory water suppliers (1) develop comprehensive conservation BMP programs using sound economic criteria and (2) consider water conservation on an equal basis with other water management options.
7. It is recognized that present urban water use throughout the State varies according to many factors including, but not limited to, climate, types of housing and landscaping, amounts and kinds of commercial, industrial and recreational development, and the extent to which conservation measures have already been implemented. It is further recognized that many of the BMPs identified in Exhibit 1 to this MOU have already been implemented in some areas and that even with broader employment of BMPs, future urban water use will continue to vary from area to area. Therefore, this MOU is not intended to establish uniform per capita water use allotments throughout the urban areas of the State. This MOU is also not intended to limit the amount or types of conservation a water supplier can pursue or to limit a water supplier's more rapid implementation of BMPs.
8. It is recognized that projections of future water demand should include estimates of anticipated demand reductions due to changes in the real price of water.



Table 1.2
BMPs and PBMPs

Best Management Practices	
1.	Interior and exterior water audits and incentive programs for single-family residential, and multifamily residential, and governmental/institutional customers.
2.	Plumbing - new and retrofit: <ol style="list-style-type: none"> a. Enforcement of requirements of ultra-low-flush toilets in all new construction beginning January 1, 1992; b. Support of State and Federal legislation prohibiting sale of toilets using more than 1.6 gallons per flush; c. Plumbing retrofit.
3.	Distribution system water audits, leak detection and repair.
4.	Metering with commodity rates for all new connections and retrofit of existing connections.
5.	Large landscape water audits and incentives.
6.	Landscape water conservation requirements for new and existing commercial, industrial, institutional, governmental, and multifamily developments.
7.	Public information.
8.	School education.
9.	Commercial, and industrial, <i>and governmental/institutional</i> water conservation.
10.	New commercial and industrial water use review.
11.	Conservation pricing.
12.	Landscape water conservation for new and existing single-family homes.
13.	Water waste prohibition.
14.	Water conservation coordinator.
15.	Financial incentives.
16.	Ultra-low-flush toilet replacement.
Potential Best Management Practices	
1.	Rate Structures and Other Economic Incentives and Disincentives to Encourage Water Conservation
2.	Efficiency Standards for Water Using Appliances and Irrigation Devices
3.	Replacement of Existing Water Using Appliances (Except Toilets and Showerheads Whose Replacements are Incorporated as Best Management Practices) and Irrigation Devices
4.	Retrofit of Existing Car Washes
5.	Graywater Use
6.	Distribution System Pressure Regulation
7.	Water Supplier Billing Records Broken Down by Customer Class (e.g., Residential, Commercial, Industrial)
8.	Swimming Pool and Spa Conversion Including Covers to Reduce Evaporation
9.	Restrictions or Prohibitions on Devices that Use Evaporation to Cool Exterior Spaces
10.	Point-of-Use Water Heaters, Recirculating Hot Water Systems and Hot Water Pipe Insulation
11.	Efficiency Standards for New Industrial and Commercial Processes

1.2 BASIC CONCEPT OF CEA

Commonly used to assist public and private sector decision makers, CEA is a systematic method of comparing the costs and benefits of alternative courses of action. Programs or investments with benefits greater than costs are attractive; those with costs greater than benefits are not. CEA is a formalized, consistent, and detailed method to weigh the “pros and cons” of a decision, as we do in everyday life.

Terminology. These guidelines use the following terms when describing CEAs:

- Exhibit 3 of the MOU defines **Cost-Effective** in the following fashion: “*The measure will be cost-effective if the present value of the benefits exceeds the present value of the costs.*”²
- The **Measures** are the BMPs and PBMPs defined by the MOU.
- The **Benefits** are all positive consequences of programs aimed at improving water use efficiency. These may include benefits to customers, avoided capital and operating costs of water supply, treatment, and wastewater treatment, and avoided environmental costs.
- The **Costs** are all negative consequences of programs aimed at improving water use efficiency. These may include costs to customers, capital expenditures for conservation devices, operating expenses to implement conservation programs, and costs to the environment.

- The **Present Value** of a cost or benefit is the present day equivalent value of a cost or a benefit that occurs in the future. To make fair comparisons of costs and benefits realized at different times, CEAs convert future costs and benefits into their present value equivalents.

By determining the costs and benefits of BMPs, CEA can assist the Council’s efforts to address two key policy problems: (1) the protection of the environment from the effects of water diversions, and (2) the provision of reliable and affordable water supplies to urban areas in California.

1.3 BMP EXEMPTION PROCESS

The MOU is flexible regarding the portfolio of conservation programs that suppliers agree to implement. Many BMPs are worded to require conservation “at least as effective” as a specified program. This provision enables signatory suppliers to substitute more effective conservation practices for less effective ones. Furthermore, suppliers agree to implement all listed BMPs, but they can seek exemptions from implementing particular ones by demonstrating that they are not cost-effective locally.

Cost-Effectiveness. Section 4.5(a) of the MOU specifies that a supplier can be exempted from a specific BMP if it makes one of two findings:

A full cost-benefit analysis, performed in accordance with the principles set forth in Exhibit 3, demonstrates that either the program (i) is not cost-effective overall when total program

² In more formal terms, this is also known as “positive net present value.”

benefits and costs are considered; OR (ii) is not cost-effective to the individual water supplier even after the water supplier has made a good faith effort to share costs with other program beneficiaries.

To be exempt from implementing a BMP, a supplier must substantiate that the BMP is not cost-effective either from the **Total Society Perspective** or from the **Supplier's Perspective with Cost Sharing**. To maintain the exemption, the supplier must "substantiate" such findings annually.

Figure 1.1 shows one way a supplier can use a sequence of CEA tests when considering BMP exemption. The MOU does not require or imply this particular sequence of tests; this sequence simply illustrates a logical approach to making one of the two exemption findings stated in MOU Section 4.5(a)³. In the first test, the supplier determines whether the BMP is cost-effective from the **Supplier's Perspective**. If the BMP *is*, the supplier should implement it because the BMP makes economic sense from its perspective. If the BMP *is not*, the supplier should test whether the BMP is cost-effective from the **Supplier's Perspective with Cost Sharing**. If the BMP *is not*, the supplier may choose to claim an exemption from implementing the BMP.⁴ If the BMP *is*, the supplier may choose to implement the BMP *or* the supplier may choose to test whether the BMP is cost-effective from the **Total Society Perspective**. If the BMP *is not*, the supplier may choose to claim an exemption from implementing the BMP. If the BMP *is*, and if the BMP is also cost-effective from the supplier's perspective with cost sharing, the supplier has not met the conditions in Section 4.5(a).

Adequate Funding. Section 4.5(b) of the MOU also provides for an exemption from BMP implementation if adequate funding is unavailable. However, a qualifier states that the exemption cannot be used if a less cost-effective water management option can be put in place of the exempted BMP:

Adequate funds are not and cannot reasonably be made available from sources accessible to the water supplier including funds from other entities. However, this exemption cannot be used if a new, less cost-effective water management option would be implemented instead of the BMP for which the water supplier is seeking this exemption.

1.4 COUNCIL'S OBJECTION

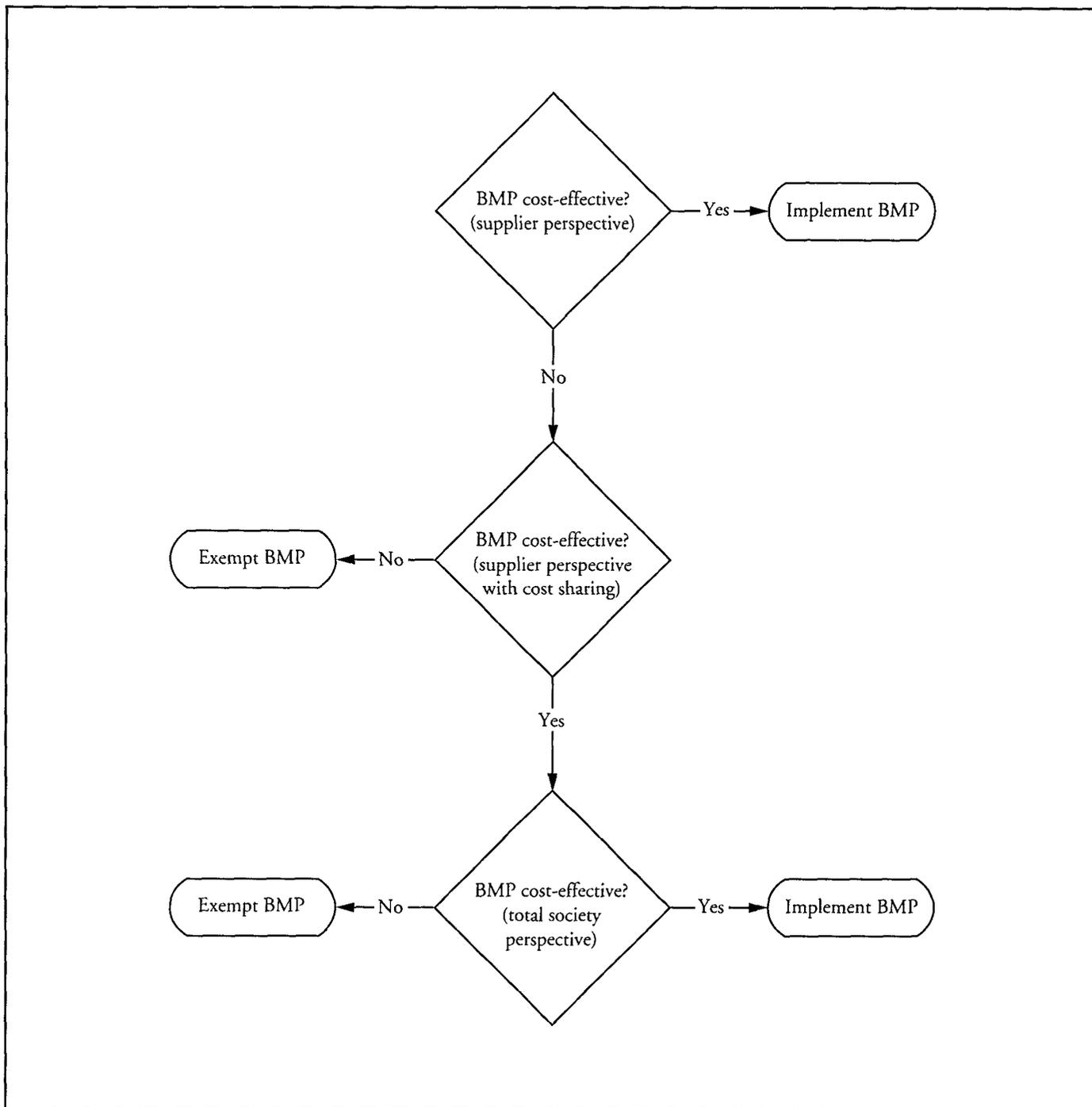
Section 4.3 of the MOU includes an assessment process that can change the composition of the BMP and PBMP lists. This process hinges in part on whether a measure is "economically reasonable." Economic reasonableness refers to assessment of costs and benefits from the total society perspective (Section 4.3(b)). The Council can remove from the list BMPs that are not economically reasonable (Section 4.3(c)). The Council can also add PBMPs to the BMP list if they are economically reasonable (Section 4.3(d)). The first two paragraphs in Table 1.3 contain the total costs and total benefits—defined by the MOU—that a CEA should use when determining if measures are economically reasonable.

³ The sequence starts with the simplest test, and then proceeds to the next more complex test if it is desirable. In this way, the supplier does not need to expend more analytic effort than necessary.

⁴ The supplier may elect to claim an exemption, but is never required to do so.



Figure 1.1
CEA Decision Flow Chart



[NOTE: This sequence of decisions is illustrative. The MOU does not require or imply any particular sequence of tests. Rather, to be exempt from implementing a BMP, MOU Section 4.5(a) calls on the supplier to substantiate that the BMP is not cost-effective either from the *total society perspective* or from the *supplier's perspective with cost sharing*.]

Table 1.3
MOU Identified Costs and Benefits

Total Benefits
Total benefits exclude financial incentives received by water suppliers or by retail customers. These benefits include:
<ul style="list-style-type: none"> a. Avoided capital costs of production, transport, storage, treatment, wastewater treatment and distribution capacity b. Avoided operating costs, including but not limited to, energy and labor c. Environmental benefits and avoided environmental costs d. Avoided costs to other water suppliers, including those associated with making surplus water available to other suppliers e. Benefits to retail customers, including benefits to customers of other suppliers associated with making surplus water available to these suppliers
Total Costs
Total program costs are those associated with the planning, design, and implementation of the particular BMP, excluding financial incentives paid either to other water suppliers or to retail customers. These costs include:
<ul style="list-style-type: none"> a. Capital expenditures for equipment or conservation devices b. Operating expenses for staff or contractors to plan, design, or implement the program c. Costs to other water suppliers d. Costs to the environment e. Costs to retail customers
Supplier Benefits
Program benefits to the water supplier include:
<ul style="list-style-type: none"> a. Costs avoided by the water supplier of constructing production, transport, storage, treatment, distribution capacity, and wastewater treatment facilities, if any b. Operating costs avoided by the water supplier, including but not limited to, energy and labor associated with the water deliveries that no longer must be made c. Avoided costs of water purchases by the water supplier d. Environmental benefits and avoided environmental costs e. Revenues from other entities, including but not limited to revenue from the sale of water made available by the conservation measure and financial incentives received from other entities
Supplier Costs
Program costs to the water supplier include:
<ul style="list-style-type: none"> a. Capital expenditures incurred by the water supplier for equipment or conservation devices b. Financial incentives to other water suppliers or retail customers c. Operating expenses for staff or contractors to plan, design, or implement the program d. Costs to the environment

1.5 CEA GUIDELINES DEVELOPMENT

The Council has the responsibility to develop guidelines to conduct CEAs for BMP exemption and MOU modification. The MOU states:

These guidelines will include, but will not be limited to, the following issues:

- a. analytic frameworks,
- b. avoided environmental costs,
- c. other impacts on the supply system that may be common to many water suppliers,
- d. time horizons and discount rates,
- e. avoided costs to non-water supply agencies,
- f. benefits and costs to retail customers, and
- g. benefits of water made available to other entities as a result of conservation efforts. (Exhibit 3, Paragraph 7).

GENERAL GUIDELINES FOR BMP COST-EFFECTIVENESS ANALYSIS

2.1 INTRODUCTION

Decisions made about long term conservation under the MOU agreement rely in part on the examination of costs and benefits, and this examination requires the use of a systematic and consistent approach. This chapter describes the **CEA Methodology** for examining the costs and benefits of BMPs within the context of the MOU. In so doing, it provides **General Guidelines** to assist those who conduct CEAs. (Chapter 3 describes specific guidelines for a set of BMPs and PBMPs.)

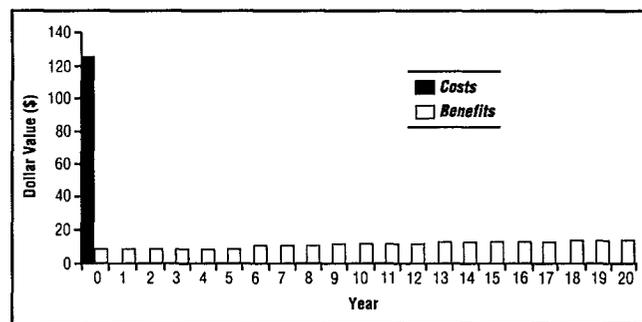
Figure 2.1 graphs the costs and benefits of a typical BMP over a 20-year period. In this example, the costs of the BMP are incurred early (e.g., the cost of installing ULF toilets) and the benefits are realized over a number of years (e.g., annual water savings). According to the MOU, as described in Chapter 1, a BMP such as this is cost-effective if the present value of its benefits exceeds the present value of its costs. The CEA methodology provides a way to sum up this “stream” of benefits into its present value, and then to compare it to the BMP’s costs.

The fundamental equation to compare benefits and costs simply subtracts the present value of costs from the present value of benefits to get **Net Present Value (NPV)**:

$$\text{Net Present Value} = \text{Present Value Benefits} - \text{Present Value Costs} \quad (2.1)$$

NPV is positive when the present value of benefits exceeds the present value of costs—that is, when the BMP is cost-effective. The MOU relies upon this consistent and reliable measure when comparing

Figure 2.1
Streams of Costs and Benefits



costs and benefits.¹ Although this equation is simple, identifying, measuring, and valuing the costs and benefits that occur each year can be difficult.² CEA methodology provides a systematic way to accomplish these tasks.

The CEA methodology consists of four steps:

1. Identify costs and benefits
2. Measure and value costs and benefits
3. Discount costs and benefits
4. Analyze uncertainty

¹ NPV indicates not only *whether* a BMP is cost-effective, but also the *magnitude* of a BMP’s net benefits. For further discussion see E.P. Rothstein, “Benefit/Cost Evaluation of Water Conservation Programs,” *Proceedings of CONSERV96*, American Water Works Association, 1995.

² The MOU process is concerned primarily with prospective analysis (i.e., an examination of future costs and benefits of a BMP) rather than retrospective analysis (i.e., an examination of past cost and benefits). However, retrospective analysis helps support prospective analysis because the historical record can, with limitations, help predict future performance.

2.2 STEP 1: IDENTIFY COSTS AND BENEFITS

For purposes of evaluating BMPs, CEAs should identify all costs and benefits. This process helps indicate the full range of program effects even if they cannot all be quantified. Exhibit 3 of the MOU lists costs and benefits that each CEA should include (Table 1.3), but it does not exclude costs and benefits not found on the list.

Costs should be identified by determining the resources needed to implement a BMP. For example, customers participating in a conservation program need water conserving devices and someone to install the devices. Suppliers need the staff to design and run the program, as well as the conservation devices they distribute to customers.

Benefits should be identified by determining the positive consequences of a BMP, including the resources derived from its implementation. For example, participating customers spend less to purchase water, which frees up money for other purposes. Suppliers avoid construction of new facilities. Society benefits from conservation that saves energy and avoids environmental damage.

Life-Cycle Costs and Benefits. Costs and benefits associated with the BMP during its entire life span³—the full life-cycle of the project—should be identified. The analysis should also indicate the year in which these costs and benefits occur.

Intangibles. Costs and benefits can also include intangibles, such as the reduced or increased aesthetic value individuals may place on xeriscaping compared to conventional landscaping. Even though the dollar value of intangible costs and benefits cannot be easily quantified, they should nevertheless be identified by the CEA since the identification of real, but difficult to quantify, effects can provide additional information to help determine if a BMP should be implemented.

Perspectives for Identifying Costs and Benefits. CEA can be used to evaluate costs and benefits from the perspective of the total society *or* from the perspectives of subgroups of society. The MOU identifies different perspectives for CEA to answer questions about the distributional consequences (“winners and losers”) of water conservation programs. Five perspectives⁴ should be considered when identifying the costs and benefits of a BMP:

- Participating customer
- Nonparticipating customer
- Supplier without cost sharing
- Supplier with cost sharing
- Total society

Table 2.1 delineates cost/benefit categories relevant to each perspective for a typical conservation BMP. For purposes of the BMP exemption process (MOU Section 4.5, as described in Chapter 1, Section 1.3), the relevant perspectives are *supplier without cost*

³ A BMP project life span frequently is not the same as the period of depreciation for tax purposes.

⁴ The MOU, Exhibit 3, Paragraphs 3 and 4 lists costs and benefits from a *total society perspective*. Exhibit 3, Paragraphs 5 and 6 lists costs and benefits from the *supplier perspective*. Since Section 4.5(a)(ii) includes cost sharing with other program beneficiaries, the MOU also includes the supplier perspective *with cost sharing*. Exhibit 3, Paragraph 7(f) includes costs and benefits from the *customer perspective*. Although not explicit in the MOU, the customer perspective should distinguish between customers who participate in a program and customers who do not. Since these perspectives are defined specifically for the MOU, they are not necessarily the same as the “Standard Practice Manual: Economic Analysis of Demand Side Management Programs” by the California Public Utilities Commission and California Energy Commission (December 1987).

sharing, supplier with cost sharing, and total society. For more general purposes, economic efficiency can be evaluated using the total society perspective, financial feasibility can be evaluated using the two supplier perspectives, and distributional consequences can be evaluated using the two customer perspectives.

Transfer Payments. Identification of costs involves determining the resources needed to get the job done: materials, labor, energy, etc. However,

identifying costs may become more subtle when determining costs from the different perspectives of analysis. For example, a rebate is a cost from the perspective of the supplier but a benefit from the perspective of the participating customer. From the total society perspective, these equal costs and benefits sum up to zero. Such payments are referred to as **Transfer Payments.**

Table 2.1
Costs and Benefits from Different Perspectives

Costs	Perspective				
	Participating Customer	Non-participating Customer	Supplier	Supplier w/Cost Sharing	Total Society
Participant Program Costs: Eqpt. & Materials; Installation; Removal; Time required	X				X
Supplier Program Costs: Capital Eqpt. & Materials; O & M; Installation; Labor; Removal; Program Admin.; Publicity; Surveys; Evaluation; Environmental Regulations Compliance			X	X	X
Financial Incentives			X	X	
Increased Water Bills		X			
External Costs: Other Utilities (water, wastewater and electricity) and their Customers				X	X
External Environmental Costs			X	X	X
Benefits	Participating Customer	Non-participating Customer	Supplier	Supplier w/Cost Sharing	Total Society
Reduced Water, Wastewater, and Energy Bills	X	X*			
Financial Incentives	X				
Avoided Supply Costs: Admin.; Labor; Capital Eqpt. and Materials; O & M; Chemical Processing; Pumping; Energy; Installation; Environmental Regulations Compliance			X	X	X
External Benefits: Other Utilities (water, wastewater and electricity) and their Customers				X	X
External Environmental Benefits			X	X	X
System Reliability**	X	X	X	X	X

*Note that a nonparticipating customer may face a higher or lower water bill as discussed more fully in the text.
**System reliability benefits should not be double counted with avoided supply costs; see text for further discussion.

Cost Categories. Table 2.1 identifies six cost categories common to most BMPs:

- **Participant Program Costs** are costs of the BMP covered by participating customers. They include the cost of equipment and materials and the time required to install equipment or to arrange for its installation.
- **Supplier Program Costs** are costs of the BMP covered by the water supplier. They include costs associated with capital, equipment, materials, operation and maintenance, installation, labor, removal, program administration, publicity, surveys, evaluation, and compliance with environmental regulations.
- **Financial Incentives** are payments or subsidies paid by the supplier to customers to encourage water conservation. The MOU (Exhibit 3, Paragraphs 3 and 4) specifically excludes financial incentives from the total society perspective because they are considered transfer payments. However, the delivery and financing costs of the financial incentives should be included as a cost from the supplier perspective.
- **Water Bills** will differ for participating and for nonparticipating customers. Conservation may change who pays what—e.g., participants may pay less and nonparticipants may pay more. Nonparticipating customers, at least in the short run, may face increased water bills due to higher rates, unless they find new ways to conserve.⁵

- **External Costs** are those faced by society but not accounted for in the market place, by the supplier conducting the CEA or its customers. They include costs to other utilities and their customers. For example, groundwater pumping at one site may increase pumping costs at other sites in the same groundwater basin.
- **External Environmental Costs** are the harmful effects to the environment not accounted for in the market place and not controlled or mitigated by environmental regulations. For example, indoor conservation programs may increase the concentration of pollutants in wastewater. External environmental costs may exist if, as a result, wastewater treatment effluents have increased pollutant concentrations.

Benefit Categories. Table 2.1 identifies six benefit categories common to most BMPs:

- **Utility Bill Benefits** include reduced water, energy, and wastewater bills that result from decreased water use. Participating customers are most likely to face reduced overall water bills, even if rates increase, because the BMP allows the participant to decrease water consumption. Nonparticipating customers may also face reduced water bills over time, when BMPs are cost-effective (see Footnote 5).
- **Financial Incentives** are payments to customers to encourage participation in the BMP. To the participating customer, the

⁵ Conservation programs do not *necessarily* increase water rates. If the supplier's costs are reflected in the rate structure, costs of conservation programs may add upward pressure to rates, at least in the short term. However, *cost-effective* conservation *reduces* supplier costs and revenue requirements over time. Examples in Chapter 4 illustrate conservation programs that reduce costs over their effective life.

benefit of the financial incentive is accrued at the expense of the supplier. This benefit, however, is offset to the extent that the customer may pay part of the cost of the incentive through future increased water bills.

- **Avoided Supply Costs** are benefits that result from deferring, eliminating, or down-sizing projects to provide future water supply. These can be measured in terms of avoided costs of capital equipment and materials, operation and maintenance, chemical processing, pumping, energy, installation, and compliance with environmental regulations. Avoided supply costs may also include reduced water purchases.
- **External Benefits** are those enjoyed by society but not accounted for in the market place by suppliers or customers, including benefits to other utilities and their customers. For example, conservation programs aimed at one region may reduce water use in a neighboring region.
- **External Environmental Benefits** are the beneficial effects on the environment caused by BMPs that are not accounted for in the market place. For example, long term conservation may increase instream water flows due to reduced water diversions. CEAs from the total society perspective should include external costs and benefits, including external environmental costs and benefits. CEAs from the supplier's perspectives should also include external environmental costs and benefits.⁶

- **System Reliability benefits** include the value of decreased probability and severity of water shortages. All customers and the total society may benefit from improved system reliability. Note that from the supplier perspective, a conservation program is unlikely to both avoid supply costs and improve system reliability. Although Table 2.1 shows supplier perspective avoided supply costs and system reliability benefits, it is more likely the program will have one or the other benefit, or one benefit in the short term and another in the long term.

Table 2.1 does not include **Taxes and Subsidies** for water supply projects since these constitute transfer payments from the perspective of the total society. However, CEAs may include taxes and subsidies (on both costs and benefits) when computing costs and benefits from the supplier and customer perspectives.

Table 2.1 also does not include **Sunk Costs**. These costs have already been incurred and are not reversible. For example, most engineering design costs are sunk costs once they have been paid for. Unlike land or equipment, they cannot be sold to someone else. CEAs should not include costs once they have been sunk.

Long Run Costs and Benefits. In the **Short Run**, costs can be **Fixed Costs**, such as capital equipment costs, or **Variable Costs**, such as pumping and chemical treatment, which increase with increases in water production. In the **Long Run**, in contrast, *all costs are variable*. For example, over a short time horizon, the capacity at existing supply and treatment

⁶ The MOU, Exhibit 3, specifies that environmental costs and benefits should be included in CEAs conducted from both total society and supplier perspectives. The MOU has been interpreted to include the same scope of environmental costs and benefits in the supplier perspective CEAs as for total society perspective CEAs.

facilities is all that is available to meet peak demand. However, over a long time horizon, capacity can be increased by building new facilities and demand can be decreased by improving conservation infrastructure. *Since the MOU specifies that BMPs are "intended to reduce long term urban demands,"⁷ CEAs should be conducted with a long run time horizon where all costs are variable (both capital and O&M costs).*

Water Rates. Some costs and benefits depend on changes in water bills resulting from changes in water rates related to conservation BMPs. Conservation programs may have widely varying impacts on rates depending on the particular supplier and ratemaking process. To put different suppliers on equal footing for the purpose of CEA under the MOU, *CEAs should assume that rates are adjusted to recover supplier costs fully in the year the costs are incurred.* For example, in the first year of a program, costs to the supplier are likely to be greater than benefits to the supplier, necessitating an increase in rates to fully recover costs.⁸ Nonparticipating customers would face higher rates and higher bills if they did not conserve. Participating customers conserve, which offsets the higher rates. In later years, the supplier benefits of a BMP will add up and, when cost-effective, exceed the supplier costs, permitting rates to decrease from what they otherwise would have been. Even nonparticipating customers would eventually face lower bills if conservation benefits exceed costs over time.

Lost Revenue. CEAs should not include revenue "lost" from reduced water sales as a cost of a BMP for the following reasons: From the perspective of the

total society, lost revenue is a transfer payment and should not be included in a CEA. The revenue "lost" by the supplier is "gained" by the customer. From the perspective of the supplier, lost revenue is not a transfer payment, but since costs are recovered with rate changes, there is no net loss to the supplier. BMPs are effectively long term supply measures and the assumption that conservation causes unrecoverable lost revenue in the long term is an unlikely planning assumption.⁹ For regulated water utilities, the Public Utilities Commission determines the recoverability of lost revenue resulting from conservation measures.

2.3 STEP 2: MEASURE AND VALUE COSTS AND BENEFITS

Measuring Costs and Benefits. To measure costs, one must count up the resources needed to implement the BMP. These may include, for example, the number of labor hours to conduct water surveys and the number of low flow fixtures installed. To measure benefits, one must count up the savings, usually in their physical units of measurement, that result from implementing the BMP. These may include acre-feet of water saved, gigawatt hours of electric energy saved, and acre-feet of wastewater treatment that is avoided.

CEAs should document in detail the data or studies on which cost and benefit calculations rest. When benefit estimates derive from a statistical study, the CEA should provide sufficient information for an independent observer to determine whether the

⁷ See, for example, MOU, Page 2, Recital B, reproduced in Chapter 1 of this document.

⁸ To the extent that the supplier does not capitalize the costs of the conservation program, this guideline suggests the supplier will face abrupt rate adjustments. If the costs of the BMP are capitalized, the rate adjustment would be modest and spread out over a number of years.

⁹ While water utilities may incur additional planning expenses to incorporate projected demand reductions into projected water sales, such indirect costs are difficult to document.

sample is representative, whether the results are statistically significant, and whether estimates were properly extrapolated.

CEAs should measure **Incremental Costs and Incremental Benefits**. These are determined by comparing the costs and benefits that would occur if the BMP were implemented with the costs and benefits that would occur if it were not implemented. Incremental costs and benefits do not include future costs and benefits that would occur even if the program is not implemented. For example, some customers will install ultra low flush toilets without a BMP to encourage it.¹⁰ To estimate a BMP's incremental water saving benefits, one must estimate the average savings of nonparticipating customers and subtract them from average savings of participating customers to arrive at net savings produced by the BMP. For example, Exhibit 6 of the MOU lays out a detailed method and example for determining incremental savings from BMP 16, including determination of the natural rate of replacement and the additional (incremental) savings from retrofit on resale. This method can be applied to other BMPs where the natural rate of replacement is relevant.

To determine the benefits of a BMP, suppliers should **Measure the Water Saved** through the BMP. Use of existing customer billing records is the easiest and least expensive method of collecting data needed to estimate water savings. Because these data are created, collected, and maintained for purposes other than measuring water savings, two caveats are in order.

First, many utilities read their meters on a continuous cycle. Consequently, measures of water use will generally not coincide with calendar months. This

creates problems of time aggregation. To address the time aggregation problem, the total amount of water consumption at a particular meter reading should be divided by the number of days since the previous meter reading to provide a consistent measure of daily use.

Second, meter readings may produce "noisy" data, which should be recognized and addressed by using:

- Large sample sizes whenever possible
- Data quality control for a small samples of customers
- Robust statistical techniques (such as a trimmed mean).

When all other things are equal, conservation boosts **Reliability**. By decreasing demand, BMPs increase the buffer between supply and demand and, therefore, reduce the probability of shortage. It is important not to double count reliability benefits and avoided supply costs. For example, if conservation savings are "banked" (not used to meet additional demand) then the BMP is not reducing the need for new supply sources. Alternatively, if conservation savings are used to meet increasing demand and reduce the need for new supply sources, then the BMP does not improve reliability. Measuring reliability requires probabilistic methods to determine how often supply is sufficient to meet demand, i.e., the distribution of water shortages. Because weather drives both water supply and water demand, the two distributions are not independent and should be modeled together.

By saving water, long term conservation measures such as the BMPs may also reduce the water savings potential for *short term demand management* strategies

¹⁰ Such customers are termed "free-riders" in the jargon of demand-side management. All new toilets sold in California are required to meet ultra-low flush standards.

used during water shortages.¹¹ This phenomenon, known as Demand Hardening, rests on the fact that the same water cannot be “saved twice”—once for long term conservation BMPs and then again during a drought. CEAs should measure the long term conservation savings from BMPs and not double count savings from short term demand management.¹²

Valuing Costs. The MOU’s requirements for CEA rely on the most fundamental criterion of economic value: net benefits—defined as benefits minus costs. Hence, CEAs should value costs and benefits in **Dollars** whenever possible. Valuation in dollar terms makes different types of costs and benefits commensurate with each other so they can be summed and compared.

Most often, CEAs should at least begin by using prevailing **Market Price** as the dollar value of costs.¹³ These are the prices of materials, labor, and capital purchased in their respective markets. For example, to the customer who has to pay part of the installation cost of a conservation device, costs should usually be valued as the price paid. Likewise, to a supplier, costs such as capital equipment and labor should usually be valued as the price paid.¹⁴ In the case of property that is already owned, or that has been otherwise acquired without a purchase price (e.g., a donation), market

price can be determined by looking at the market price of similar items bought and sold, preferably in the same region. For the perspectives of customers and taxed suppliers, taxes can be calculated using taxes on comparable assets.

The price of labor often includes **Overhead Costs**, which refer to indirect costs not attributable to salary. Usually expressed as an average rate—the overhead rate—overhead often does not indicate the true costs of labor services. Indeed, overhead rates sometimes subsidize activities or administration not associated with the service in question. Whenever possible, newer cost accounting concepts—like activity-based costing—should be used.¹⁵

Since programs designed and implemented by suppliers to fulfill a BMP may take many forms (e.g., education, incentives, or regulation) and may take place in different circumstances, there may be important differences in program costs. The costs measured and valued for a BMP should be those of the program **Design and Implementation** under consideration. The program design should be explicitly stated when conducting a CEA.

CEAs should count **Financing Costs** in the year in which they must be paid.

¹¹ See Tabors Caramanis and Associates (1994), “Long-Term Water Conservation & Shortage Management Practices: Planning that Includes Demand Hardening,” Davis, CA, June. Prepared for California Urban Water Agencies, Sacramento.

¹² CEAs should not consider demand hardening a direct cost of a BMP because conservation improves reliability. Thus, though conservation can increase customer shortage costs when a shortage occurs, long term water conservation makes these shortage events less likely.

¹³ Formally, the costs of a BMP should be valued by examining the value of the next best use of the resources needed to implement the BMP—their Opportunity Costs.

¹⁴ Caution is in order when prices do not reflect the costs of the additional item being purchased. For example, prices sometimes reflect cross-subsidies from one product to another. If a supplier sells water at less than cost to one set of customers and more than cost to another set of customers, then the price of water does not reflect its opportunity cost.

¹⁵ For a quick introduction to evaluating conservation program savings and practical recommendations for estimating program costs, see D. Pekelney et al., “Cost-Effective Cost-Effectiveness: Quantifying Conservation on the Cheap,” Presented at the June 26, 1996 at the AWWA national conference in Toronto.

Valuing Benefits. Market prices also provide data for estimating the dollar value of benefits as long as the goods and services being valued are traded in a market.¹⁶ When markets do not exist, alternative methods should be used, such as those discussed below and in Appendix A for external environmental costs and benefits.

The **Value of Conserved Water** can include the avoided costs of water supply, avoided environmental costs, avoided costs of wastewater treatment, improved reliability, and avoided energy costs:

- **Avoided Water Supply Costs** should be determined by identifying the new supply project that is deferred, downsized, or eliminated because of the conservation effort. This supply project must be a realistic alternative to the BMP. New water supplies will be needed in California and most likely they will cost more than existing supplies. To value water conserved in a particular year, the most costly of the supply sources planned for that year should be used.

Costs of avoided supply projects should be expressed as **Marginal Costs**—the cost for each additional acre-foot of water supplied. Marginal cost is comprised of **Marginal**

Operating Cost (energy, labor, chemicals, etc.) and Marginal Capacity Cost (capital equipment and facilities).¹⁷ Since many storage, treatment, and distribution facilities are designed to handle peak flow, marginal costs of supply can be higher during peak periods.

If the highest cost source of supply to a supplier comes from a wholesaler, the marginal cost from the *supplier perspective* is the rate paid to the wholesaler. Often, a wholesaler's rates reflect the average cost of all the existing wholesaler's supplies; these rates would not fully reflect the *total society's* marginal costs of new supply. From the *total society perspective*, the marginal cost should be the highest cost of planned new supply to the wholesaler.

New water supply sources tend to be more costly than existing ones for two major reasons. First, the least costly water supplies have already been tapped. Second, future water supply infrastructure will be built to meet increased performance standards, which in turn leads to greater costs. These increased performance standards result from concerns about environmental conservation,

¹⁶ Formally, the value of benefits should reflect **Willingness-to-Pay**, measured by the value that individuals would pay to enjoy particular benefits.

¹⁷ Avoided costs in this context does not refer simply to the cost of current supply sources, but instead includes the new sources of supply needed and planned for the future that can be deferred, downsized, or eliminated. Determining the marginal cost of additional water supply can be a challenging task. For more information, see Chesnutt et al. (forthcoming), "The CUWCC Handbook for Designing, Evaluating, and Implementing Conservation Rate Structures," A & N Technical Services, Inc., especially Appendix C, prepared for the California Urban Water Conservation Council; J.A. Beecher and P.C. Mann (1991), "Cost Allocation and Rate Design for Water Utilities, National Regulatory Research Institute, Report Number NRRI 90-17; R.E. Burns et al. (1982), "The Appropriateness and Feasibility of Various Methods of Calculating Avoided Costs," National Regulatory Research Institute, Report Number NRRI 92-2; and Maddaus et al. (forthcoming), "Integrating Water Conservation into Water Supply Planning," *Journal AWWA*. A practical approximation for marginal capacity costs known as *average incremental costs* can be determined by calculating the annualized capacity cost with the following formula and then dividing by annual water production:

$$K = \frac{C \times i \times \{1 + i\}^n}{(1 + i)^n - 1}$$

Where K is annualized capacity cost, C is total capital expenditure, n is life span, and i is interest rate.

reliability, risk management, and earthquake resistance. It is preferable to project these future costs based on a project-by-project cost accounting. When this detailed information about the cost of supply alternatives is unavailable, CEAs should use an **Escalation Rate**. An escalation rate is the average rate of increase in the inflation-adjusted future cost of water; it is the real increase in the value of water saved.¹⁸

Information on planned sources of water supply can be obtained from supplier planning documents, long term budget projections, rate studies, and from interviews with supplier engineering staff. Table 2.2 contains example costs of planned water supply sources for one local supplier and one regional wholesaler.

When identification and valuation of the avoided water supply is not possible, CEAs should use the estimates of the marginal costs of water published by the California Department of Water Resources.¹⁹

- The **Avoided Cost of Wastewater Treatment** is another component of the value of conserved water for many indoor conservation measures.²⁰ The avoided cost of waste-water treatment is the avoided (long run) capital and O&M treatment costs per acre-foot

Table 2.2
Sample Supply Costs

Marin Municipal Water District	Metropolitan Water District of So. California
\$1241/AF Phase V: Recycling and In-System Improvements	\$230/AF Colorado River Aqueduct Development
\$1224/AF Phase III: Pipeline Improvements and Recycling	\$300/AF Storage
\$1316/AF Phase IV: Recycling and Pipe Improvements	\$320/AF Low Cost Transfers
	\$330/AF State Water Project
	\$390/AF Low Cost Reclamation
	\$420/AF High Cost Transfers
	\$595/AF High Cost Reclamation
	\$700/AF Groundwater Recovery
	\$740-1550 Ocean Desalination

Source: "Urban Water Management Plan," Marin Municipal Water District, 1995; "Southern California's Integrated Water Resources Plan," Metropolitan Water District of Southern California, 1995.

of water saved.²¹ If the supplier or customer pays another utility for wastewater treatment, their avoided costs are the rate payments avoided by reducing wastewater. Wastewater treatment costs and rates may be determined by hydraulic loading or solids loading. Wastewater treatment costs have been a deciding factor in a number of important conservation programs.

- The benefits of **Improved System Reliability** derive from the decreased probability and severity of shortages, which impose costs on customers and suppliers. Since long term conservation is one way to improve system

¹⁸ The escalation rate accounts for expected cost increases due to increases in real resources needed to complete the project. For example, new projects may have more concrete, thicker walled pipes, or longer distances to pump. Escalation should be distinguished from inflation, which refers to changes in the prices of these resources, which tend to increase over time. For example, the price per foot of the same heavy walled pipe may rise over time due to inflation, even without changes in manufacturing or materials. However, the real (inflation adjusted) cost remains constant without such changes. Escalation is calculated as $B_t = B_0 \times (1 + e)^t$ where B_t is the escalated benefit in year t ; B_0 is the benefit in year 0, and e is the escalation rate.

¹⁹ For example, see "Water Plan Service Area Information," California Department of Water Resources, August 1990.

²⁰ Note that the avoided costs of wastewater treatment from the total society perspective may be relatively small because wastewater plants are designed to handle wet weather flows and solids loading. Wet weather flows from leaks and illegal intrusion dominate designed capacity requirements compared to conservation. However, if the customer or supplier pays for wastewater per volume measure, from the customer or supplier perspective, avoided costs of wastewater treatment may be large—conservation reduces waste water volume.

²¹ Marginal capacity costs can be calculated using the average incremental cost method described above for avoided water supply costs. To the extent that real costs are expected to rise over time, project-by-project accounting or an escalation rate should be applied as for avoided water supply costs.

reliability, avoided shortage costs constitute a valuable benefit to customers from BMPs. Several methods have been used to value improved system reliability.²² A practical, though imperfect, working assumption for valuing reliability without double counting is to assume that the *value of improved reliability is implicit in the valuation of avoided new supply sources.*

- Although the avoided costs of water supply, avoided cost of wastewater treatment, and the value of improved reliability are important, willingness to pay for saved water may extend beyond these items. The value of saved water, ideally, should include the entire willingness to pay for conservation, which may include, for example, energy savings and intangibles.

External Environmental Costs and Benefits.

External environmental costs and benefits constitute a special class of externality because they are often difficult to identify, measure, and value.

For BMPs in California, external environmental effects often occur outside the boundaries of the supplier's service area but within the state. Therefore, a statewide perspective is likely to be adequate for determining most environmental costs.

To measure external environmental costs or benefits, the CEA should estimate what would happen with and without the BMP, and this involves judgments concerning how both natural and social systems react to changes. For example, in the absence of groundwater pumping by the utility, what groundwater pumping by other parties would have occurred, and how would this have affected the water table? Whenever assessments rely on such judgments, they must clearly state their underlying assumptions.

Since external environmental costs and benefits are generally not bought and sold in markets, market price cannot be used for valuation in dollar terms. To value external environmental costs or benefits, one of two approaches should be used:

- Willingness to pay (WTP). This is the amount an individual would be willing to pay to obtain the benefit or to avoid the cost.
- Willingness to accept (WTA). This is the amount one would have to pay an individual to forego the benefit or to avoid the cost.

When assessing WTP or WTA, economists typically blend economic theory and statistical analysis of economic data. In general, the methods all require the use of data specific of the item being valued.²³ For these reasons, if an external environmental valuation

²² Two recent reports sponsored by the California Urban Water Agencies have measured and valued shortage costs for industrial and residential customers: "The Cost of Industrial Water Shortages," Spectrum Economics (1991); "The Value of Water Supply Reliability: Results of a Contingent Valuation Survey of Residential Customers," Barakat & Chamberlin (1994a).

²³ Four main methods are used: *travel cost, averting expenditures, hedonic pricing, and contingent valuation.* A fifth method, known as *benefits transfer*, extrapolates an existing estimate of value for some other item in order to value the particular item of interest. For this to produce satisfactory results, there must be an existing study "on the shelf," and it must match the item of interest reasonably closely. These are quite stringent conditions that often fail to hold. Values tend to be highly specific to both particular items and particular groups of people. Extrapolating from one group of people to another, or from one point in time or one set of circumstances to another, is something of a leap of faith. For an example of the contingent valuation method used to value riparian wetlands, see C.L. Lant and R.S. Robert, "Greenbelts in the Cornbelt: Riparian Wetlands, Intrinsic Values, and Market Failure," *Environment and Planning A*, Vol. 22, 1990. Examples of the travel cost method include L.D. Sanders, R.G. Walsh, and J.R. McKean, "Comparable Estimates of Recreational Value of Rivers," *Water Resources Research*, Vol. 27, No. 7, July 1991, and "Recreation Forecasts and Benefits Estimate for California Reservoirs: Recalibrating the California Travel Cost Model," Spectrum Economics, Prepared for the Joint Agency Recreation Committee, July 1991.

exercise is conducted, the analysis should be carefully tailored to the particular circumstances involved.²⁴ The details of assessing WTP or WTA are complex and involve a number of technical methods that are described and discussed in Appendix A.²⁵

Even with substantial resources, it is often difficult and time consuming to reliably measure and value external environmental costs and benefits. In lieu of measurement and valuation of external environmental costs and benefits, the following guidelines should be pursued:

- **Screening.** Assess the need to measure and value external environmental costs and benefits. If a BMP is cost-effective (benefits greater than costs) before external environmental benefits have been included, then there is no need to measure and value external environmental costs and benefits.²⁶
- **Break-Even Analysis.** Calculate the break-even value and make a judgment about its importance. If a BMP is not cost-effective (costs greater than benefits) before external environmental benefits have been included, calculate the difference between costs and benefits (the break-even value). Then make a judgement about whether the break-even value is important by comparing it to the
- **Environmental Externality Description.** Describe external environmental benefits of the BMP by: 1) identifying sources of new water supply planned that would be reduced during the period of analysis by implementing the BMP; 2) measure or otherwise quantify (as described above) these water savings; 3) identify and list external environmental costs of the new water supply sources (the external environmental benefits associated with conservation).

When identifying and describing external environmental benefits of conservation, it is important to determine the source of the avoided water supply. Table 2.3 shows the different types of environmental benefits associated with different supply sources.²⁷

²⁴ With electricity, some PUCs have attempted to develop data bases on environmental values tailored to the circumstances of their state. These have generally involved quite extensive efforts of research and data collection. Even then, there have been failures where the resulting analysis has been considered too generic to be credible. The "environmental adders" approach involves adding these type of external environmental values to the normal O&M and capital cost estimates for a project to capture the external environmental costs or benefits associated with the project.

²⁵ The choice of whether to employ WTP or WTA depends conceptually on a value judgement of the allocation of property rights associated with environmental quality; see Hanemann (1987) for further discussion. Practically, WTA is considered to have greater difficulties in empirical estimation than WTP.

²⁶ A exception to this conclusion is when there is reason to believe external environmental costs of a conservation measure might be substantial enough to outweigh external environmental *benefits*.

²⁷ For additional description of environmental issues see, for example, "California Water Plan Update, Volume 1," Bulletin 160-93, California Department of Water Resources, October 1994.

Table 2.3
Typical External Environmental Benefits of Conservation

Bay-Delta Estuary	Eastern Sierra	Groundwater
<ul style="list-style-type: none"> • Fish populations, including their migration routes and spawning areas (e.g., salmon, steelhead, delta smelt species) • Riparian vegetation and wildlife • Marshlands • Reduced salt water intrusion 	<ul style="list-style-type: none"> • Mono Lake (e.g., shrimp, bird populations, alkali dust storms) • Stream fish populations • Owens Lake/River 	<ul style="list-style-type: none"> • Fewer low water tables • Reduced land subsidence • Reduced contamination from salt water intrusion

2.4 STEP 3: DISCOUNT COSTS AND BENEFITS

The method of discounting enables CEA to compare costs and benefits incurred and realized at different points in time. This method converts the "streams" of costs and benefits over time into their equivalent present day value, and sums them up. The MOU defines a cost-effective BMP as one that has present value of benefits greater than the present value of costs. The present value of benefits and the present value of costs should be calculated as follows:

$$PresentValueBenefits = \sum_{t=1}^n \frac{Benefits_t}{(1 + DiscountRate)^t} \quad (2.2)$$

$$PresentValueCosts = \sum_{t=1}^n \frac{Costs_t}{(1 + DiscountRate)^t} \quad (2.3)$$

In equations 2.2 and 2.3, $Benefits_t$ are benefits in year t ; $Costs_t$ are costs in year t ; n is years in the period of analysis, and "year" refers to a calendar year. For example, benefits and costs that occur immediately at the outset of the program accrue in "year zero" ($t=0$).²⁸ Benefits and costs that occur during the first year of the program accrue in "year one" ($t=1$), etc.

The discount rate depends on whether the benefits and costs are measured in real (adjusted for inflation) or nominal (not adjusted for inflation) terms. Costs and benefits should be valued in either real or nominal terms—not a combination of the two. If costs and benefits are in real terms, a real discount should be used. If costs and benefits are in nominal terms, a nominal discount rate should be used.²⁹

Since typical BMP costs tend to concentrate in the early years and benefits are spread out over the entire life span of the project, the discount rate has a particularly important impact on conservation benefits. Since discounting greatly influences the outcomes of CEAs, one should carefully document reasons for choosing particular discount rates. In addition, one should choose the relevant discount rate for each perspective of analysis: total society, supplier, and customer.

²⁸ The first year of the program (or the last year of construction if relevant) is year zero. If the construction period exceeds one year, construction years are identified as year 0 ($t=0$, the last year of construction), year -1 ($t=-1$), year -2 ($t=-2$), etc.

²⁹ Real and nominal discount rates can be converted as follows:

$$d = (r - i) / (1 + i)$$

where d is the real discount rate, r is the nominal discount rate, and i is the expected inflation rate.

Total Society Perspective. CEAs conducted from the total society perspective should select a discount rate³⁰ equal to the expected U.S. Treasury borrowing rate on marketable securities with maturity comparable to the period of analysis, according to the most recent OMB Circular A-94.³¹ Table 2.4 presents real and nominal expected interest rates reported for securities of three, five, seven, 10 and 30 years. Note that these values are updated annually by OMB. CEAs with different periods of analysis should use a linear interpolation of these rates. For example, a four year project should be evaluated at 4.35 percent real rate (8.0 percent nominal).

Supplier Perspective. Analyses of costs and benefits from the supplier perspectives should choose a discount rate based on the supplier's cost of capital. The discount rate should be the real borrowing rate on marketable securities with maturity comparable to the period of analysis. Analyses that use nominal costs and benefits should use nominal rates. The tax-exempt rate should be used if the supplier does not pay federal tax on its bonds.

Customer Perspective. Analyses of costs and benefits from the *customer perspective* should use the approximate marginal pre-tax rate of return on an

average investment in the private sector as published in the most recent OMB Circular A-94. This discount rate is seven percent (real) as reported in the latest OMB Circular.³²

Table 2.4
Interest Rates on Treasury Notes and
Bonds of Specified Maturities

Real Interest Rates (percent)				
3-year	5-year	7-year	10-year	30-year
4.2	4.5	4.6	4.8	4.9
Nominal Interest Rates (percent)				
3-year	5-year	7-year	10-year	30-year
7.3	7.6	7.7	7.9	8.1

SOURCE: Circular No. A-94, "Benefit-Cost Analysis of Federal Programs: Guidelines and Discounts," Appendix C, Office of Management and Budget, Washington, D.C., revised January 1995.

Sensitivity Analysis. Because discount rates constitute an important source of uncertainty in CEA, sensitivity analyses should be conducted to test results over a range of discount rates by perspective. The following ranges are expressed as real rates:³³

³⁰ The basic concept underlying the literature on public sector discounting is that economic welfare is directly determined by consumption and only indirectly by investment. (See OMB, 1996). Costs and benefits related to investment should be converted into equivalent consumption. In practice, this results in a complex procedure known as the "shadow price of capital" approach. For water conservation investments, several conditions eliminate the need for this procedure, which involves adjusting costs and benefits by the fraction of private investment displaced by the project or the fraction of benefits that contribute to private capital. First, most of the benefits of water conservation are avoided costs (e.g., avoided costs of new water supply). When benefits are avoided costs, their financing is similar to the initial project costs. Second, with high capital mobility in an open economy, public investment will not substantially impact private capital markets. Under these conditions it is appropriate to discount with the "social rate of time preference" approach; a calculation of positive (or negative) net present value will stay positive (or negative) regardless of fractional adjustments to account for private investment. (See Zerbe and Dively, 1995). The expected real rate of return on treasury bonds described above is a practical discount rate for society perspective CEAs.

³¹ This rate is computed using the President's economic assumptions for the budget. The rate is published in January of each year in Appendix C of Circular No. A-94, "Benefit-Cost Analysis of Federal Programs: Guidelines and Discounts by the Office of Management Budget." Copies are available from the OMB Publications Office (202/395-7332).

³² See OMB Circular A-94 (1992a; 1995).

³³ These discount ranges are suggested to reflect the range of uncertainty. For example, the Congressional Budget Offices utilizes sensitivity analysis of plus and minus 2 percent (Lyon 1990). Consumer behavior exhibits wide ranges in time preferences (Hartman and Doane 1986) and supplier finance opportunities may vary considerably (AWWA 1988).

- For total society perspectives: test at plus and minus 2 percent
- For supplier perspectives: test at plus and minus 2 percent
- For the customer perspectives: test at plus and minus 4 percent

Project Life Spans and Period of Analysis. CEAs should use project life spans as the period of analysis when determining costs and benefits. If a supplier plans to implement a series of conservation measures to fulfill a BMP (e.g., landscape audits, followed by additional audits every four years), then the period of analysis should include the entire planned project (e.g., 12 years if two follow-up audits are planned).

If two projects with different life spans need to be compared, they must be assessed on equal terms before a valid comparison can be made. Several methods exist for comparing projects with different life spans, including replication, equivalent annuities, assigning a terminal value, and best available alternative rate.³⁴ When comparing two projects with different life spans using these methods, the same discount rate should be used for both projects, selected to be comparable to the period of analysis. For example, comparison of a ULF toilet program that lasts 20 years with an audit program replicated every four years over the 20 year period should use the discount rate appropriate for a 20 year period of analysis. The analysis should not use a 20 year discount rate for the ULF toilet program and a four year discount rate for the audit program.

2.5 STEP 4: ANALYZE UNCERTAINTY

In analyzing uncertainty, CEAs should determine how different assumptions used in the calculations influence the predicted results. CEAs should also attempt to account for inherent variability in costs and benefits, especially when they result from shifts in weather and market forces.

Sensitivity Analysis. Where benefit or cost estimates heavily depend on certain assumptions, CEAs should make these assumptions explicit and, where alternative assumptions are plausible, carry out sensitivity analyses based on plausible alternative assumptions. If the results prove sensitive to alternative plausible assumptions, further efforts should be made to narrow the range of uncertain variables. Because the adoption of a particular estimation methodology sometimes implies major hidden assumptions, it is important to analyze estimation methodologies carefully to make hidden assumptions explicit.

For a BMP, CEAs should typically investigate the sensitivity to such variables as the discount rate, estimated program costs, and projected program benefits. Models used in the analysis, whether simple or complex, should be well documented and available to facilitate independent review. Sensitivity analysis can help identify the need for additional analysis.

Expected Values. The expected values of the distribution of costs and benefits can be obtained by weighing each outcome by its probability of

³⁴ See Zerbe and Dively (1994), Chapter 9.

occurrence, and then summing across all potential outcomes. If estimated benefits and costs are characterized by point estimates rather than as probability distributions, the expected value (an unbiased estimate) is the appropriate estimate for use.

Simulation. Simulation methods can be useful to explicitly characterize the sources, nature, and likely effect of uncertainties. The uncertainties surrounding key cost and benefit drivers should be specified and combined to examine their joint effect.

For example, simulation methods are required to tractably quantify the known time dependencies induced by the hydrological cycle. Traditional water supply augmentation alternatives, for example, are negatively correlated with weather induced demand fluctuations--hot and dry years tend to have higher water demand and lower realized water supply. Long term conservation programs, on the other hand, tend to be uncorrelated or positively correlated with demand or demand fluctuations. Thus, investment in

conservation Best Management Practices can lower both (1) the financial risks of society's water resource investment portfolio and, more importantly, (2) the outcome uncertainty of water resource investments (high future water demand implies greater conservation potential).

2.6 CONCLUSION

These CEA guidelines are designed to direct CEAs in a consistent and explicit fashion. This chapter has provided general guidelines that are applicable to all of the MOU's water conservation measures. The guidelines have covered each step of CEA methodology relevant to the MOU: Identify Costs and Benefits, Measure and Value Costs and Benefits, Discount Costs and Benefits, and Analyze Uncertainty. The next chapter provides guidelines that are specific to each of a selected set of BMPs and PBMPs.

CEA GUIDELINES FOR SPECIFIC BMPs AND PBMPs**3.1 INTRODUCTION**

Most of the methodology contained in Chapter 2's CEA guidelines is applicable to all BMPs and PBMPs. For example, identification of costs and benefits, valuing conserved water, discounting, and analyzing uncertainty are performed similarly for all conservation measures. There are, however, aspects of CEA methodology for specific BMPs and PBMPs that do not easily fit into the general guidelines because they are unique in some respect. This chapter contains CEA guidelines that are specific to individual BMPs and PBMPs. The BMPs and PBMPs covered include:

- BMP 1 Interior and Exterior Water Audits and Incentive Programs
- BMP 2 Plumbing, New and Retrofit
- BMP 3 Distribution System Water Audits, Leak Detection, and Repair
- BMP 5 Large Landscape Water Audits and Incentives
- BMP 9 Commercial, Industrial, and Governmental/Institutional Water Conservation
- BMP 10 New Commercial and Industrial Water Use Review
- BMP 15 Financial Incentives
- BMP 16 Ultra Low Flow Toilet Replacements
- PBMP 3 Replacement of Existing Water Using Appliances/Irrigation
- PBMP 4 Retrofit Existing Car Washes
- PBMP 5 Graywater Use

This chapter starts with a table of device life spans for BMP and PBMP conservation devices. Then, the chapter presents a section for each of the BMPs and PBMPs listed above. Each section includes a table with typical costs and benefits, and text describing CEA guidelines and issues related to the particular BMP or PBMP that do not fit into the general guidelines in Chapter 2.

3.2 DEVICE LIFE SPANS

A number of the BMPs rely on water conservation devices and landscape measures. In CEA, it is necessary to make an estimate or assumption about the life span of these devices and measures. Tables 3.1 and 3.2 below include life span assumptions for a number of these water conserving devices and landscape measures. The life spans serve as a starting point for CEA assumptions, or a default value in lieu of better data. All such assumptions should be evaluated to determine their applicability for a particular CEA and its circumstances. When a range of values is presented in these tables, the range indicates that life span can differ significantly depending on the particular circumstances. For example, a showerhead's effective life is higher in service areas where water quality is very high.

¹ As amended at the June 1996 CUWCC Plenary session.

Table 3.1
Device Life Spans: Indoor Residential and Commercial

Indoor Devices and Measures	Residential Life Span (Years)	Commercial Life Span (Years)
Ultra Low Flush Toilets	15-25	10-20
Toilet Displacement Dams or Bags	1.5	1.5
Low-Flow Showerhead	2-10	2-10
Low-Flow Faucet (i.e., Hospitals)	10-20	10-20
Faucet Aerator	2	1
Leak Detection Tablets and Leak Repair	1	1
Efficient Clothes Washer	12	2
Efficient Dishwasher	12	3-5
Metering Residential Water Use	15-20	15-20
Self-Closing Faucet	10-15	10-15

Table 3.2
Device Life Spans: Landscape

Landscape Measures	Life Span (Years)
Automatic Timer Shutoffs for Manual Hose Systems	2-5
Electronic Controllers and Automatic Valves, Residential	10-15
Irrigation Guides, Commercial/Multifamily	0
Landscape Water Management: Irrigation Audits, Commercial/Multifamily	5
Automatic Controllers and Valves, Commercial/Multifamily	10
Soil Moisture Sensors, Commercial/Multifamily	5
Xeriscaping, Residential/Commercial/Multifamily	10

3.3 BMP 1: INTERIOR AND EXTERIOR WATER AUDITS AND INCENTIVE PROGRAMS FOR SINGLE FAMILY RESIDENTIAL AND MULTI-FAMILY RESIDENTIAL GOVERNMENTAL/INSTITUTIONAL CUSTOMERS¹

“Implementation methods shall be at least as effective as identifying the top 20% of water users in each sector, directly contacting them (e.g., by mail and/or telephone) and offering the service on a repeating cycle; providing incentives sufficient to achieve customer implementation (e.g., free showerheads, hose and sprinkler timers, adjustment to high water use bills if customers implement water conservation measures, etc.). This could be a cooperative program among organizations that would benefit from its implementation.”

Identify Costs and Benefits

The method of contacting the top water users and the design of the audit program should be explicitly identified because different programs will have different costs. Since the BMP uses the qualifier “at least as,” there may be considerable differences in the design of conservation programs to fulfill this BMP. If there is a cooperative program among organizations, such as suggested in the BMP, costs and benefits to all of the cooperating organizations should be identified. Costs and benefits to organizations other than the supplier are “external” costs and benefits and, therefore, should be included in CEAs from the *supplier with cost sharing and total society* perspectives.

Although difficult to quantify, meeting organizational objectives other than saving water should be considered benefits. Audits can assist water suppliers in providing customer service, good will, and in response to customer bill complaints. See Table 3.3.

Measure and Value Costs and Benefits

When audits are performed by the staff of the supplier, costs should be valued by considering salaries, the relevant portion of overhead, and cost of materials. When audits are performed by contractors, cost estimates can be directly obtained from contracts.

If the CEA involves measurement of audit water savings, an attempt should be made to estimate and project the persistence of water savings. When the customer is not directly motivated to enact recommendations from a water audit, the achieved water savings may be much less, in magnitude and duration, than potential water savings.

Audit programs have been justified because they tend to produce water savings during periods of *peak* demand because outdoor savings tend to be higher during seasonal peak periods. Since capital expansion costs are often driven by peak design capacity, avoided costs measured and valued should consider the incremental reductions in peak demand.

Water suppliers may attach additional value, above and beyond water savings, to the customer outreach role played by water audit conservation programs. Since it is difficult to objectively measure and value such benefits, assumptions should be explicit, with justification, and tested for sensitivity.

¹ As amended at the June 1996 CUWCC Plenary session.

Table 3.3
BMP 1 Cost and Benefits

Interior and Exterior Water Audits and Incentive Programs			
Category	Costs	Data Needed	Data Sources
Participant Program Costs	<ul style="list-style-type: none"> • Cost of water audits to participating customer, including time and materials • Cost of device installation, if not fully subsidized 	<ul style="list-style-type: none"> • Retail prices • Share of costs paid by participant customer 	<ul style="list-style-type: none"> • Plumbing retailers • Plumbing installation services • Existing studies • Supplier planning departments
Supplier Program Costs	<ul style="list-style-type: none"> • Staff time to identify and contact top water users • Staff time to conduct audit • Incentive costs (showerheads, sprinkler timers, adjustment to bills) • Administration • Contractors • Marketing 	<ul style="list-style-type: none"> • Staff salaries and related overhead • Equipment purchase prices • Contractor rates • Media costs for marketing • Incentive size and structure 	<ul style="list-style-type: none"> • Supplier personnel and finance departments • Plumbing and landscape equipment wholesalers • Reports from similar programs • Contractors
Category	Benefits	Data Needed	Data Sources
Participant Benefits	<ul style="list-style-type: none"> • Reduced water, wastewater, and energy bills 	<ul style="list-style-type: none"> • Incentive size and structure • Data to measure water savings: toilet displacement device type, meter reading, climate, geographic, and demographic variables • Savings degradation rates • Water, wastewater, and energy rates data 	<ul style="list-style-type: none"> • Supplier billing systems and meter readings • Survey forms or calls • NOAA weather data • Billing rate forms • Reports of similar programs
Supplier Benefits	<ul style="list-style-type: none"> • Decreased capital costs for production, transport, storage, treatment, distribution, and wastewater treatment • Decreased O&M costs: energy, chemicals, treatment, labor 	<ul style="list-style-type: none"> • Data to measure water savings (above) • Capital cost data per capacity for construction of pipelines, pumping stations, treatment plants, and distribution systems • O&M cost data per unit water or wastewater 	<ul style="list-style-type: none"> • Planning documents • Construction and engineering cost estimation sources • Contractors and contractor estimates • Construction budgets • Equipment suppliers

3.4 BMP 2: PLUMBING, NEW AND RETROFIT

- a. *Enforcement of Water Conserving Plumbing Fixture Standards Including Requirement for Ultra Low Flow Flush ("ULF") Toilets in All New Construction Beginning January 1, 1992.*

Implementation methods shall be at least as effective as contacting the local building departments and providing information to the inspectors; and contacting major developers and plumbing supply outlets to inform them of the requirement.

- b. *Support of State and Federal Legislation Prohibiting Sale of Toilets Using More than 1.6 Gallons per Flush. [Status of BMP2b: Inactive. State legislation prohibiting sale of toilets using more than 1.6 gallons per flush was enacted in October, 1992.]*

- c. *Plumbing Retrofit.*

Implementation methods shall be at least as effective as delivering retrofit kits including high quality low-flow showerheads to pre-1980 homes that do not have them and toilet displacement devices or other devices to reduce flush volume for each home that does not already have ULF toilets; offering to install the devices; and following up at least three times."

Identify Costs and Benefits

BMP 2a and 2b are considered satisfied by state legislation that requires ULF toilets. Retrofit of existing devices (BMP2c) will include direct program costs in addition to supplier staff time. The CEA should identify and distinguish among retrofit kits with different components (e.g., shower heads and toilet displacement devices). See Table 3.4.

Measure and Value Costs and Benefits

Savings measurement should be made over time, where possible, to determine the persistence of savings and frequency of device removal or modification. If savings estimates are extrapolated from existing studies, efforts should be made to match components of the retrofit program. A difficulty of standards and codes is the enforcement required; if no other incentives are present, customers can remove or defeat some types of water efficient devices.

CEAs should make consideration of marketing costs explicit. The cost-effectiveness of plumbing retrofit programs can vary greatly depending on marketing costs. Considerable uncertainty exists about cost of attaining different levels of market penetration.

The CEA should include explicit consideration of wastewater costs. Plumbing retrofit programs save indoor water use and, therefore, usually have benefits of avoided wastewater costs.

Table 3.4
BMP 2 Cost and Benefits

Plumbing, New and Retrofit			
Category	Costs	Data Needed	Data Sources
Participant Program Costs	<ul style="list-style-type: none"> • Cost of retrofit kit and installation, if not fully subsidized, including time and materials 	<ul style="list-style-type: none"> • Retail prices • Share of costs paid by participant customer 	<ul style="list-style-type: none"> • Plumbing retailers • Plumbing installation services • Existing studies • Supplier planning departments
Supplier Program Costs	<ul style="list-style-type: none"> • Staff time to contact building departments, developers, and plumbing supply outlets • Retrofit kits: showerheads, toilet displacement devices, installation costs • Administration • Contractors • Marketing 	<ul style="list-style-type: none"> • Staff salaries and related overhead • Equipment purchase prices • Contractor rates • Media costs for marketing 	<ul style="list-style-type: none"> • Supplier personnel and finance departments • Plumbing equipment wholesalers • Reports from similar programs • Contractors
Category	Benefits	Data Needed	Data Sources
Participant Benefits	<ul style="list-style-type: none"> • Reduced water, wastewater, and energy bills 	<ul style="list-style-type: none"> • Data to measure water savings: toilet and displacement device type, meter reading, climate, geographic, and demographic variables • Rates of savings degradation • Water, wastewater, and energy rates data 	<ul style="list-style-type: none"> • Supplier billing systems and meter readings • Survey forms or calls • NOAA weather data • Billing rate forms • Reports of similar programs
	<ul style="list-style-type: none"> • Decreased capital costs for production, transport, storage, treatment, distribution, and wastewater treatment • Decreased O&M costs: energy, chemicals, treatment, labor 	<ul style="list-style-type: none"> • Data to measure water savings (above) • Capital cost data per capacity for construction of pipelines, pumping stations, treatment plants, and distribution systems • O&M cost data per unit water or wastewater 	<ul style="list-style-type: none"> • Planning documents • Construction and engineering cost estimation sources • Contractors and contractor estimates • Construction budgets • Equipment suppliers

3.5 BMP 3: DISTRIBUTION SYSTEM WATER AUDITS, LEAK DETECTION, AND REPAIR

"Implementation methods shall be at least as effective as at least once every three years completing a water audit of the water supplier's distribution system using methodology such as that described in the American Water Works Association's "Manual of Water Supply Practices, Water Audits and Leak Detection;" advising customers whenever it appears possible that leaks exist on the customers' side of the meter; and performing distribution system leak detection and repair whenever the audit reveals that it would be cost effective."

Identify Costs and Benefits

CEA of this BMP should include identification of the costs and benefits of implementing programs to audit, detect, and repair leaks in water distribution systems.² Water audit costs include the costs to systematically examine water distribution system records and control equipment to identify and quantify water (and revenue) losses. "Water losses, whether due to leakage, theft, under-billing of customers, or faulty control systems, represent monetary losses to the water agency."³ Leak detection usually utilizes listening equipment to locate underground or concealed leaks. Repair actions may include repairs of leaky pipes and valves, replacement of mains with history of serious leaks, annual exercise of valves, and corrosion control procedures.

Although the primary aim of this BMP is supplier system leak detection, customers may benefit or may face costs of leak repairs. See Table 3.5.

Audit program costs should include (where applicable): 1) analysis of supplier records of water supply and use; 2) staff and/or consultants to conduct audit; 3) verifying and updating system maps; 4) meter testing (master/source and sales meters); 5) verifying, quantifying, and updating water source inflow records, metered use records such as billing and accounting information, unmetered use records such as estimates of water use for parks, community centers, government facilities, and fire fighting; 6) field checking distribution controls and system operating procedures.

The primary benefit of early leak detection is the benefit of stopping the leak sooner than it would be otherwise. The water lost has a cost which includes pumping, purchase, and treatment. Leak repair keeps leaks from deteriorating into a large leak or system failure causing emergency conditions, both of which are much more expensive to repair. Many leaks are hidden and would go unnoticed for considerable periods of time without the leak detection program.

² For more background on leak detection and repair, see California Department of Water Resources (1986), "Water Audit and Leak Detection Guidebook," Office of Water Conservation, August, jointly sponsored with the American Water Works Association; and Moyer, E.E. (1985), "Economics of Leak Detection: A Case Study Approach," American Water Works Association.

³ California Department of Water Resources (1986).

Table 3.5
BMP 3 Cost and Benefits

Distribution System Water Audits, Leak Detection, and Repair			
Category	Costs	Data Needed	Data Sources
Participant Program Costs	<ul style="list-style-type: none"> Leak repairs (on customer's side of meter) 	<ul style="list-style-type: none"> Repair prices 	<ul style="list-style-type: none"> Plumbing repair services Existing studies Supplier operations departments
Supplier Program Costs	<ul style="list-style-type: none"> Audits: examination of system records and control equipment Leak detection: listening equipment and labor Leak repairs on supplier's side of meter Administration Contractors 	<ul style="list-style-type: none"> Staff salaries and related overhead Equipment purchase prices Contractor rates 	<ul style="list-style-type: none"> Supplier personnel and finance departments Leak detection equipment wholesalers Repair services Reports on similar programs from supplier operations departments Contractors DWR Leak Detection Program
Category	Benefits	Data Needed	Data Sources
Participant Benefits	<ul style="list-style-type: none"> Reduced water bills for leaks on customers side of meter Reduced frequency and cost of major leaks on customer's side of meter 	<ul style="list-style-type: none"> Data to measure water savings: meter readings Water rates data Cost of major leak repairs 	<ul style="list-style-type: none"> Supplier billing systems and meter readings Survey forms or calls Billing rate forms Reports of similar programs Repair contractors
Supplier Benefits	<ul style="list-style-type: none"> Decreased cost of large leak repairs and emergencies Decreased capital costs for production, transport, storage, treatment, distribution, and wastewater treatment Decreased O&M costs: energy, chemicals, treatment, labor 	<ul style="list-style-type: none"> Data to measure water savings (above) Capital cost data per capacity for construction of pipelines, pumping stations, treatment plants, and distribution systems O&M cost data per unit water or wastewater 	<ul style="list-style-type: none"> Planning documents Construction and engineering cost estimation sources Contractors and contractor estimates Construction budgets Equipment suppliers

Measuring and Valuing Costs and Benefits

Key variables to measure to determine leak detection costs include: wage rates of leak detection teams, the number of contact points to be surveyed, spacing of contact points to be surveyed, types of mains and services, accuracy of maps, and the type of leaks to be pinpointed. Sample equipment costs are presented in Appendix J of "Water Audit and Leak Detection Guidebook" by the California Department of Water Resources (1986). Leak detection costs are often expressed in dollars per mile of main surveyed.

The CEA should distinguish the incremental increase in leak detection due to the BMP from the ongoing leak detection that would occur otherwise. Leaks are found and repaired on an ongoing basis, even without a specific leak detection program. Some leaks would be found sooner or later—either by detection of a system failure or by a customer or member of the public noticing the leak. Since it is often difficult to estimate how much sooner leaks are detected, CEAs should be explicit about the assumptions that are used. For example, Moyer (1985) reports that it is often assumed that leak detection programs find leaks one year earlier than would be otherwise, that this figure is probably a low estimate, and that the figure is based on judgement rather than empirical data analysis.

Measuring the potential benefits of BMP 3, including reduction of water losses, should include quantifying water supply, authorized metered water

use, authorized unmetered water use, and then water losses. When quantifying water supply, select a period of analysis long enough to collect data on the total water system, which usually is at least one full year. Measurement error is possible and should be identified with meter testing. Meters with errors should be repaired and recalibrated.⁴ When analyzing meter data, it is important to make meter lag corrections by prorating metered water for overlapping months.⁵ Often source meters and customer meters are read on different days of the month. Also, customer meters are read on different days for different meter reading routes.

3.6 BMP 5: LARGE LANDSCAPE WATER AUDITS AND INCENTIVES

"Implementation methods shall be at least as effective as identifying all irrigators of large (at least 3 acres) landscapes (e.g., golf courses, green belts, common areas, multi-family housing landscapes, schools, business parks, cemeteries, parks and publicly owned landscapes on or adjacent to road rights-of-way); contacting them directly (by mail and/or telephone); offering landscape audits using methodology such as that described in the Landscape Water Management Handbook prepared for the California Department of Water Resources; and cost-effective incentives sufficient to achieve customer implementation; providing follow-up audits at least once every five years; and providing multi-lingual training and information necessary for implementation."

⁴ Reasons for meter error include incorrect installation, wrong size meter, hard-water encrustation, and misreading a meter. If a master meter is determined to be inaccurate, correct the source data by the amount of systematic bias. When master meters are upstream from storage facilities, changes in storage levels must be used to adjust the water flow (e.g., if storage level has increased during period of analysis, the increase must be subtracted from measured water).

⁵ California Department of Water Resources (1986).

Identify Costs and Benefits

The primary purpose of these audits is to determine the application rate of the sprinklers and to produce good irrigation schedules. Identifying deficiencies in the irrigation system equipment may be a byproduct of the audit or designed to be part of a more comprehensive survey.

Costs to the supplier include the costs of identifying and contacting the large landscape customers and the cost of delivering the audit. The audit costs should include the staff time to conduct the audit, computer costs if relevant, and the incentives, if paid by the supplier. See Table 3.6. To the extent irrigation equipment improvements are included in the program, costs to the participant should include the equipment installed as a result of the audit, including sprinkler timers, controls, and soil moisture sensors.

Since this BMP uses the qualifier "at least as effective" there is flexibility in the design of the program, and, therefore, identification of the program components should be explicit.

A potential external environmental benefit that should be identified is the reduced contaminated surface runoff due to reduced water volume at large landscape sites. Another potential benefit that may be difficult to quantify is the improved health of landscape plants.

Measure and Value Cost and Benefits

Although empirical evaluations have not been common, large landscape audits are thought to offer the promise of high benefits because each audit targets a site that uses a great deal of water. Conservation practices targeting landscape sites should seek to measure savings where and when they occur. For

example, some audits have revealed that more water can be saved in the Spring and Fall when seasonal scheduling is adjusted, rather than in the peak demand summer months.

Measurement of water savings should consider carefully the savings that would have occurred without the BMP. The documentation of water savings from large landscape water audits has been impaired by a lack of an easily assessable and matched control group. In part, this is due to the limited number of target sites within any given water supplier's service area. During drought periods, irrigation practices and equipment tend to improve to some degree even without the BMP. The persistence of water savings should be evaluated because water savings depends, in part, on the training of new employees by large landscape managers, home owners associations, and large landscape contractors. Such training includes use and maintenance of irrigation equipment, soil moisture sensor maintenance, scheduling, etc.

Measurement of water savings should be based on an established methodology, such as University of California Leaflet 21493, "Estimating Water Requirements of Landscape Plantings," and the "University of California Water Use Classification of Landscape Species."⁶

Valuation of saved water also needs to carefully consider where and when the savings take place. For example, the value of an acre-foot of water saved at a peak demand summer period in an area not serviced by reclaimed water may be quite high—water savings reduce the need for maximum capacity of potable supply. Alternatively, one would expect an acre-foot of water saved in the winter months at a site served by reclaimed water to be valued at a lower level.

⁶ See also California Department of Water Resources (1994), "Graywater Guide: Using Graywater in Your Home Landscape," December, Sacramento.

Table 3.6
BMP 5 Cost and Benefits

Large Landscape Water Audits and Incentives			
Category	Costs	Data Needed	Data Sources
Participant Program Costs	<ul style="list-style-type: none"> • Landscape crew training • Irrigation system leak repair • Sprinkler timers and soil moisture sensors if related to audit • Permit from local agency 	<ul style="list-style-type: none"> • Wholesale or retail prices • Share of costs paid by participant customer 	<ul style="list-style-type: none"> • Irrigation equipment dealers • Plumbing installation services • Existing studies • Supplier planning departments
Supplier Program Costs	<ul style="list-style-type: none"> • Staff time to identify large landscape customers, contact them, and offer audit • Audits: examination of irrigation practices, landscape vegetation, and existing equipment • Irrigation system leak detection • Administration • Contractors 	<ul style="list-style-type: none"> • Staff salaries and related overhead • Equipment purchase prices • Contractor rates 	<ul style="list-style-type: none"> • Supplier personnel and finance departments • Irrigation equipment wholesalers • Reports from similar programs • Contractors
Category	Benefits	Data Needed	Data Sources
Participant Benefits	<ul style="list-style-type: none"> • Reduced water bills • Reduced frequency and cost of major leaks 	<ul style="list-style-type: none"> • Meter readings data to measure water savings • Water rates data • Cost of major leak repairs 	<ul style="list-style-type: none"> • Supplier billing systems and meter readings • Survey forms or calls • Billing rate forms • Reports of similar programs • Repair contractors
Supplier Benefits	<ul style="list-style-type: none"> • Decreased capital costs for production, transport, storage, treatment, distribution, and wastewater treatment • Decreased O&M costs: energy, chemicals, treatment, labor 	<ul style="list-style-type: none"> • Data to measure water savings (above) • Capital cost data per capacity for construction of pipelines, pumping stations, treatment plants, and distribution systems • O&M cost data per unit water or wastewater 	<ul style="list-style-type: none"> • Planning documents • Construction and engineering cost estimation sources • Contractors and contractor estimates • Construction budgets • Equipment suppliers

3.7 BMP 9: COMMERCIAL, INDUSTRIAL AND GOVERNMENTAL/INSTITUTIONAL WATER CONSERVATION

"Implementation methods shall be at least as effective as identifying and contacting the top 10 percent of the industrial and commercial customers, and top 20 percent of governmental/institutional customers directly (by mail and/or telephone); offering audits and incentives sufficient to achieve customer implementation; and providing follow-up audits at least once every five years if necessary."

Identify Costs and Benefits

CEAs should identify the range of costs and benefits from commercial, industrial and governmental/institutional water conservation audits. Two categories that frequently have a large impact on overall program costs are staffing and marketing. Marketing includes both identifying the top sites and communicating the importance of conservation. Staff time can add up due to the great variety of commercial and industrial operations that consume water. Two broad categories of operations are cooling and process use. Additional costs include equipment, contractors, and program evaluation.

Commercial, industrial and governmental/institutional water conservation can have a large impact on the volume and content of wastewater and other waste products. These secondary benefits (and costs) should be determined in the analysis. Wastewater and other waste products are frequently cited as potentially large participant benefits of conservation. See Table 3.7.

Measure and Value Costs and Benefits

It is important to attribute to the costs of the BMP only the additional costs that the audits would incur. For example, routine repairs and maintenance should not be included if they would otherwise take place without the BMP.

When estimating the costs or benefits of this BMP, careful consideration must be given to the different process types in the region under study.

Water savings should be estimated as fresh water avoided. One common method of commercial and industrial water conservation is reuse or recycling. Sometimes the recycled water does not replace fresh water on a one to one basis.

⁷ As amended at the June 1996 CUWCC Plenary session.

Table 3.7
BMP 9 – Costs and Benefits

Commercial, Industrial and Governmental/Institutional Water Conservation			
Category	Costs	Data Needed	Data Sources
Participant Program Costs	<ul style="list-style-type: none"> Additional water savings equipment or processes that would not have been utilized without the audit 	<ul style="list-style-type: none"> Wholesale prices Share of costs paid by participant customer Time and material for the measure, if applicable 	<ul style="list-style-type: none"> Equipment dealers Plumbing contractors Existing studies
Supplier Program Costs	<ul style="list-style-type: none"> Program marketing Staff time to audit existing water uses and make recommendations Administration Contractors 	<ul style="list-style-type: none"> Staff salaries and related overhead Contractor rates, if applicable 	<ul style="list-style-type: none"> Supplier personnel and finance departments Reports from similar programs Contractors
Category	Benefits	Data Needed	Data Sources
Participant Benefits	<ul style="list-style-type: none"> Reduced water, wastewater, and energy bills 	<ul style="list-style-type: none"> Data to measure water savings: meter readings Water rates data Energy data Discharge to sewer 	<ul style="list-style-type: none"> Supplier billing systems and meter readings Survey forms or calls Billing rate forms Reports of similar programs Repair contractors
Supplier Benefits	<ul style="list-style-type: none"> Decreased capital costs for production, transport, storage, treatment, distribution, and wastewater treatment Decreased O&M costs: energy, chemicals, treatment, labor 	<ul style="list-style-type: none"> Data to measure water savings (above) Capital cost data per capacity for construction of pipelines, pumping stations, treatment plants, and distribution systems O&M cost data per unit water or wastewater 	<ul style="list-style-type: none"> Planning documents Construction and engineering cost estimation sources Contractors and contractor estimates Construction budgets Equipment suppliers

3.8 BMP 10: NEW COMMERCIAL AND INDUSTRIAL WATER USE REVIEW

"Implementation methods shall be at least as effective as assuring the review of proposed water uses for new commercial and industrial water service and making recommendations for improved water use efficiency before completion of the building permit process."

Identify Costs and Benefits

CEAs should identify the range of costs and benefits from commercial and industrial water use review. There is a great variety of commercial and industrial operations that consume water. Two broad categories of operations are cooling and process use. Since the water review takes place before completion of the building permit process, commercial and industrial facilities have the opportunity to improve the water efficiency of their designs.

Commercial and industrial water conservation can have a large impact on the volume and content of wastewater and other waste products. These secondary benefits (and costs) should be determined in the analysis. See Table 3.8.

Measure and Value Costs and Benefits

It is important to attribute to the costs of the BMP only the additional costs that the review would incur. Many facilities would be built with relatively efficient processes and equipment even without the BMP. Likewise, it is important to attribute only the additional water savings benefits from the BMP; many new facilities are more water efficient, even without such review.

When estimating the costs or benefits of this BMP, careful consideration must be given to the different process types in the region under study. Since equipment is less uniform, conservation studies may require more time or the use of case study methods.

Water savings should be estimated as fresh water avoided. One common method of commercial and industrial water conservation is reuse or recycling. Sometimes the recycled water does not replace fresh water on a one to one basis.

Table 3.8
BMP 10 Cost and Benefits

Large Landscape Water Audits and Incentives			
Category	Costs	Data Needed	Data Sources
Participant Program Costs	<ul style="list-style-type: none"> Additional water savings equipment or processes that would not have been utilized without the review 	<ul style="list-style-type: none"> Wholesale prices Share of costs paid by participant customer Time and material for the measure, if applicable 	<ul style="list-style-type: none"> Equipment dealers Plumbing contractors Existing studies
Supplier Program Costs	<ul style="list-style-type: none"> Staff time to review the proposed water uses and make recommendations Administration Contractors 	<ul style="list-style-type: none"> Staff salaries and related overhead Contractor rates, if applicable 	<ul style="list-style-type: none"> Supplier personnel and finance departments Reports from similar programs Contractors
Category	Benefits	Data Needed	Data Sources
Participant Benefits	<ul style="list-style-type: none"> Reduced water, wastewater, and energy bills 	<ul style="list-style-type: none"> Data to measure water savings: meter readings Water rates data Energy data Discharge to sewer 	<ul style="list-style-type: none"> Supplier billing systems and meter readings Survey forms or calls Billing rate forms Reports of similar programs Repair contractors
Supplier Benefits	<ul style="list-style-type: none"> Decreased capital costs for production, transport, storage, treatment, distribution, and wastewater treatment Decreased O&M costs: energy, chemicals, treatment, labor 	<ul style="list-style-type: none"> Data to measure water savings (above) Capital cost data per capacity for construction of pipelines, pumping stations, treatment plants, and distribution systems O&M cost data per unit water or wastewater 	<ul style="list-style-type: none"> Planning documents Construction and engineering cost estimation sources Contractors and contractor estimates Construction budgets Equipment suppliers

3.9 BMP 15: FINANCIAL INCENTIVES

"Implementation methods shall be at least as effective as:

- a. Offering financial incentives to facilitate implementation of conservation programs. Initial recommendations for such incentives will be developed by the Council within two years of the initial signing of the MOU, including incentives to improve the efficiency of landscape water use; and*
- b. Financial incentives offered by wholesale water suppliers to their customers to achieve conservation."*

Identify Costs and Benefits

From the *total society* perspective, financial incentives are transfer payments. As such they should not be included in the CEA, or alternatively, they should be included equally as both costs and benefits. However, administration costs to conduct a financial incentives program are costs from the total societal perspective. From *supplier* and *participating customer* perspectives, incentives are costs and benefits respectively. See Table 3.9.

Measure and Value Costs and Benefits

For measuring both costs and benefits, this BMP needs particular attention to the issue of dependencies. Since this BMP may provide incentives for a wide variety of conservation measures, it could overlap with most of the other BMPs.

Measurement of costs to retail customers should include any portion of BMP-related conservation costs greater than the incentive.

For programs that focus on customer behavior, such as training and procedures to conserve water, the CEA should make explicit the analysis or assumptions regarding the effectiveness and persistence of water savings. The duration of conservation from behavior-based programs is more uncertain than device-based programs.

Table 3.9
BMP 15 Cost and Benefits

Financial Incentives			
Category	Costs	Data Needed	Data Sources
Participant Program Costs	<ul style="list-style-type: none"> The customer's share of costs above the incentive amount 	<ul style="list-style-type: none"> Retail and wholesale prices Share of costs paid by participating customers Time and materials, if applicable 	<ul style="list-style-type: none"> Equipment dealers Plumbing contractors Existing studies
Supplier Program Costs	<ul style="list-style-type: none"> Staff time to design and implement the incentives program Incentive payments or subsidies Administration Contractors 	<ul style="list-style-type: none"> Staff salaries and related overhead Amount and design of incentive programs Contractor rates, if applicable 	<ul style="list-style-type: none"> Supplier personnel and finance departments Program designs Reports from similar programs Contractors
Category	Benefits	Data Needed	Data Sources
Participant Benefits	<ul style="list-style-type: none"> Reduced water, wastewater, and energy bills Incentive payment or subsidy 	<ul style="list-style-type: none"> Incentive amounts Data to measure water savings: device type, meter reading, climate, geographic, and demographic variables Rates of savings persistence Water, wastewater, and energy rates data 	<ul style="list-style-type: none"> Supplier billing systems and meter readings Survey forms or calls Billing rate forms Reports of similar programs Repair contractors
Supplier Benefits	<ul style="list-style-type: none"> Decreased capital costs for production, transportation, storage, treatment, distribution, and wastewater treatment Decreased O&M costs: energy, chemicals, treatment, labor 	<ul style="list-style-type: none"> Data to measure water savings (above) Capital cost data per unit of capacity for pipelines, pumping stations, treatment plants, and distribution systems O&M cost data per unit water or wastewater 	<ul style="list-style-type: none"> Planning documents Construction and engineering cost estimation sources Contractors and contractor estimates Construction budgets Equipment suppliers

3.10 BMP 16: ULTRA LOW FLOW TOILET REPLACEMENTS

"Water suppliers agree to implement programs for replacement of existing high-water-using toilets with ultra-low-flush toilets (1.6 gallons or less) in residential, commercial, and industrial buildings. Such programs will be a least as effective as offering rebates of up to \$100 for each replacement that would not have occurred without the rebate, or requiring replacement at the time of resale, or requiring replacement at the time of change of service. This level of implementation will be reviewed by the Council after development of the assumptions included in the following two paragraphs using the economic principles included in paragraphs 3 and 4 of Exhibit 3."

[See MOU pp. 16-17 for the rest of BMP 16, which contains procedural requirements].

Identify Costs and Benefits

In all cases, the identification of costs and benefits should consider the ULF toilets and installation materials above that would occur at the natural time of replacement due to standards and codes. Programs may include rebates, direct installations, community-based organizations, and distribution.

Costs to the participant customers include the costs of the ULF replacement that are not covered by the rebate. Costs to the supplier include the rebate, or the entire cost if the program provides for a direct installation. Supplier operating expenses for the BMP should include staff, relevant administration and overhead, and contractors, if applicable. See Table 3.10.

The external environmental costs of old toilet disposal due to the BMP should be identified as those costs that (1) are not internalized in the cost of

transportation or disposal and (2) are due to the additional number of toilets from the BMP, rather than from the natural replacement that would occur without the program.

Measure and Value Costs and Benefits

The cost-effectiveness of toilet retrofit programs can vary greatly depending on marketing costs, which vary depending on different levels and types of market penetration.

CEAs of BMP 16 should include also wastewater reduction benefits. Toilet replacement programs save indoor water use and result in wastewater reductions.

The analysis should consider the uncertainty of the persistence of toilet replacement program savings. In cases where the ULF toilets installed are not those that perform well, toilets may be later removed by the customer. Since all new toilets must be ultra low flush toilets, this replacement problem increases program costs, but does not decrease savings.

In addition to the Chapter 4 ULF toilet example, detailed cost-effectiveness evaluations of residential and public facility ULF toilet replacement programs can be found in T.W. Chesnutt, C.N. McSpadden, and A. Bamezai (1994), "Ultra Low Flow Toilet Programs: Evaluation of Program Outcomes and Water Savings," A & N Technical Services, Inc., Santa Monica, November, prepared for the Metropolitan Water District of Southern California, Los Angeles; and A. Bamezai and T.W. Chesnutt (1994), "Water Savings from Non-Residential Toilet Retrofits: An Evaluation of the City of San Diego's Public Facilities Retrofit Program," A & N Technical Services, Inc., Santa Monica, November, prepared for the Metropolitan Water District of Southern California, Los Angeles.

Table 3.10
BMP 16 Cost and Benefits

Ultra Low Flow Toilet Replacements			
Category	Costs	Data Needed	Data Sources
Participant Program Costs	<ul style="list-style-type: none"> • Cost of ULF toilet and installation not reimbursed by rebate 	<ul style="list-style-type: none"> • Retail prices • Rebate size and structure 	<ul style="list-style-type: none"> • Plumbing retailers • Plumbing installation services • Existing studies • Supplier planning departments
Supplier Program Costs	<ul style="list-style-type: none"> • Staff time to administer rebate program • Rebate incentive • Contractors • Marketing 	<ul style="list-style-type: none"> • Staff salaries and related overhead • Rebate size and structure • Contractor rates • Media costs for marketing 	<ul style="list-style-type: none"> • Supplier personnel and finance departments • Plumbing equipment wholesalers • Reports from similar programs • Contractors
Category	Benefits	Data Needed	Data Sources
Participant Benefits	<ul style="list-style-type: none"> • Reduced water, wastewater, and energy bills • Rebate incentive 	<ul style="list-style-type: none"> • Data to measure water savings: toilet type, meter reading, climate, geographic, and demographic variables • Rates of savings degradation • Water, wastewater, and energy rates data 	<ul style="list-style-type: none"> • Supplier billing systems and meter readings • Survey forms or calls • NOAA weather data • Billing rate forms • Reports of similar programs
Supplier Benefits	<ul style="list-style-type: none"> • Decreased capital costs for production, transport, storage, treatment, distribution, and wastewater treatment • Decreased O&M costs: energy, chemicals, treatment, labor 	<ul style="list-style-type: none"> • Data to measure water savings (above) • Capital cost data per capacity for construction of pipelines, pumping stations, treatment plants, and distribution systems • O&M cost data per unit water or wastewater 	<ul style="list-style-type: none"> • Planning documents • Construction and engineering cost estimation sources • Contractors and contractor estimates • Construction budgets • Equipment suppliers

**3.11 PBMP 3: REPLACEMENT OF EXISTING WATER
USING APPLIANCES (EXCEPT TOILETS AND
SHOWERHEADS WHOSE REPLACEMENTS ARE
INCORPORATED AS BEST MANAGEMENT
PRACTICES) AND IRRIGATION DEVICES**

Identify Costs and Benefits

This PBMP should identify a broad range of appliances, such as dishwashers, clothes washers, and existing irrigation devices. The costs should include the costs of the low-water appliances or irrigation devices, with installation. The costs should be split between the participant customer and supplier depending on the incentive program, if applicable. Supplier costs should also include staffing, administration, and/or contracting costs. Benefits of water efficient household appliances often include reduced sewer and electricity costs. See Table 3.11.

If environmental costs of appliances disposal are identified, they should be identified as those costs that (1) are not internalized in the cost of transportation or disposal and (2) are due to the additional appliances and materials from the BMP, rather than from the natural replacement that would occur without the program.

Measure and Value Costs and Benefits

Estimating water conservation of *clothes washers* should involve measurement of water savings from comparable loads of wash (gallons per load, or gallons per pound of clothes washed). The number of loads (or pounds cleaned) per person per unit of time is needed to estimate total savings.

Estimating water conservation of *dish washers* should involve measurement of water savings from comparable loads of dishes cleaned (gallons per load, or gallons per dish cleaned). The number of loads (or dishes cleaned) per person per unit of time is needed to estimate total savings.

To the extent this BMP applies to commercial customers, the CEA should account for solids, not just volume of wastewater. When saved sewer costs are based on solids content, not just volume, costs may not be reduced because solids content usually does not change with water efficient washers. Most residential sewer rates are based on volume.

Table 3.11
PBMP 3 Costs and Benefits

Replacement of Existing Water Using Appliances and Irrigation Devices			
Category	Costs	Data Needed	Data Sources
Participant Program Costs	<ul style="list-style-type: none"> Cost of appliances and irrigation devices not reimbursed by incentive 	<ul style="list-style-type: none"> Retail prices Incentive size and structure, if applicable 	<ul style="list-style-type: none"> Plumbing retailers Plumbing installation services Existing studies Supplier planning departments
Supplier Program Costs	<ul style="list-style-type: none"> Staff time to administer program Rebate or incentive Contractors Marketing 	<ul style="list-style-type: none"> Staff salaries and related overhead Incentive size and structure Contractor rates Media costs for marketing 	<ul style="list-style-type: none"> Supplier personnel and finance departments Plumbing equipment wholesalers Reports from similar programs Contractors Trade associations
Category	Benefits	Data Needed	Data Sources
Participant Benefits	<ul style="list-style-type: none"> Reduced water, wastewater, and energy bills Rebate incentive 	<ul style="list-style-type: none"> Data to measure water savings: appliance type, meter reading, climate, geographic, and demographic variables Rates of savings degradation Water, wastewater, and energy rates data 	<ul style="list-style-type: none"> Supplier billing systems and meter readings Survey forms or calls Billing rate forms Reports of similar programs Trade associations
Supplier Benefits	<ul style="list-style-type: none"> Decreased capital costs for production, transport, storage, treatment, distribution, and wastewater treatment Decreased O&M costs: energy, chemicals, treatment, labor 	<ul style="list-style-type: none"> Data to measure water savings (above) Capital cost data per capacity for construction of pipelines, pumping stations, treatment plants, and distribution systems O&M cost data per unit water or wastewater 	<ul style="list-style-type: none"> Planning documents Construction and engineering cost estimation sources Contractors and contractor estimates Construction budgets Equipment suppliers Trade associations

3.12 PBMP: RETROFIT OF EXISTING CAR WASHES**Identify Costs and Benefits**

It is important to identify costs and benefits that are distinct for the different types of car washes: self serve, exterior-only conveyor, full-service conveyor, and in-bay roll over. Participant customer costs for retrofit equipment and installation materials should include items such as filters, pumps, drains, and tanks. Supplier costs should consider staffing, administration, and contracting costs. Since this PBMP may be implemented in a number of ways, the costs and benefits need to be consistent with the type of program design—incentive program, audit, technology demonstration, etc. For example, an incentive program's costs should be distributed between the customer and supplier depending on the incentive structure. See Table 3.12.

Since wastewater volume may drop (solids *concentration* may increase), there may be external benefits (or costs) realized by other utilities—the wastewater treatment utilities.

Environmental benefits should also acknowledge the differences between different types of car washes. For example, professional car washes should have less uncontrolled and untreated wastewater. Other car washes usually do not have approved storage and

treatment facilities for waste material washed off cars (road dirt, oil, salt, soap, etc.). The costs of proper waste disposal services for filter muck should be considered “internalized” environmental costs, not an external environmental cost.

Measure and Value Costs and Benefits

When determining the BMP related retrofit costs for a car wash, the age of the existing car wash is important. If the facility would have required replacement or refitting in the near future without the BMP, only the additional increment of cost related to the BMP should be measured as a cost of the BMP. Newly constructed facilities may already have water efficiency technology.

Water savings should be measured as fresh water avoided. Water saved by recycling may not replace freshwater on a one to one basis.

Reduced wastewater/sewer discharge volume should be valued as a benefit to the participant customer to the extent it reduces their wastewater/sewer bill. If the bill is determined by contaminant mass or density, the bill may not be lower.

Table 3.12
PBMP 4 Costs and Benefits

Retrofit of Existing Car Washes			
Category	Costs	Data Needed	Data Sources
Participant Program Costs	<ul style="list-style-type: none"> • Cost of retrofit equipment and installation materials (e.g., filters, pumps, drains, tanks) • O&M, if greater than conventional equipment • Additional energy costs, if any 	<ul style="list-style-type: none"> • Equipment prices • Retrofit design specifications for each car wash type • Incentive size and structure if applicable 	<ul style="list-style-type: none"> • Equipment wholesalers • Plumbing installation services • Existing studies • Supplier planning departments
Supplier Program Costs	<ul style="list-style-type: none"> • Staff time to develop car wash conservation program and technology • Incentives if used to offset retrofit costs • Contractors 	<ul style="list-style-type: none"> • Staff salaries and related overhead • Incentive size and structure • Contractor rates 	<ul style="list-style-type: none"> • Supplier personnel and finance departments • Equipment wholesalers, manufacturers • Reports from similar programs • Contractors • Car wash associations
Category	Benefits	Data Needed	Data Sources
Participant Benefits	<ul style="list-style-type: none"> • Reduced water, wastewater, and energy bills • Incentive if applicable • O & M costs are less than conventional equipment 	<ul style="list-style-type: none"> • Data to measure water savings: car wash type, meter reading, and demographic variables • Rates of savings degradation • Water, wastewater, and energy rates data 	<ul style="list-style-type: none"> • Supplier billing systems and meter readings • Survey forms or calls • Billing rate forms • Reports of similar programs • Car wash associations
Supplier Benefits	<ul style="list-style-type: none"> • Decreased capital costs for production, transport, storage, treatment, distribution, and wastewater treatment • Decreased O&M costs: energy, chemicals, treatment, labor 	<ul style="list-style-type: none"> • Data to measure water savings (above) • Capital cost data per capacity for construction of pipelines, pumping stations, treatment plants, and distribution systems • O&M cost data per unit water or wastewater 	<ul style="list-style-type: none"> • Planning documents • Construction and engineering cost estimation sources • Contractors and contractor estimates • Construction budgets • Equipment suppliers

3.13 PBMP 5: GRAYWATER USE**Identify Costs and Benefits**

Costs of graywater systems should include surge tank, filter, pump, irrigation system, pipes and valves, and installation. The systems require monitoring and maintenance for continued effectiveness, which should also be included in the cost estimates. These are costs to the participant customer, unless the supplier contributes in the form of an incentive or rebate program. The customer may also need less fertilizer, which should be counted as a benefit to the participant customer. See Table 3.13.

The CEA should consider the reduced costs to the wastewater utility, which would be an external benefit unless the water and wastewater utility are part of the same organization.

Measure and Value Costs and Benefits

Measurement of water savings should be based on an established methodology, such as University of California Leaflet 21493, "Estimating Water Requirements of Landscape Plantings," and the "University of California Water Use Classification of Landscape Species." Irrigation landscape area should be calculated as follows:

$$LA = \frac{GW}{ET \times PF \times .62} \quad (3.1)$$

Where LA is landscaped area that can be irrigated (square feet); GW is estimated graywater produced (gallons per week); ET is evapotranspiration (inches per week); PF is plant factor, and .62 is the conversion factor from inches of ET to gallons per week. "Evapotranspiration is the amount of water lost through evaporation (E) from the soil and transpiration (T) from the plant. (This formula does not account for irrigation efficiency. If your irrigation system does not distribute water evenly, extra water will need to be applied.)"⁸

8 California Department of Water Resources (1994), "Graywater Guide: Using Graywater in Your Home Landscape," December, Sacramento.

Table 3.13
PBMP 5 Costs and Benefits

Graywater Use			
Category	Costs	Data Needed	Data Sources
Participant Program Costs	<ul style="list-style-type: none"> • Cost of surge tank, filter, pump, irrigation system, pipes, valves, and installation not reimbursed by incentive 	<ul style="list-style-type: none"> • Retail prices • Incentive size and structure, if any 	<ul style="list-style-type: none"> • Plumbing retailers • Plumbing installation services • Existing studies • Supplier planning departments
Supplier Program Costs	<ul style="list-style-type: none"> • Staff time to disseminate “how to” information about graywater use • Incentives, if applicable • Contractors • Marketing 	<ul style="list-style-type: none"> • Staff salaries and related overhead • Rebate size and structure • Contractor rates • Media costs for marketing 	<ul style="list-style-type: none"> • Supplier personnel and finance departments • Plumbing equipment wholesalers • Reports from similar programs • Contractors
Category	Benefits	Data Needed	Data Sources
Participant Benefits	<ul style="list-style-type: none"> • Reduced water bills • Incentive if applicable 	<ul style="list-style-type: none"> • Data to measure water savings: equipment type, meter reading, climate, geographic, and demographic variables • Rates of savings degradation • Water, wastewater, and energy rates data 	<ul style="list-style-type: none"> • Supplier billing systems and meter readings • Survey forms or calls • NOAA weather data • Billing rate forms • Reports of similar programs
Supplier Benefits	<ul style="list-style-type: none"> • Decreased capital costs for production, transport, storage, treatment, distribution, and wastewater treatment • Decreased O&M costs: energy, chemicals, treatment, labor 	<ul style="list-style-type: none"> • Data to measure water savings (above) • Capital cost data per capacity for construction of pipelines, pumping stations, treatment plants, and distribution systems • O&M cost data per unit water or wastewater 	<ul style="list-style-type: none"> • Planning documents • Construction and engineering cost estimation sources • Contractors and contractor estimates • Construction budgets • Equipment suppliers

ILLUSTRATIVE EXAMPLES: ULF TOILET REPLACEMENTS AND LARGE LANDSCAPE AUDITS

This chapter illustrates the guidelines for CEA provided in Chapters 2 and 3 using two examples: “ultra low flush” (ULF) toilet replacements and large landscape audits. These examples illustrate how to use the guidelines by emphasizing the different issues raised with two very different BMPs.

4.1 ULF TOILET PROGRAM

All new toilets sold in California must meet the ULF uniform standard (not more than 1.6 gallons per flush). Many water utilities have found that programs designed to speed up the replacement of existing toilets with ULF toilets can be an attractive alternative for improving the reliability of future water supplies. Given the importance of ULF toilet replacement programs in the MOU, they constitute a good example for illustration. This chapter’s first illustrative CEA is based on the City of Santa Monica’s BAYSAVER toilet rebate program.¹ This type of program is consistent with BMP 16—Ultra Low Flow Toilet Replacements.

To give a better impression of the importance of program design and marketing, the CEA examines different customer classes. One major finding of a recent impact evaluation (“the ULFT Study”) was that ULF toilet replacements achieve different water savings in single family versus multiple family residences.² Commercial applications are interesting due to the higher costs of purchasing and installing commercial ULF toilets *and* due to the potentially

higher water savings from higher frequency use. Santa Monica’s BAYSAVER program resulted in approximately 5,500 single family, 30,200 multi-family, and 1800 commercial ULF toilet installations between 1990 and 1995.

The ULF toilet replacement illustration follows the steps for CEA, as set forth in Chapter 2:

- 1) Identify Costs and Benefits;
- 2) Measure and Value Costs and Benefits;
- 3) Discount Costs and Benefits; and
- 4) Analyze Uncertainty.

4.2 IDENTIFY COSTS AND BENEFITS

Table 4.1 summarizes costs and benefits of the illustrative ULF toilet replacement program. *Participant program costs* include the cost of the ULF toilet and installation. *Supplier program costs* include the rebate payment plus contractors for rebate processing, marketing, and fixture disposal. *Participant benefits* include reduced water/wastewater bills and also the rebate incentive. *Supplier benefits* include the avoided costs of water supply and wastewater treatment. In the case of Santa Monica, the City contracts with the Hyperion wastewater facility, the costs of which are paid by the City.

For the City of Santa Monica’s BAYSAVER program, replaced toilets are crushed and used to make street pavement, so *external environmental costs* are zero

¹ Although this illustration is based on the BAYSAVER program, it does not represent official policies, plans, or opinions of the City of Santa Monica.

² For further documentation see T.W. Chesnutt and C.N. McSpadden, and A. Bamezai (1994), *Ultra Low Flow Toilet Programs: Evaluation of Program Outcomes and Water Savings*, A & N Technical Services, Inc., Santa Monica, November. Prepared for the Metropolitan Water District of Southern California, Los Angeles.

Table 4.1
Identify Costs and Benefits

Ultra Low Flow Toilet Replacements	
Category	Costs
Participant Program Costs	<ul style="list-style-type: none"> • Cost of ULF toilet and installation not reimbursed by rebate
Supplier Program Costs	<ul style="list-style-type: none"> • Rebate incentive • Contractors to process rebates and perform inspections • Marketing (workshops and advertising) • Fixture disposal • Staff time to design and manage the rebate program
External Environmental Costs	<ul style="list-style-type: none"> • External environmental costs of fixture disposal, if any
Category	Benefits
Participant Benefits	<ul style="list-style-type: none"> • Reduced water and wastewater bills • Rebate incentive
Supplier Benefits	<ul style="list-style-type: none"> • Avoided cost of purchasing water from MWD (and, consequently, decreased MWD capital costs for production, transport, storage, treatment, and distribution, as well as decreased O&M costs, such as energy, chemicals, labor) • Avoided per unit and capacity costs of Hyperion wastewater treatment (and consequently, decreased Hyperion capital and O&M costs for wastewater treatment)
External Environmental Benefits	<ul style="list-style-type: none"> • Reduced environmental costs of water diversion, supply, and transportation • Reduced waste discharge to Santa Monica Bay

or near zero. *External environmental benefits* are derived from reduced water diversion and supply—less damage from surface and groundwater storage, pipelines, and water diversions. In particular, since Santa Monica purchases its “marginal” supplies of water from the Metropolitan Water District of Southern California (MWD), external environmental benefits derive from deferred or reduced new supply developed for the region.³ By reducing wastewater flows, the BAYSAVER program reduces the likelihood of spillage from the stressed treatment plant, reducing waste discharge into Santa Monica Bay.

4.3 MEASURE AND VALUE COSTS AND BENEFITS

Costs. The program costs in this illustration are determined by starting with figures from City planning documents and the ULFT Study, and then making assumptions where necessary (Table 4.2). City documents describe Phase I and II of the BAYSAVER program as they were initially planned (“BAYSAVER Phase I and II Proposals”).⁴ A key determinant of cost is the delivery mechanism for the ULF toilet program: About half of the single family ULF toilets used the

³ Since the City of Santa Monica is within MWD’s “Common Pool,” treated water may be supplied from either the Jensen, Weymouth, or Diemer Filtration Plants. These filtration plants receive water from a complex regional supply and storage system (e.g., State Water Project and the Colorado River Aqueduct).

⁴ “Recommendation to Approve the Residential Plumbing Fixture Rebate Program,” Proposal to the Mayor and City Council from City Staff, City of Santa Monica, July 25, 1989 and “Recommendation to Approve Phase II of the BAYSAVER Plumbing Fixture Rebate Program,” Proposal to the Mayor and City Council from City Staff, City of Santa Monica, February 11, 1992.

Table 4.2
Program Costs (\$/ULFT)

Sector	Toilet Cost [1]	Installation [2]	Rebate [3]	Other Costs [4]	Participant Costs [5]	Supplier Costs [6]	Total Society Costs [7]
Single Family Rebate	\$120	\$70	\$75	\$40	\$115	\$115	\$230
Single Family Direct	\$60	\$65		\$40	\$35	\$130	\$165
Multi-Family Direct	\$60	\$55		\$40	\$35	\$120	\$155
Commercial Direct	\$170	\$80		\$40	\$35	\$255	\$290

Notes:
 All costs are dollars per ULF toilet
 [4] "Other Costs" includes contract inspections and processing, advertising, workshops, and toilet recycling.
 [5] = [1]+[2] - [3] for Rebate and \$35 Copayment for Direct Installation
 [6] = [3]+[4] for Rebate and [1]+[2]+[4] - [5] for Direct Installation
 [7] = [1]+[2]+[4]

"rebate" option and half were directly installed. In contrast, the majority of multi-family and commercial ULF toilets were directly installed. With the rebate, the participant purchases and installs the toilet, after which the City provides a rebate check (\$75 in BAYSAVER Phase II). With direct installation, the City purchases and installs the toilet and the customer provides a copayment (\$35 in BAYSAVER Phase II).

With the rebate, customers purchase the ULF toilet at retail prices—approximately \$120 per toilet. With direct installation, the City purchases the toilets in bulk at wholesale prices—approximately \$60 per toilet.⁵ Commercial ULF toilets are often more expensive, especially in high use locations.⁶

⁵ The ULFT Study reports retail toilet purchase costs of \$130 and the BAYSAVER Phase II Proposal reports the ULF Toilet prices are falling and are available for as low as \$100. Bulk purchases were made at approximately \$60 per toilet (Interview with City Staff). Commercial ULF toilets retail for \$150 to \$170, but we assume they are less expensive in bulk, as are residential fixtures.

⁶ The purchase cost estimate comes from the direct installation program in the City of Santa Monica and assumes that all installed commercial ULF toilets were flushometer valve-type. Since both flushometer-valve and gravity-fed toilets are used in commercial applications, the \$170 purchase cost estimate represents an upper bound. Gravity-fed commercial ULF toilet costs are about the same as multi-family residential toilets.

Although single family installation costs are approximately \$70, they are considerably less when negotiated in large number by the City for direct installation and for multiple family sites where economies of scale become apparent (\$50 and \$40 respectively).⁷ Other costs of the program (rebate processing, advertising, and workshops) were estimated by dividing program budget categories by number of ULF toilets.⁸

With the *rebate*, from the *participating customer perspective*, costs include the toilet and its installation, less the rebate.⁹ From the *supplier perspective* costs include the rebate and other costs. From the *total society perspective*, costs include the toilet, its installation, and other costs.¹⁰ With *direct installation*, from the *participating customer perspective*, costs include only the \$35 copayment. From the *supplier perspective*, costs include the toilet, its installation, and other costs, less the customer copayment.

Benefits. The statistical models used in the ULFT Study of the Santa Monica (and Los Angeles) toilet replacement programs use water demand of more than 23,000 households over an eight year time period. Explaining the variation in historical water demand required daily climatic data from four weather stations, measurements of household characteristics from inspection surveys, and measures of changes in water rates and water meter replacement over time. The empirical estimation was complicated by

measuring water savings during an ongoing drought emergency when other conservation inducements were in effect. The nature of meter-read water use data also required careful attention to measurement and modeling issues.

Table 4.3 gives the net water savings measured in the ULFT Study. The ULFT Study did not find that savings decayed over time, so we use these savings rates for the entire 20 year physical life of the ULF toilets. To value these water savings in dollar terms, we first consider the perspective of the supplier, the City of Santa Monica. For each acre-foot of water conserved by the City, one less acre-foot of water needs to be

Table 4.3
ULF Toilet Water Savings

Sector	Savings per Toilet (gpd) [1]	Savings per Toilet (AF/yr) [2]
Single Family	29.9	0.0335
Multiple Family	44.0	0.0493
Commercial	60.0	0.0672
Notes: [1] Water Saved per ULF toilet replacement in gallons per day (gpd). [2] = [1] x 365 days + 325,900 gallons per acre-foot.		

⁷ Some rebate participants installed their ULF toilets themselves. We assume the opportunity cost for self-installers is equivalent to the cost of plumber installation. The installation cost for commercial toilets are higher to reflect the additional plumbing reconfiguration sometimes required in commercial applications.

⁸ See, for example, the BAYSAVER Phase II Proposal.

⁹ For convenience, we sum costs from the participating customer's perspective net of the rebate ($[1]+[2]-[3]$). An alternative formulation is to sum costs from the participating customer's perspective ($[1]+[2]$) and to consider the rebate a benefit from the participating customer's perspective. Either formulation is equivalent when our main result, Net Present Value, is calculated from the participating customer's perspective.

¹⁰ The rebate does not enter into the equation because it is a "transfer payment"—that is, the rebate is both a cost (to the supplier) and an equal benefit (to the customer), so from the total society perspective the rebate sums to zero.

purchased from MWD at \$579/AF.¹¹ Avoided wastewater costs depend on the contract between the City and the Hyperion treatment facility. This contract reflects a unit charge and a share of the capital costs to increase capacity. The unit charge, \$308/AF, is avoided for each acre-foot of water saved. Capital costs are incurred at the time of capacity increase. For example, the City would incur a capital cost of \$8.2 million for an additional 1.1 million gallons per day capacity, or approximately \$409/AF over the life of the capital improvement.¹² Avoided wastewater costs sum to \$717/AF ($=\$308/\text{AF} + \$409/\text{AF}$). Table 4.4 shows the quantified costs and benefits per ULF toilet replacement over time from the supplier perspective.

Customers likewise benefit from ULF toilet conservation. Santa Monica retail water rates are currently \$.50/HCF in the lower of two tiers and \$.97/HCF in the higher. Since most customers consume some water in the higher tier, their avoided cost is more heavily weighted to the high tier rate: \$.92/HCF (\$402/AF) avoided.¹³ Customers also benefit from reduced wastewater charges because the City of Santa Monica sewer rate structure is linked to water use. Since wastewater costs depend on the

portion of water use that is discharged, avoided cost of wastewater is different for each sector: \$366/AF for single family, \$645/AF for multi-family, and \$638/AF for commercial customers.¹⁴

From the total society perspective, the avoided costs of water derive from avoiding the need to develop new regional supply by the MWD, Santa Monica's marginal water wholesaler. MWD has recently estimated the regional costs of new supply to be \$602/AF for supply, treatment, and distribution.¹⁵ These costs are expected to increase at about 1.5 percent per year real growth. Total society also benefits from conservation when new wastewater treatment is avoided. Since the prices that would be paid by the City of Santa Monica for additional wastewater treatment reflect the costs of the new facilities, they are a measure of avoided wastewater costs from the total society perspective (\$717/AF).

As described previously, there may be important external environmental benefits from the BAYSAVER rebate program. The external environmental benefits are addressed below utilizing the screening guidelines described in Chapter 2.

¹¹ Predicted value from BAYSAVER Phase II proposal.

¹² The marginal capacity costs is determined by first calculating the annualized capacity cost ($K=\$503,411$) as described in Chapter 2 to approximate the marginal capacity costs with $C=\$8.2$ million, $i=4.5$ percent (.045), and $n=30$ years for the life of the wastewater facility. Dividing the annualized capacity cost by the capacity ($1,232\text{AF}/\text{YR}=1.1$ million gpd $\times 365 + 325900$) yields the marginal capacity costs ($\$409/\text{AF} = \$503,411/\text{YR} + 1,232\text{AF}/\text{YR}$).

¹³ A large majority of customers use high tier water, on the order of 90 percent, so the average rate is approximately $\$.92/\text{HCF} = (.9 \times \$.97) + (.1 \times \$.5)$.

¹⁴ Using the guidelines in Chapter 2 we assume that new wastewater operating and capacity costs incurred by the City would be passed on to customers in the form of a rate increase. The avoided wastewater costs (\$717/AF as described above), need to be adjusted by the discharge factor in the sewer rate structure. For example, the discharge factor for single family customers is 51 percent, so avoided wastewater costs to single family customers are $\$366/\text{AF} = \$717/\text{AF} \times .51$. The discharge factor is between 80 and 95 percent for multi-family customers and 89 percent for commercial customers.

¹⁵ See "Southern California's Integrated Water Resources Plan," Draft Report Number 1107, Metropolitan Water District of Southern California, December 1995. These costs are average costs within supply categories (transfers, storage, reclamation); however, the highest cost source for each category would be a better reflection of the avoided supply costs.

4.4 DISCOUNT COSTS AND BENEFITS

In the next step, the future streams of costs and benefits are summed in present value terms. Calculating the present value of costs involves less effort than the *benefits* in this illustration because program costs are incurred *immediately*, and are, therefore, already in present value terms.¹⁶ In contrast, the benefits, which derive from the quantity of water saved, accrue over many years into the future. To convert the stream of future benefits into present value terms requires selection of a discount rate.

Discounting from a Supplier Perspective. According to the guideline in Chapter 2, the supplier's cost of capital should be used to select the discount rate from the supplier's perspective. The supplier in this illustration has a real (inflation-adjusted) borrowing rate on securities with 20 year maturity of 4.5 percent per year. Twenty year maturity is appropriate because our period of analysis is selected to be 20 years, based on the physical life span of a ULF toilet. For this example, a life span of 20 years is used and tested for sensitivity.

Table 4.4 presents calculations of the present value of water conserved from a ULF toilet replacement over a 20 year period. The calculations use Equation 2.2 from the guidelines in Chapter 2.¹⁷

The present value of benefits over a 20 year period is \$602/ULFT, the present value of costs is \$115/ULFT, and, therefore, net present value is \$487/ULFT from the supplier's perspective. Hence, this BMP 16 "cost-effective" because present value of benefits is greater than the present value of costs.

Table 4.5 provides calculations of the present value of costs and benefits, by sector, from the supplier's perspective. ULF toilet replacements are cost-effective in each of the sectors—the present value of benefits is greater than the present value of costs.

Discounting from a Participating Customer's Perspective. The guidelines in Chapter 2 call for a customer discount rate of 7 percent, tested for sensitivity at 3 and 11 percent. Table 4.6 displays the cost-effectiveness calculations from a participant's perspective when calculated at 7 percent. For each of the sectors, single family (rebate and direct install), multiple family, and commercial, ULF toilet replacement is cost-effective.

Discounting from a Total Society Perspective. The total society perspective includes all costs and all benefits to society. Table 4.7 shows the present value of costs and benefits from the total society perspective, to the extent they are readily quantifiable. The benefits exceed the costs in each sector.

¹⁶ In this illustration, the costs and benefits are denominated in current (1995) dollars.

¹⁷ Under certain circumstances, calculating the present value of benefits can also be performed with the short-cut method described in Appendix C.

Table 4.4
 Supplier Perspective: Present Value of Costs and Benefits
 (Single Family ULF Toilet Rebate)

Year	Water Savings (AF/ULFT) [1]	Undiscounted Benefits (\$/ULFT) [2]	Present Value Benefits (\$/ULFT) [3]	Undiscounted Costs (\$/ULFT) [4]	Present Value Costs (\$/ULFT) [5]	NPV [6]
0	0.0000	\$ 0.00	\$ 0.00	\$115.00	\$115.00	(\$115.00)
1	0.0335	\$43.69	\$41.81	\$0.00	\$0.00	\$41.81
2	0.0335	\$43.99	\$40.28	\$0.00	\$0.00	\$40.28
3	0.0335	\$44.29	\$38.81	\$0.00	\$0.00	\$38.81
4	0.0335	\$44.59	\$37.39	\$0.00	\$0.00	\$37.39
5	0.0335	\$44.90	\$36.03	\$0.00	\$0.00	\$36.03
6	0.0335	\$45.21	\$34.72	\$0.00	\$0.00	\$34.72
7	0.0335	\$45.53	\$33.46	\$0.00	\$0.00	\$33.46
8	0.0335	\$45.85	\$32.24	\$0.00	\$0.00	\$32.24
9	0.0335	\$46.18	\$31.07	\$0.00	\$0.00	\$31.07
10	0.0335	\$46.51	\$29.95	\$0.00	\$0.00	\$29.95
11	0.0335	\$46.85	\$28.87	\$0.00	\$0.00	\$28.87
12	0.0335	\$47.19	\$27.83	\$0.00	\$0.00	\$27.83
13	0.0335	\$47.54	\$26.83	\$0.00	\$0.00	\$26.83
14	0.0335	\$47.89	\$25.86	\$0.00	\$0.00	\$25.86
15	0.0335	\$48.25	\$24.93	\$0.00	\$0.00	\$24.93
16	0.0335	\$48.61	\$24.04	\$0.00	\$0.00	\$24.04
17	0.0335	\$48.98	\$23.18	\$0.00	\$0.00	\$23.18
18	0.0335	\$49.36	\$22.35	\$0.00	\$0.00	\$22.35
19	0.0335	\$49.74	\$21.55	\$0.00	\$0.00	\$21.55
20	0.0335	\$50.12	\$20.78	\$0.00	\$0.00	\$20.78
Total	0.67	\$935.28	\$601.97	\$115.00	\$115.00	\$486.97

Notes:

- [1] = Savings per single family ULF toilet
- [2] = $[1] \times ((\$579 \times (1+e)^t) + \$717)$ where e is the escalation rate (1.5% real) and t is year
- [3] = $[2] \div (1+r)^t$ where r is the discount rate (4.5% real)
- [4] = Costs per ULF toilet
- [5] = $[4] \div (1+r)^t$ where r is the discount rate (4.5% real)
- [6] = [3] - [5] is Net Present Value

Table 4.5
Supplier Perspective: Present Value of Costs and Benefits

Sector	Savings per ULFT (AF/yr) [1]	Present Value Benefits (\$/ULFT) [2]	Present Value Costs (\$/ULFT) [3]
Single Family Rebate	0.0335	\$601.97	\$115.00
Single Family Direct	0.0335	\$601.97	\$130.00
Multiple Family Direct	0.0493	\$885.85	\$120.00
Commercial Direct	0.0672	\$1,207.97	\$225.00

Notes:
 [1] = Savings per ULF toilet replacement
 [2] = $\sum B_t + (1+r)^t$, where $B_t = [1] \times ((\$579 \times (1+e)^t) + \$717)$, the water savings benefit in year t, r is a 4.5% real discount rate, and e is a 1.5% real escalation rate
 [3] = Supplier cost per toilet replacement

Table 4.6
Participating Customer Perspective: Present Value of Costs and Benefits

Sector	Savings per ULFT (AF/yr) [1]	Present Value Benefits (\$/ULFT) [2]	Present Value Costs (\$/ULFT) [3]
Single Family Rebate	0.0335	\$291.81	\$115.00
Single Family Direct	0.0335	\$291.81	\$35.00
Multiple Family Direct	0.0493	\$575.07	\$35.00
Commercial Direct	0.0672	\$779.21	\$35.00

Notes:
 [1] = Savings per ULF toilet replacement
 [2] = $\sum B_t + (1+r)^t$, where $B_t = [1] \times ((\$402 \times (1+e)^t) + W)$, the water savings benefit in year t, r is a 7% real discount rate, e is a 1.5% real escalation rate, and W is the wastewater benefit (\$366/AF single family, \$645/AF for multiple family, and \$638 for commercial).
 [3] = Customer cost per toilet replacement

Table 4.7
Total Societal Perspective: Present Value of Costs and Benefits

Sector	Savings per ULFT (AF/yr) [1]	Present Value Benefits (\$/ULFT) [2]	Present Value Costs (\$/ULFT) [3]
Single Family Rebate	0.0335	\$603.54	\$230.00
Single Family Direct	0.0335	\$603.54	\$165.00
Multiple Family Direct	0.0493	\$888.16	\$155.00
Commercial Direct	0.0672	\$1,211.12	\$290.00

Notes:
 [1] = Savings per ULF toilet replacement
 [2] = $\sum B_t + (1+r)^t$, where $B_t = [1] \times ((\$620 \times (1+e)^t) + \$717)$, the water savings benefit in year t, r is a 4.85% real discount rate, e is a 1.5% real escalation rate.
 [3] = Total society cost per toilet replacement

Environmental Costs and Benefits. To complete the supplier perspective and total society perspective CEAs, environmental costs and benefits need to be considered. The environmental *benefits* may be significant and depend on the amount of water saved. Applying the guidelines in Chapter 2, we follow the sequence of steps for CEA of external environmental costs and benefits: *Screening, Break-Even Analysis, and Environmental Externality Description.*

- **Screening.** Since the benefits exceed costs from the supplier and total society perspectives, there is no need to measure and value environmental benefits. We can conclude the BMP is cost-effective without going through the additional analysis. This conclusion depends on the fact that we identified above that the environmental *costs* of this program appear to be small or zero. Per the screening guideline, there is no need to proceed further with the Break-Even Analysis or Environmental Externality Description.

- **Break-Even Analysis.** If, unlike this ULF toilet illustration, the avoided costs of water supply benefits do not exceed costs, then the guidelines call for calculation of the break-even value. For example, if the total society perspective benefits calculated above turned out to be \$215 (instead of \$602) for a single family rebate, then net present value is -\$15 per ULF toilet (benefits minus costs = \$215 - \$230). The break-even value is the amount external environmental benefits would have to be worth for the ULF toilet to be cost-effective; in this example, the break-even value is \$15 per ULF toilet. Equivalently, given the savings estimates described above, the external environmental benefits would have to be at least \$28.39/AF [= \$15 + (.0335AF/ULFT/YR x 20 Years)] of conserved water for the measure to be cost-effective.

- **Environmental Externality Description.** If the break-even value is not conclusive, then the guidelines call for description of the external environmental benefits. Since Santa Monica's conserved water translates into reduced MWD purchases, external environmental benefits are those associated with MWD's supply system. MWD planning documents describe future water supply options for new water supply, storage, or transportation that would be delayed or avoided by water conservation.¹⁸ The additional water supply options include sources such as the State Water Project, the Colorado River Aqueduct, storage projects, transfers, reclamation, ground-water recovery, and ocean desalination.

Describing the external environmental costs avoided or delayed from an expansive water system such as MWD's is an expansive task, but existing documents can provide substantial information. For example, one new storage facility with identified external environmental costs is the Eastside Reservoir Project. "Unavoidable Adverse Impacts" of this project that remain despite mitigation measures include aesthetic changes to topography, surface water quality during construction, and cultural resources.¹⁹

4.5 ANALYZE UNCERTAINTY

This illustrative example tests some of the major sources of uncertainty using variable-by-variable sensitivity testing. Three key variables in the present value of benefits calculations are the discount rate,

escalation rate, and the physical life span of the ULF toilet. The discount rate is important to test for sensitivity, especially for the customer perspective as described in Chapter 2. The escalation rate is a key source of uncertainty because it relies on projections of the future cost of avoided water supply. The physical life span of the stock of ULF toilets is uncertain because, although there are many old toilets, the ULF toilets are of substantially different design. Physical life span projections based on the existing installed stock of toilets may not be representative of new fixtures.

Figure 4.1 summarizes the results of a sensitivity test of these three key variables. The horizontal axis is the net present value of a ULF toilet rebate in the single family sector, as calculated from the supplier perspective. The bars show these calculations for a variety of assumptions. In the base case, the discount rate is 4.5 percent, the escalation rate is 1.5 percent, and the physical life span is 20 years. Notice the center bar for each of the three sets of bars in the figure is calculated with these base case calculations. The top set of bars show the impact on present value calculations when one variable is changed, the discount rate. We see that the lower the discount rate, the higher the present value of net benefits. Likewise, the middle and bottom sets of bars indicate the sensitivity to the escalation rate and physical life span.

Figure 4.2 shows sensitivity testing as well, but it focuses primarily on the choice of a discount rate. The vertical axis shows the net present value (NPV) of single family ULF toilet installation for discount rates ranging between 0 and 10 percent. The thick line is plotted by calculating the net present value with a

¹⁸ See "Southern California's Integrated Water Resources Plan," Draft Report Number 1107, Metropolitan Water District of Southern California, December 1995.

¹⁹ See "Eastside Reservoir Project: Final Environmental Impact Report," Metropolitan Water District of Southern California, Planning Division, October 1991.

1.5 percent escalation rate and a 20 year physical life span. With a discount rate based on the illustrative supplier's cost of capital, 4.5 percent real, the net present value is \$487 per ULF toilet. With a 6 percent real discount rate, NPV is approximately \$414 and

with a 2 percent real discount rate, NPV is \$646 per ULF toilet. The two dashed lines surrounding the thick line in Figure 4.2 are calculated with alternative escalation rates, .5 and 2.5 percent.

Figure 4.1
Sensitivity Analysis

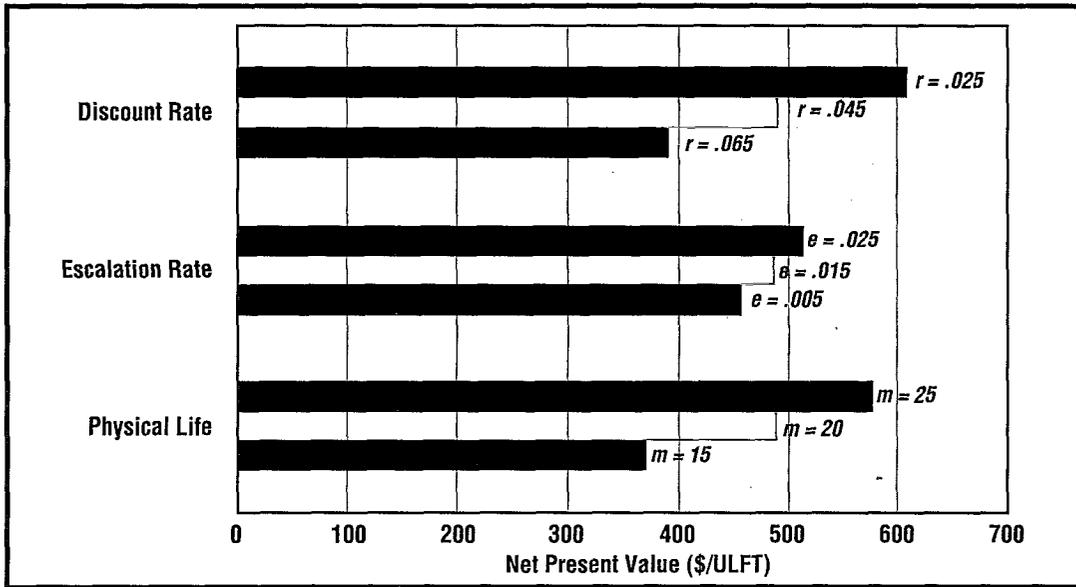


Figure 4.2
Sensitivity of NPV to Discount Rate

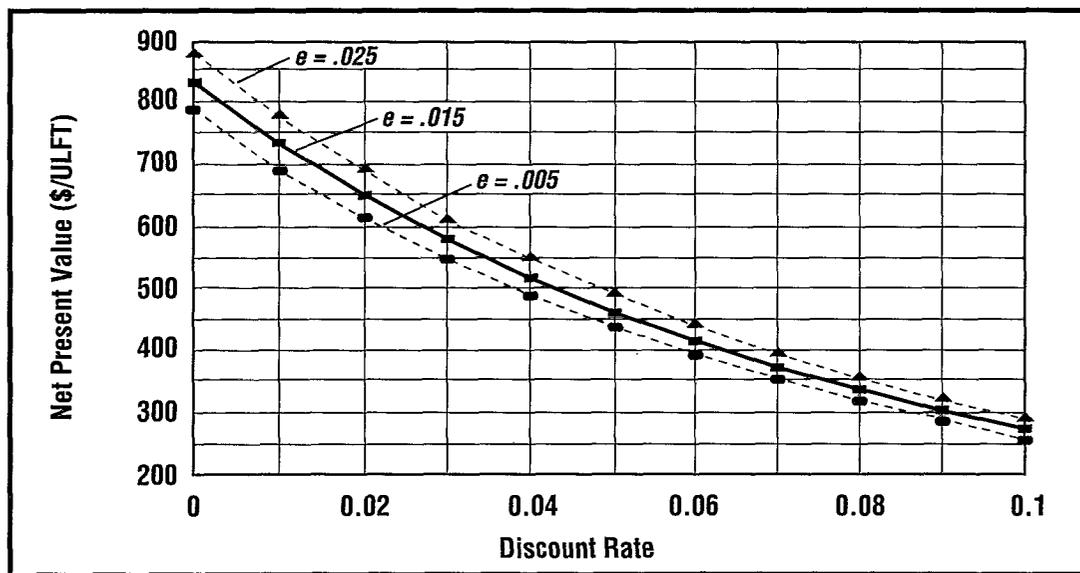


Table 4.8
Results Summary: Single Family ULFT Rebate

Sector	Present Value Benefits* (\$/ULFT) [1]	Present Value Costs* (\$/ULFT) [2]	NPV (\$/ULFT) [3]
Supplier	\$601.97	\$115.00	\$486.97
Single Family Direct	\$291.81	\$115.00	\$176.81
Multiple Family Direct	\$603.54	\$230.00	\$373.54
Notes: *Present Value of Costs and Present Value of Benefits are calculated with the same discount rates, escalation rates, and value of conserved water as presented previously. [3] = [1] - [2]			

4.6 SUMMARY OF ULL TOILET COST-EFFECTIVENESS

Table 4.8 presents summary results that are most central to MOU decisions. Columns [1] and [2] contain the present value of benefits and present value of costs, respectively. Each of these statistics is presented for the supplier, participating customer, and total society perspectives. Net present value (NPV), in column [3], is calculated as described in Chapter 2. The MOU relies on CEA to determine whether the present value of benefits exceeds the present value of costs, which occurs when NPV is positive.

4.7 LARGE LANDSCAPE AUDITS

Water agencies have identified large landscape programs as an area with potentially large water savings. Each site typically utilizes a large quantity of

water each year, and water conservation technology for these sites has developed rapidly, including water sensors, more sophisticated irrigation timers, and more readily available weather data (e.g., CIMIS). Large landscape audit programs raise an important question: will water savings persist over time? Although ULFT toilet savings have been evaluated in a number of careful studies that involved actual meter readings and controlled research designs, large landscape programs have seen much less research. Since large landscape programs constitute a best management practice in the MOU (BMP 5—Large Landscape Audits and Incentives) and have large questions surrounding the level and persistence of their water savings, they constitute another good illustration.

This CEA example uses the case of large landscape audit programs conducted by the Contra Costa Water District (CCWD).²⁰ CCWD has

²⁰ Although this illustration is based on the CCWD Landscape Audit Program, it does not represent official policies, plans, or opinions of the Contra Costa Water District.

conducted large landscape audits as part of their ongoing conservation program. The audits conducted to date have contacted large sites by letter. The auditor first visually inspects the irrigation system and then measures selected sprinkler precipitation rates and distribution uniformities using catch-can tests. This information is fed into a computer that generates spring and summer irrigation schedules. A written report with recommendations is provided to each site and maintenance contractor.

4.8 IDENTIFY COSTS AND BENEFITS

Table 4.9 summarizes costs and benefits of the large landscape example. Since the audits focus on irrigation system scheduling and maintenance, the *participant program costs* include the extra time needed

to maintain the irrigation system and to fix leaks; additional costs may be incurred if the participant elects to upgrade sprinkler heads, irrigation controllers, or to install rain shut-off devices according to an auditor's recommendation. The *supplier's program costs* include the time needed to identify and contact large landscape customers, the costs of the audits conducted by CCWD staff, and administration. *Participant benefits* include a reduced water bill and a more uniformly watered landscape. Properly controlled watering results in more even greening in turf areas and less chance of root rot in shrub areas. *Supplier benefits* include the avoided costs of supply and fewer complaints from customers about high bills. External environmental benefits are derived from reduced water diversion and supply.

**Table 4.9
Identify Cost and Benefits**

Large Landscape Audits	
Category	Costs
Participant Program Costs	<ul style="list-style-type: none"> • Landscape crew taining and irrigation adjustments • Irrigation system leak repair • Irrigation equipment upgrades (e.g., sprinkler heads, controllers, and/or rain shut-off devices)
Supplier Program Costs	<ul style="list-style-type: none"> • Staff time to identify large landscape customers, contact them, and offer audit • Audits: examination of irrigation practices, landscape vegetation, and existing equipment • Irrigation system leak detection • Administration • Contractors
Category	Benefits
Participant Benefits	<ul style="list-style-type: none"> • Reduced water bills • Reduced frequency and cost of major leaks • Improved landscape quality
	<ul style="list-style-type: none"> • Decreased capital costs for water production, transport, storage, treatment, and distribution • Decreased O&M costs: energy, chemicals, labor • Fewer customer complaints
External Environmental Benefits	<ul style="list-style-type: none"> • Reduced environmental costs of water diversion, supply, and transportation

4.9 MEASURE AND VALUE COSTS AND BENEFITS

Costs. The program costs in this illustration derive, in part, from the landscape audit program costs estimated for CCWD (Table 4.10).²¹ The supplier program costs have been estimated at \$309.80 for a one acre site.²² Each additional acre takes about three more hours during the audit. An average large landscape site is assumed to be 1.37 acres,²³ so the estimated supplier program cost is \$394.60 for an average audit.

Table 4.10
Program Costs

Sector	Supplier Program Cost (\$/Audit) [1]	Participant Program Cost (\$/Audit) [2]	Total Society Program Cost (\$/Audit) [3]
One Acre Site (no repairs)	\$309.80	\$0.00	\$309.80
Average Site (1.37 acres)	\$394.60	\$1,300.00	\$1,694.60
Notes: [1] Supplier program cost per audit, (labor, equipment, and administration) [2] Participant program costs per audit is \$900 (controller/sprinkler heads) plus \$100 per year ongoing maintenance for four years [3] = [1] + [2]			

Participant program costs can vary widely depending on existing equipment and practices, and how much the participant chooses to invest in the irrigation system.²⁴ Since we do not have good information on actual equipment upgrades for this large landscape program, we assume that an average customer will invest \$900²⁵ in equipment upgrades and test this assumption for sensitivity below. Maintenance of the irrigation system and scheduling is usually included in a landscape contract, so there are often no ongoing costs to the customer. To the extent that better contractors, revised contracts, or additional staff time (for non-contract landscape work) are needed we add \$100 per year to participant costs.

Total society program costs in Table 4.10 are the sum of supplier and participant program costs.

Benefits. CCWD has calculated water savings from audits they have already conducted.²⁶ It calculated savings by comparing the percent change in water use before and after the audit for audited sites, less the percent change in water use during the same time period by a "control group" of sites that were not audited. The use of a control group accounts for water savings that would have occurred without the program

²¹ In this illustration, all costs and benefits are denominated in current (1995) dollars.

²² This cost estimate includes labor for the audit, the report with irrigation schedule, and administration costs, as well as equipment costs for the computer, catch cans, soil probe, pressure gauge, flags, wheel, walkie-talkie, mileage, and mailings. See "Landscape Water Audit Evaluation," Contra Costa Water District, August 1994.

²³ This is the average acreage of sites in the Landscape Water Audit Evaluation. Average acreage in the overall service area, as well as sites targeted for future water audits may be different from this average.

²⁴ At the low end, equipment costs are zero for those customers who simply adjust their irrigation schedule. Moderate equipment upgrades often include sprinkler heads. Many older irrigation systems have brass sprinkler heads, which do not spray high enough when conserving fescue grass is grown and maintained at 2.5 to 3 inches high; to prevent water pooling and uneven water spray distribution, new pop-up sprinkler heads are often installed. Irrigation control systems are at the high end of equipment upgrades.

²⁵ For commercial sites, computer controllers with installation cost from \$400 to \$2000 depending on controller features and wiring configuration. Small residential controllers cost as little as \$100 plus installation. Pop-up heads usually cost about \$25 installed, although this varies depending on the compatibility of new and old fittings. The \$900 average figure includes one controller or 36 sprinkler heads. Cost figures are available from landscape contractors.

²⁶ See "Landscape Water Audit Evaluation," Contra Costa Water District, August 1994.

due to drought rationing, weather, and higher water rates.²⁷ A total of 62 sites were audited and the non-audit (control) group consisted of the remaining 900 large landscape sites in the service area for which comparable data were available.

An important finding of the analysis is that the average water saving from the audit for all sites is 12.09 percent. Variation in savings ranges from a 64 percent reduction in water use to a 22 percent increase in water use. One explanation for the 17 sites that experienced increased water use is deficit irrigation before the audit. An additional finding of the analysis is that the larger the landscape, the less water was applied per acre before the audit—larger sites were more efficient.²⁸ In terms of savings persistence, the analysis shows that water savings decline in the years after the audit. Table 4.11 shows that savings were

20.6 percent in the first year, but only 7.7 percent in the second year after the audit and 6.5 percent in the third.²⁹

To value these water savings in dollar terms, from the *supplier perspective*, we consider first the cost of new water supply avoided by conservation. Although CCWD currently purchases nearly all of its water from the U.S. Bureau of Reclamation for \$42/AF, their contract entitlement may compete with environmental needs as specified in the Central Valley Project Improvement Act; the entitlement is subject to change before or upon contract renewal in 2010. Furthermore, the region is experiencing growth resulting in increased demand and supply shortfalls during drought years. These two factors warrant additional water supplies and conservation to manage future demand. “Extremely rough” CCWD estimates

Table 4.11
Program Savings

Years Since Audit	Baseline Water Use (AF/yr) [1]	Percent Savings [2]	Water Savings (AF/yr) [3]
0	12.25	0.0	0.00
1	12.25	20.6	2.52
2	12.25	7.7	0.94
3	12.25	6.5	0.80
4	12.25	3.0	0.37

Notes:
 [1] Baseline water use is for a 1.37 acre site
 [2] Savings rates in Years 1-3 are from the CCWD report; we assume Year 4 savings are 3%
 [3] = [1] x [2]

²⁷ Since the audit program’s mailing targeted the largest water use landscape sites, the audit group may have a heavier weighting of large sites than the non-audit group.

²⁸ Future landscape audits can be improved by examining the results of past experience. CCWD is considering targeting medium or smaller sites in the future because they appear less water efficient and they may have more potential for savings. When conducting prospective analyses of BMP 5, this type of information permits selection of savings estimates that match the sites targeted for future programs.

²⁹ Since the audit program had been operating only three years at the time of its evaluation, savings could be calculated only for three years. However, we expect continued, albeit lower, savings and assume 3 percent savings in year 4—approximately half of the measured savings in the third year of the program.

of new incremental raw water costs range from \$75/AF to \$175/AF, and up to \$200/AF. When these raw water supply costs are added to the costs of distribution and treatment, we calculate total long run marginal costs of new water supply range from \$1133 to \$1258/AF.³⁰ Supply costs are assumed to increase in steps as new supplies are needed in the future; we utilize a simplifying assumption of 1.5 percent per year real growth on average (the real escalation rate).

The external environmental benefits, which are part of supplier perspective and total society perspective benefits, are addressed below.

From the *total society perspective*, we consider the avoided new supply costs estimated above for the supplier to be reflective of the readily quantifiable benefits of conserved water. The costs are specific to the agency's future planned supplies. A detailed study of future water needs and supplies is presently being performed by CCWD and is expected to be available this summer (the "Future Water Supply Study").

From the *participating customer perspective*, saving water reduces water bills. Retail rates in CCWD are approximately \$1.85/HCF (or \$805.86/AF = \$1.85/HCF x 435.6AF/HCF), which includes water and electricity charges for pumping (which vary depending on location within the service area).³¹ In addition to water savings, the audit often results in improved appearance at the site—an intangible

characteristic—because more uniform water distribution results in more uniform greening.

4.10 DISCOUNT COSTS AND BENEFITS

Discounting from the Supplier Perspective.

CCWD's cost of capital for long term projects is approximately 6 percent per year (nominal); short term project financing is thought to be similar. Four years is our period of analysis, based on the persistence of large landscape audit savings determined in previous CCWD audits. Based on the 6 percent nominal rate and a 3 percent inflation rate, the real (adjusted for inflation) discount rate is 3 percent.³² Table 4.12 shows the year-by-year costs and benefits from the supplier's perspective. Undiscounted benefits are calculated by multiplying the water savings (Column [1]) times the value of conserved water. As described above, we expect the costs of new water supply to rise, so benefits per acre-foot saved are escalated over time (Column [2]). Column [4] contains the year-by-year costs. Columns [3] and [5] calculate the present value of benefits and costs, respectively. Finally, column [6] contains, as specified in the MOU, the present value of benefits minus the present value of costs (Net Present Value). Notice from the supplier perspective that for the life of the large landscape audit that NPV is nearly \$5000, indicating the measure is cost-effective.

³⁰ The costs of water supply, treatment, and distribution are approximately \$1100/AF, of which \$42/AF is the cost of raw water purchases from the Bureau of Reclamation. Since new water supply costs are expected to be as high as \$200/AF, new supply costs may be \$1258/AF [= \$1100/AF + (\$200-\$42)]. In the tables that follow, we utilize a middle of the road value of \$1196/AF. Since this agency is growing, we assume long run marginal costs avoided by conservation include new costs of supply, treatment, and distribution.

³¹ A fixed monthly cost, which is small relative to the unit charges for large landscape sites (approx \$.50/day), is also paid and should be included to determine (long run) marginal capacity costs as described in Chapter 2. Although the savings determined in the study are short lived, we utilize the long run because the program is part of BMP 5, a long term MOU conservation measure.

³² Nominal rates are converted to real rates according to the guidelines in Chapter 2:

$$.029 = (.06 - .03) / (1 + .03)$$

Table 4.12
Supplier Perspective: Present Value of Costs and Benefits

Year	Water Savings (AF/Audit) [1]	Undiscounted Benefits (\$/Audit) [2]	Present Value Benefits (\$/Audit) [3]	Undiscounted Costs (\$/Audit) [4]	Present Value Costs (\$/Audit) [5]	NPV [6]
0	0.00	\$0.00	\$0.00	\$394.60	\$394.60	(\$394.60)
1	2.52	\$3,062.83	\$2,973.62	\$0.00	\$0.00	\$2,973.62
2	0.94	\$1,162.02	\$1,095.31	\$0.00	\$0.00	\$1,095.31
3	0.80	\$995.64	\$911.15	\$0.00	\$0.00	\$911.15
4	0.37	\$466.42	\$414.41	\$0.00	\$0.00	\$414.41
Total	4.63	\$5,686.90	\$5,394.48	\$394.60	\$394.60	\$4,999.88

Notes:
 [1] = Savings per large landscape audit
 [2] = [1] x \$1196 x (1+e)^t where e is the escalation rate (1.5% real) and t is year
 [3] = [2] + (1+r)^t where r is the discount rate (3% real)
 [4] = Costs per large landscape audit
 [5] = [4] + (1+r)^t where r is the discount rate (3% real)
 [6] = [3] - [5] is Net Present Value

Since we have not identified external environmental costs associated with the large landscape audit program, and since the benefits exceed costs from the supplier perspective, there is no need to measure and value the external environmental benefits—the measure is cost-effective regardless of the magnitude of the external environmental benefits.

Discounting from the Customer’s Perspective.

Table 4.13 displays the cost-effectiveness calculations from a participating customer’s perspective when calculated with a 7 percent discount rate. Unlike the ULF toilet illustration, customer benefits do not include avoided costs of wastewater treatment (sewer charges). The large landscape audit program in this illustration is clearly cost-effective from the perspective of the participating customer; NPV is \$2161 per audit.

From the nonparticipating customer perspective, we examine the potential changes in water rates over time. To do so, according to the guidelines in Chapter 2, we examine the present value of costs and benefits

from the supplier perspective to indicate rate and bill changes. Examination of Table 4.12 indicates that at the initiation of the program, NPV is negative, indicating that nonparticipating customers may initially face higher water rates, and without additional conservation, higher water bills. However, after the first year, nonparticipating customers face lower rates and lower bills, which continue over the life of this program.

Discounting from a Total Society Perspective.

Table 4.14 shows the present value of costs and benefits from the total society perspective. To complete the total society perspective CEA, environmental costs and benefits need to be considered. As with the supplier perspective analysis, we know the measure is cost-effective, even without measuring and valuing external environmental benefits, because (1) the present value of benefits exceeds the present value of costs and (2) we have not identified external environmental costs associated with the large landscape audit program.

Table 4.13
Participating Customer Perspective: Present Value of Costs and Benefits

Year	Water Savings (AF/Audit) [1]	Undiscounted Benefits (\$/Audit) [2]	Present Value Benefits (\$/Audit) [3]	Undiscounted Costs (\$/Audit) [4]	Present Value Costs (\$/Audit) [5]	NPV [6]
0	0.00	\$0.00	\$0.00	\$900.00	\$900.00	(\$900.00)
1	2.52	\$2,063.72	\$1,928.71	\$100.00	\$93.46	\$1,835.25
2	0.94	\$782.96	\$683.87	\$100.00	\$87.34	\$596.53
3	0.80	\$670.86	\$547.62	\$100.00	\$81.63	\$465.99
4	0.37	\$314.27	\$239.76	\$100.00	\$76.29	\$163.47
Total	4.63	\$3,831.81	\$3,399.95	\$394.60	\$1,238.72	\$2,161.23

Notes:
 [1] = Savings per large landscape audit
 [2] = [1] x \$805.86 x (1+e)^t where e is the escalation rate (1.5% real) and t is year
 [3] = [2] + (1+r)^t where r is the discount rate (7% real)
 [4] = Costs per large landscape audit
 [5] = [4] + (1+r)^t where r is the discount rate (7% real)
 [6] = [3] - [5] is Net Present Value

Table 4.14
Total Society Perspective: Present Value of Costs and Benefits

Year	Water Savings (AF/Audit) [1]	Undiscounted Benefits (\$/Audit) [2]	Present Value Benefits (\$/Audit) [3]	Undiscounted Costs (\$/Audit) [4]	Present Value Costs (\$/Audit) [5]	NPV [6]
0	0.00	\$0.00	\$0.00	\$1,294.60	\$1,294.60	(\$1,294.60)
1	2.52	\$3,062.83	\$2,935.15	\$100.00	\$95.83	\$2,839.32
2	0.94	\$1,162.02	\$1,067.15	\$100.00	\$91.84	\$975.32
3	0.80	\$995.64	\$876.24	\$100.00	\$88.01	\$788.23
4	0.37	\$466.42	\$393.37	\$100.00	\$84.34	\$309.03
Total	4.63	\$5,686.90	\$5,271.92	\$1,694.60	\$1,654.62	\$3,617.30

Notes:
 [1] = Savings per large landscape audit
 [2] = [1] x \$1196 x (1+e)^t where e is the escalation rate (1.5% real) and t is year
 [3] = [2] + (1+r)^t where r is the discount rate (4.35% real)
 [4] = Costs per large landscape audit
 [5] = [4] + (1+r)^t where r is the discount rate (4.35% real)
 [6] = [3] - [5] is Net Present Value

4.11 ANALYZE UNCERTAINTY

In this illustrative example, we test different sources of uncertainty than for the ULF toilet program. First, we are less confident in the savings estimates for the large landscape audit program than for the ULF toilet program because (1) audit savings are widely variable from site to site and (2) the audit sites may vary systematically from the control group used to account for non-audit savings. Second, we have little information on the equipment upgrades that actually took place at the audit sites. The reader is referred to the ULF toilet illustration for examples of uncertainty analysis of discount rate, escalation rate, and physical life.

Table 4.15 shows results of sensitivity tests focusing on savings and persistence of savings. Net present value is calculated for each of four savings

profiles: "Measured" is the savings profile of past large landscape audits as shown in Table 4.11. "High" is a savings profile that assumes near perfect savings persistence, and "Low" assumes both less initial savings and less persistence of savings. Even with low savings, the program benefits exceed costs for all perspectives.

As discussed previously, the cost of equipment upgrades for the participating customers can vary from zero to \$3000 or more per site depending on existing equipment and how extensively the customer responds to the audit. We test the average equipment upgrade costs at zero and \$3000, extreme values for *average* upgrade costs. NPV is still positive across this range of equipment upgrade costs, varying from \$61 to \$3061 for the participating customer perspective and from \$1517 to \$4517 for the total society perspective.

Table 4.15
Sensitivity to Water Savings and Persistence

Savings Profiles*			
Year	High	Measured	Low
1	0.206	0.206	0.100
2	0.200	0.077	0.050
3	0.200	0.065	0.030
4	0.200	0.030	0.010
NPV**			
Perspective	High	Measured	Low
Supplier	\$10,990	\$5,000	\$2,319
Participating Customer	\$5,750	\$2,161	\$774
Total Society	\$9,371	\$3,617	\$1,299
Notes: *Percent annual savings per large landscape audit **NPV calculated with same discount rates, escalation rates, and value of conserved water as presented previously in this illustration, by perspective			

**4.12 SUMMARY OF LARGE LANDSCAPE
AUDIT COST-EFFECTIVENESS**

Table 4.16 presents summary CEA results that are important to MOU decisions. In particular, the table shows that the large landscape audit program is likely to be cost-effective from the perspectives most important for BMP exemption decisions: the supplier perspective and the total society perspective. In addition, the BMP is cost-effective from the participating customer perspective.

4.13 CONCLUSIONS

The two illustrations in this chapter highlight some of the different circumstances in which the CEA guidelines may be applied. Differences include geographic region (Northern v. Southern California), cost of capital, and the value of conserved water, among others. These differing circumstances may cause CEAs of the same BMP to yield different results.

These illustrations require three caveats:

- Savings estimates for Santa Monica’s ULF toilet program have a high level of reliability, because they derive from extensive empirical measurement.

However, ULF toilet programs for other regions in California may require extrapolating from other studies and/or more thorough sensitivity testing. This is also true for other BMPs, such as large landscape audits.

- In these illustrations, the screening guideline indicates no need to measure and value external environmental costs and benefits. In other cases, the guidelines might indicate that breakeven analysis is appropriate, or potentially, that additional benefits valuation is warranted. (Appendix A).
- The illustrations are not conducted from a “cookbook recipe” for CEA. Instead, the intent is to show how to apply the guidelines and exercise judgment in doing so. In each case, the guidelines can be applied to the unique set of circumstances. It is very important to make explicit all assumptions that go into each analysis.

This chapter has used the guidelines from Chapters 2 and 3 to illustrate how CEA can analyze BMP programs related to ULF toilets and large landscape audits. Chapter 5 draws conclusions regarding these guidelines and the use of CEA in the MOU process.

**Table 4.16
Results Summary: Large Landscape Audit Program**

Perspective	Present Value Benefits* (\$/Audit) [1]	Present Value Costs* (\$/Audit) [2]	Net Present Value NPV (\$/Audit) [3]
Supplier	\$5,394	\$395	\$5,000
Total Society	\$5,271	\$1,654	\$3,617
Participating Customer	\$3,400	\$1,239	\$2,161
Notes: [3] = [1] - [2] *Present value of costs and benefits is calculated with the same discount rates, escalation rates, and value of conserved water as presented previously in this illustration, by perspective			

CONCLUSIONS

The MOU has ushered in a major change in water resource management in California. Water conservation is now integral to water planning, and the MOU provides the process and structure to determine which conservation measures to implement. The MOU relies on CEA as an important criterion to determine which BMPs are on the list for implementation and to determine if a supplier is eligible for BMP exemption. These guidelines should provide a consistent structure and specific methods for the Council and its signatory organizations to evaluate BMPs and BMP exemptions.

Chapters 1-3 of this document have interpreted the MOU's requirements for CEA and translated them into specific guidelines for analysis. Chapter 1 reviewed the MOU's requirements and background on cost-effectiveness analysis. Chapter 2 provided general guidelines that are applicable to all BMPs. Chapter 3 provided guidelines that are specific to particular BMPs. Each of these chapters shows that CEA cannot

be applied in a in a "cookbook" fashion, using the exact same method for each circumstance. The method requires judgment, and this document provides guidance in making such judgments.

Although the guidelines are directive, they do not pretend to resolve all issues that arise in the conduct of CEA. There is ample controversy within the economics and water planning professions regarding CEA methodology. For example, Chapter 2 provides practical guidance on the choice of a social discount rate, but it should be expected that the Council may choose to enhance or revise this guideline over time. Valuing environmental benefits is another area where future research could enhance existing guidelines. Even where there is agreement on a method, the resources needed to conduct such analyses may be prohibitively expensive. As more information becomes available, as methods develop, and as experience is gained, these guidelines will inevitably evolve. CUWCC will enhance these guidelines in the fashion of a "living document," like the MOU itself.

REFERENCES

- Acton, J.P. (1973), "Evaluating Public Programs to Save Lives: The Case of Heart Attacks," Research Report R-73-02, Rand Corporation, Santa Monica, CA.
- AWWA (1988), "Water Utility Capital Financing," American Water Works Association, Denver.
- Barakat & Chamberlin (1994a), "The Value of Water Supply Reliability: Results of a Contingent Valuation Survey of Residential Customers," Oakland, August. Prepared for California Urban Water Agencies, Sacramento.
- Barakat & Chamberlin (1994b), "A Guide To Customer Incentives for Water Conservation," Oakland, February. Prepared for California Urban Water Agencies with the California Urban Water Conservation Council and the U.S. Environmental Protection Agency.
- Beecher, J.A. (1995), "Integrated Resource Planning Fundamentals," Journal: American Water Works Association, June.
- California Department of Water Resources (1986), "Water Audit and Leak Detection Guidebook," Office of Water Conservation, August. Jointly sponsored with the American Water Works Association, California-Nevada Section.
- California Department of Water Resources (1990), "Water Plan Service Area Information," August.
- California Water Resources Control Board (1992), "Water Reclamation Loan Program, Background Information on Economic Analysis of Reclamation Projects," Office of Water Recycling, April.
- California Department of Water Resources (1993), "Water Conservation Bond Law of 1988 Loan Application for Local Water Supply Project Construction," Division of Local Assistance, September.
- California Public Utilities Commission and California Energy Commission (1987), "Standard Practice Manual: Economic Analysis of Demand Side Management Programs," December.
- [Carson et al.] Carson, R.T., N. Carson, A. Alberini, N. Flores, and J. Wright (1993), *A Bibliography of Contingent Valuation Studies and Papers*, Natural Resource Damage Assessment, Inc., La Jolla, CA, December.
- Chesnutt, T.W., C.N. McSpadden, and A. Bamezai (1994), "Ultra Low Flow Toilet Programs: Evaluation of Program Outcomes and Water Savings," A & N Technical Services, Inc., Santa Monica, November. Prepared for the Metropolitan Water District of Southern California, Los Angeles.
- Clawson, M. (1959), "Methods of Measuring the Demand for the Value of Outdoor Recreation," Reprint no. 10, Resources for the Future, Washington, DC.
- Cummings et al. (1986), *Valuing Environmental Goods: A State of the Arts Assessment of the Contingent Method*, Totowa, NJ: Rowman and Allanheld.
- Davis, Robert (1963), "The Value of Outdoor Recreation: An Economic Study of the Maine Woods," Ph.D. Dissertation, Harvard University.
- EPA (U.S. Environmental Protection Agency) (1995), "Cleaner Water Through Conservation," Office of Water, Washington, DC, April.

- Freeman, A.M. (1993), *The Measurement of Environmental and Resource Values, Theory and Methods*, Washington, DC: Resources for the Future.
- Gramlich, F.W. (1977), "The Demand for Clean Water: The Case of the Charles River," *National Tax Journal*, Vol. 30, No. 2, pp. 183-194.
- Green, P.E., and Y. Wind (1973), *Multiattribute Decisions in Marketing: A Measurement Approach*, Hinsdale, IL: Dryden Press.
- Hanemann, W.M. (1987), "WTP and WTA As Benefit Measures--How Do They Differ? How Can They Be Measured?" in The Bay Institute of San Francisco, "Proceedings of a Workshop on Economic Non-Market Evaluation of Losses to Fish, Wildlife and Other Environmental Resources," May.
- Hartman, R.S., and M.J. Doane (1986), "Household Discount Rates Revisited," *The Energy Journal*, Vol.7, No. 1, January.
- Keeney, R.L., and H. Raiffa (1976), *Decisions with Multiple Objectives: Preferences and Value Tradeoffs*, New York: Wiley.
- Lind, R.C. (1990), "Reassessing the Government's Discount Rate Policy in Light of New Theory and Data in a World Economy with a High Degree of Capital Mobility," *Journal of Environmental Economics and Management*, Vol. 18, pp. S8-S28.
- Lind, R.C., et al. (1982), *Discounting for Time and Risk in Energy Policy*, Washington, D.C.: Resources for the Future.
- Lyon, R.M. (1990), "Federal Discount Policy, the Shadow Price of Capital, and Challenges for Reforms," *Journal of Environmental Economics and Management*, Vol. 18.
- Maddaus, W.O., et al. (forthcoming), "Integrating Water Conservation into Water Supply Planning," *Journal AWWA*.
- Mitchell, R.C., and R.T. Carson (1989), *Using Surveys to Value Public Goods, The Contingent Valuation Method*, Washington, DC: Resources for the Future.
- MOU (1994), "Memorandum of Understanding Regarding Urban Water Conservation in California," California Urban Water Conservation Council, Last Amended March 9, 1994.
- Moyer, E.E. (1985), "Economics of Leak Detection: A Case Study Approach," American Water Works Association.
- Navrud, S. (1992), *Pricing the European Environment*, New York: Oxford University Press.
- [NPS] U.S. National Park Service (1949), *The Economics of Public Recreation: An Economic Study of the Monetary Evaluation of Recreation in the National Parks*, Washington, DC.
- Office of Management and Budget (1992a), "Benefit-Cost Analysis of Federal Programs; Guidelines and Discounts," *Federal Register*, Vol. 57, No. 218, p. 53519, November 10. Appendix C revised January 1995.
- Office of Management and Budget (1992b), "Regulatory Impact Analysis Guidance," Appendix V of *Regulatory Program of the United States Government* for April 1, 1991 to March 31, 1992.
- Office of Management and Budget (OMB, 1996), "Economic Analysis of Federal Regulations Under Executive Order 12866."

- Oster, S. (1977), "Survey Results on the Benefits of Water Pollution Abatement in the Merrimack River Basin," *Water Resources Research*, Vol. 13, pp. 882-884.
- Planning and Management Consultants, Ltd. (1993) "Evaluating Urban Water Conservation Programs: A Procedures Manual," Carbondale, IL. Prepared for California Urban Water Agencies, Sacramento. Distributed by the American Water Works Association, Denver, CO.
- QED Research, Inc. (1987), "Economic Value of Reliable Water Supplies for Industrial Water Users," Palo Alto, June. Prepared for the Metropolitan Water District of Southern California, Los Angeles.
- RCG/Hagler Bailly, Inc. (1991), "Impact Evaluation of Demand-Side Management Programs, Volume I: A Guide to Current Practice," Boulder, CO, February. Prepared for the Electric Power Research Institute, Palo Alto.
- Randal, A., B.C. Ives and C. Eastman (1974), "Bidding Games for Valuation of Aesthetic Environmental Improvements," *Journal of Environmental Economics and Management*, Vol.1, pp. 132-149.
- Ridker, R. (1967), *Economic Costs of Air Pollution Control*, New York: Praeger.
- Stokey, E. and R. Zeckhauser (1978) *A Primer for Policy Analysis*, New York: Norton, Chapter 14.
- Spectrum Economics (1991), "The Cost of Industrial Water Shortages", Prepared for the California Urban Water Agencies.
- Tabors Caramanis and Associates (1994), "Long-Term Water Conservation & Shortage Management Practices: Planning that Includes Demand Hardening," Davis, CA, June. Prepared for California Urban Water Agencies, Sacramento.
- Trice, A. and S. Wood (1958), "Measurement of Recreation Benefits," *Land Economics* 34, August.
- Warner, K.E. and B.R. Luce (1982) *Cost-Benefit and Cost-Effectiveness Analysis in Health Care*, Ann Arbor: Health Administration Press.
- Zerbe, R.O., and D.D. Dively (1994) *Benefit-Cost Analysis in Theory and Practice*, New York: Harper Collins College Publishers.

APPENDIX A

VALUING ENVIRONMENTAL EXTERNALITIES

A.5 What Are External Environmental Costs and Benefits?

The term "externality," used to cover both "external costs" and "external benefits," is a technical term in economics. It is not necessarily limited to *environmental* effects, although most of the focus in recent years has been on those. An external cost occurs when one party, as a result of its actions, adversely affects another party either by reducing its productivity or its well being, or by raising its costs. An external benefit occurs when one party beneficially affects another party either by raising its productivity or its well being, or lowering its costs. These interactions are labeled externalities when the effect is essentially not a market interaction. For example, if someone buys up a large amount of waterfront land and thereby drives up the price of other waterfront land on the market, rendering it more valuable for current owners and more costly for potential buyers, this is known as a "pecuniary" effect, not an externality. This is because, although there is an interaction, it is an interaction among participants in a market and *it is transmitted purely through the market*. By contrast, if a someone puts up a building that casts a shadow on his neighbors' property or blocks their view, this is an externality not a pecuniary effect. There certainly can be market implications — the value of the neighbors' property is lowered — but the underlying interaction is a *physical* one (casting a shadow, blocking a view) rather than a market one (pushing up price by increasing demand). The essential idea, then, is that one party's action has a direct, physical effect on the welfare or cost of others.

The concomitant implication is that, in the case of an externality, the market does not confront people with costs or benefits that they impose on others. While a decision maker takes into account the benefits and costs that accrue to her, she is likely to disregard those that accrue to others. For this reason, in the face of externalities, private decisions are likely to lead to socially undesirable outcomes. This argument was first developed systematically in the 1920s as an example of what subsequently became known as "market failure": because of uncompensated externalities, competitive markets can produce an inefficient allocation of resources. The identified remedy was corrective taxes or subsidies. The government would impose taxes or offer subsidies for activities that cause external costs or benefits. In the case of an external cost, the tax would equal the amount of the external cost; in the case of an external benefit, the subsidy would equal the amount of the external benefit. While people might disregard the costs and benefits they impose on others, they do pay attention to taxes and subsidies; hence, in the language of economics, the corrective taxes and subsidies *internalize* the externality.

Taxes on externalities, such as taxes on the discharge of water or air pollutants, have been used occasionally, for example along the Ruhr River in Germany, but they were very rare until recently. In the last decade, however, there has been a revival of interest in them in the US and many other countries. One manifestation of this interest is the move toward environmental costing by many public utility commissions (PUC's) in the US — since the late 1980's more than half the states have either adopted methods for incorporating external costs in planning and decision making for new electric generating capacity or are investigating the desirability of doing so. These typically involve what are known as "environmental adders," cost factors added to the normal O&M and capital cost estimates for a new source of electric power that are intended to capture the external social and



environmental costs associated with generating power in that source. In the case of a coal fired plant, for example, these could include air pollution damages from burning coal, environmental damage from mining coal, and also social costs such as the increased number of cases of lung disease among coal miners. Thus, for a coal fired plant, while the normal capital and operating marginal costs might amount to, say, 8¢/kWh, the external social and environmental marginal costs might amount to, say, 2¢/kWh, making for an aggregate marginal cost of 10¢/kWh. By contrast, a clean source of power might have a higher private cost (say, 9¢/kWh) but a much lower "environmental adder" (say, 0.5¢/kWh), leading to a smaller aggregate cost (9.5 versus 10¢ per kWh). Factoring in the adder would change the plant selected by planners and regulators. But, as most PUCs have implemented this, it would not affect the prices paid by electricity consumers since environmental adders are generally being used only for planning purposes, not for actual billing.

A.2 How Should Environmental Externalities Be Identified, Measured, and Valued?

An analysis assessing external environmental costs has two main components, neither of them simple. First, one has to identify and quantify (measure) the environmental impacts associated with water utility action. Second, one has to convert the impacts to monetary benefits and costs (valuation).

With regard to the first step, external environmental impacts arising in connection with water utility activities could include such things as impacts on wetlands, riparian habitat, fisheries, in-stream pollution assimilation capacity, etc. resulting from the diversion of stream flow, impacts on recreation from creating a new reservoir, impacts on water tables due to changes in groundwater pumping or return flows, and impacts on coastal aquifers subject to saline intrusion. An important question in this part of the analysis is how to delimit the impacts, both geographically and in terms of the directness of the linkage with the water utility actions.

Most of the external impacts are likely to occur outside the boundaries of the utility's service area. With electricity generation the impacts could occur in distant parts of the country (e.g. where the coal is mined), so that there is a case for adopting a national perspective in environmental costing. In the case of water supply in California, it seems likely that most of the external environmental impacts will occur somewhere within the state. Therefore, a statewide perspective is likely to be adequate for environmental costing in this case.

In delineating external environmental impacts, one is making an assessment of cause and effect. One has to identify what would have happened in the absence of the utility's actions, which involves judgments of how both natural and social systems react to changes in their circumstances. For example, in the absence of stream flow diversion by the utility, what species of fish would have occupied the stream segment *given the other changes that were occurring in the system?* Similarly, in the absence of groundwater pumping by the utility, what groundwater pumping by other parties would have occurred, and how would this have affected the water table? These counterfactuals are matters of judgment. Likewise, how remote a causal linkage can be before it is discounted is a matter of judgment. It is important that the assumptions underlying the analysis be clearly identified, so that the judgments being made by the analyst are transparent to outside readers.

A.3 How Are External Environmental Costs and Benefits Valued?

Given that one has identified and quantified a set of positive or negative environmental impacts associated with a water utility action, how does one express these in monetary terms? How can one convert environmental outcomes to dollars and cents? To many non-economists this seems either impossible or ill-advised. It is, in fact, a branch of economics that has grown out of benefit-cost analysis and is known as *non-market valuation*. Here we offer a brief description, supplemented by a longer exposition below.

We will start with some remarks about the valuation strategies that have been adopted so far by PUC's in connection with environmental adders for electricity generation. Critics have argued that some of the early PUC efforts at environmental costing involved arbitrary adders that bore no plausible relationship to the environmental damages they purported to measure (Joskow, 1992). The criticism is focused particularly at environmental adders derived via the *cost of control method*. With this method, adders for various environmental impacts are based on estimates of the highest cost of controlling the pollution emissions that caused these impacts. The criticism is that this measures the cost of abating the environmental damage, not the cost of the damage itself.

This is both an old and confusing issue in economics. It was actually dealt with in Adam Smith's *Wealth of Nations*, which emphasized the crucial distinction between *supply* and *demand*. Supply has to do with what things *cost*. Demand has to do with *what things are worth*. The two are fundamentally distinct. Something can cost a lot but be socially worthless (e.g. diamonds), or it can be extremely valuable socially but very cheap (e.g. water). Smith resolved the diamond/water paradox by showing that economists had been overlooking the key distinction between supply and demand. Confounding the two is something that continues to happen from time to time, partly because it often seems easier or more objective to measure what things cost than what they are worth. Nevertheless, it is a mistake to confuse one with the other.

There is an important exception to this principle which arises from what is known as the *lesser of rule* in economics. If someone is to be compensated for a loss, the appropriate compensation is the lesser of what the lost item was worth to the individual or what it would cost to replace it. If it can be replaced to the individual's satisfaction at some cost lower than what the item is worth, the compensation can appropriately be based on the cost of replacement not on the value of the item. This is the one case where cost can be used as a measure of value. But, if the cost of replacement exceeds the value of the item, then it would be wrong to measure value by cost. This is what critics argued was happening with some environmental adders by PUCs. Whether or not they were right is an empirical question. For our purposes, the important conclusion is that, in general, one should assess environmental adders on the basis of what the external environmental impacts are worth to people, rather than what it would cost to prevent them from occurring.

How does one assess what something is worth to people in monetary terms? Most people tend to equate monetary value with market price. If something sells for \$6 in a market, then this must be its value. Thus, economic valuation is the science of market prices. The implication is that, when something does *not* sell in a market and, therefore, does *not* have a price, there is *no* monetary value. By this logic, a fishery can be valued in monetary terms if it is a commercial fishery, but it has no value otherwise. The bald eagle, for which there is no commercial market by law, has no monetary value.

This is incorrect; monetary valuation has a much broader meaning for economists today. The modern view is that economics is not about markets *per se* but about people, their preferences, and their behavior in relation to scarce resources. Markets offer one arena in which choices are made and from which preferences can be deduced — but by no means the *only* arena. Money — income — is important for people's well-being because it brings command over market goods and services which give them pleasure and satisfaction. But, economists also recognize that people gain pleasure and satisfaction from many *other* things that do not pass through the market — personal relationships, moral or religious beliefs, great art or music, a pristine environment, a beautiful sunset, etc. The modern economic theory of value encompasses both sources of satisfaction.

What, then, does it mean to place a monetary value on non-market sources of satisfaction ("non-market commodities")? In economics, the key to measuring people's preferences for commodities — *any* commodity, whether market or non-market — is to measure their welfare in terms of their income, or rather *to measure changes in their welfare in terms of equivalent changes in their income*. Generically, there are two alternative ways to do this, known as willingness to pay (WTP) and willingness to accept (WTA). Suppose the item in question makes people better off — they regard it as a good rather than a bad. One approach is to measure how much the individual would be willing to pay *if* he could obtain the item by making a payment. The maximum amount he would be willing to pay for it measures its value to him in monetary terms. The alternative approach is to measure how much one would have to pay the individual *if* he could be induced by a payment to go without the item. The minimum amount that he would be willing to accept to forego the item is the alternative monetary measure of its value.¹

WTP and WTA are the fundamental monetary measures of value in economics. All economic valuation can be shown to correspond to one or the other. Economists employ these concepts, for example, when they measure the impact on firms of some event that causes a loss of income or profit; when they measure the impact on consumers of a price reduction, an improvement in quality, or the appearance of a previously unavailable commodity; and when they measure the impact associated with a change in the availability of a non-market good, including a change in the quality of the natural environment.

The quantities WTP and WTA are closely related to a concept for market goods called *consumer's surplus*. It is usually explained as follows. Consider a consumer buying a market good — chocolate truffles, say — which sell for \$1.50 each. Suppose the individual buys two truffles a week, so that he spends \$156 per year on truffles. You might ask, "What are the truffles worth to him?" Suppose there is a fire at the factory where the truffles are made and it is completely destroyed. No more truffles are available for one year. What is the monetary measure of the individual's loss? One might suggest that the loss is \$156, the amount that he would have *spent* on truffles during the year. But, this is a bad measure for two reasons. First, while truffles must clearly be worth at least \$156 per year to him if he spends this much on them, they could be worth *far more* than that. It may be that he would be willing to spend, say, \$250 on truffles a year if he really had to. The \$156 is what the truffles cost, not what they are *worth*. Total *willingness to pay* measures what things are worth to a consumer — in this case, \$250 per year. Since his actual expenditure is \$156, he has a *net gain* of \$94 each year when he buys the truffles. Second, it is this net gain that measures the consumer's loss. When the factory burns down, he does not lose the \$156 he

¹ If the item were a bad that makes the person worse off, WTP measures the maximum amount that he would be willing to pay to avoid the item, while WTA measures the minimum amount he would be willing to accept to put up with it.



would have spent; it stays in his wallet. What he loses is the opportunity to buy for \$156 something that he would have been willing to buy for \$250. He loses the net gain of \$94. This net gain is what economists call consumer's surplus: it is the difference between what a commodity is worth to a consumer and what he actually pays for it. When we measure total worth in terms of total WTP, then consumer's surplus is simply *net* WTP. When we measure total worth in terms of total WTA, then consumer's surplus is simply net WTA.

There is a parallel concept for producers known as *producer's surplus*. Like consumer's surplus, this is a *net* concept — it is the difference between what a commodity is worth to a *seller* and what he actually receives for it. This is generally equivalent to profit plus any economic rent. The sum of producer's plus consumer's surplus represents the economic criterion of value. All actions can be assessed in terms of their impact on producer's plus consumer's surplus.

When it comes to non-market commodities, the same logic carries over, except that usually no expenditures are incurred for these commodities because they are not sold in a market. Hence, usually (but not always) no producer's surplus is involved, and the distinction between *total* and *net* WTP (or WTA) vanishes, so that we just refer to WTP or WTA without a modifier, as the criterion of value.

A.4 Types of Economic Value

People benefit from many different aspects of the natural environment, and in many different ways. Hence, there is no single typology that is useful in all circumstances for classifying the benefits of environmental protection or the damages from environmental degradation. What is the best classification depends on the particular questions being asked and the particular purposes for which the valuation exercise is being performed.

One approach is to classify environmental benefits/damages from a physical or biological point of view — focusing, for example, on the source of pollution or the type of resource or environmental medium. We will follow this approach here, discussing first water pollution and then air pollution. Within the two broad categories, however, we will adopt elements of other typologies. One such typology classifies environmental effects in terms of whether they impact humans directly or other things that humans care about [see Table A.1, which is taken from Freeman (1993)]. The first category, *direct effects on humans*, includes the value of preventing morbidity and mortality associated with air and water pollution. Most of the existing literature here focuses on air rather than water pollution. Also in this category are visibility, visual aesthetics, and direct human enjoyment of both clean air and clean water. The second category is impacts that affect humans indirectly because they fall on ecosystems and living organisms from which humans benefit in some way. This is particularly important for water pollution and aquatic ecosystems, but there are also impacts of air pollution on vegetation, forests, and aquatic ecosystems through acid rain. The third category is nonliving systems, and it includes factors such as materials damage from air pollution and climate change from carbon emissions.

An alternative is to use an economic classification. One economic distinction is that between when the environment is enjoyed as a final good versus as an input to the production of something else. An example of the latter would be materials damage where water quality matters not in its own right but because it affects the use of water in some production process. In that case, the value of the environment depends on both the production function linking input to output and the value of the final output itself. In both cases, the value of the environment is affected by the possibility of substitution — substitution with other outputs if the environment is a final good, and substitution with other inputs if it is an input.

- A. Direct impacts on humans
 - 1. Human health—morbidity and mortality effects associated with air and water pollution
 - 2. Odor, visibility, visual aesthetic
- B. Ecosystem impacts—biological mechanisms
 - 1. Impacts on the economic productivity of ecological systems
 - Agricultural productivity
 - Forestry
 - Commercial fisheries
 - 2. Other ecosystem impacts
 - Recreational uses of ecosystems—fishing, hunting
 - Ecological Diversity, stability
- C. Impacts through nonliving systems
 - 1. Materials damage, soiling, production costs
 - 2. Weather, climate

Table A.1 – Typology of Environmental Impacts [from Freeman (1993)]

Another distinction is whether the effects of the environmental resource are conveyed through the market system (in the form of changes in income for producers or workers, or changes in the price, availability, or quality of marketed goods for consumers) versus through changes in the availability or quality of commodities *not* usually provided through markets. A related distinction is that between private and public goods [for an illustration see Table A.2, from Mitchell and Carson (1989)]. In economics, a pure *private good* is one that is bought and sold in an organized market where those participating have identifiable individual property rights to the goods. A pure *public good* has the properties that economists term "non-rivalry" and "non-excludability." Non-rivalry means that the same commodity can be consumed simultaneously by more than one consumer. This is *not* true of, say, chocolate truffles: if I eat a truffle, there is one less available for you. Not so with, say, the national defense or a beautiful sunset: if it is there for you to enjoy, it must be there for me too. This does not imply that everybody likes the commodity to the same degree — far from it. Excludability relates to whether or not it is possible to restrict consumers's access to the commodity. This is related to non-rivalry but not quite the same thing. Consider the Golden Gate Bridge, for example; this is a non-rival commodity (once it was constructed it was, in principle, available for all) but one that is clearly excludable (you don't get on without paying the toll). To deal with such commodities, a third category has been proposed, called *quasi-public* goods, which are non-rival but excludable.

Class of Good	Characteristics	Examples
Pure Private	Individual property rights Ability to exclude potential consumers Traded freely in competitive markets	Agricultural products Automobiles Financial Services
Quasi-private	Individual property rights Ability to exclude potential consumers Not freely traded in competitive markets	Public libraries Recreation in parks TV frequencies
Pure public	Collective property rights Cannot exclude potential consumers Not traded in any organized market	Air visibility Environmental risks National defense

Table A.2 – Classes and Characteristics of Goods [from Mitchell and Carson 1989]

There must be excludability in order for markets to function; otherwise one can never force another to pay for the commodity. There are no markets, therefore, in public goods. With quasi-public goods, however, there may or may not be a market. Some aspects of the environment (e.g. a fishery at a pier) fall into the latter category. Others (a beautiful sunset) are pure public goods. Such distinctions affect the choice of measurement strategy, which is discussed further in the next section.

The other common economic typology classifies the values that people place on the natural environment into three general categories: use values, option values, and existence values [a version of this classification is shown in Figure 3, taken from Mitchell and Carson (1989)]. *Use values* can arise in the context of either consumptive or non-consumptive uses of the natural environment, for example, hunting or fishing versus wildlife viewing. These may involve a commercial activity (e.g. commercial fishing) or a private activity (e.g., sport fishing). Moreover, these values can reflect the current generation's use of the natural environment or its concern for future generations' uses (bequest values). *Option value* is the value attached to preserving the option to enjoy the resource in the future against the possibility that it may be impaired or become unavailable. *Existence value* (also called non-use value or intrinsic value) is the value an individual places on the environmental commodity from motives *unconnected* with his own use of the resource (e.g., the satisfaction gained from knowing that it is undisturbed and undamaged, even if you never use it or see it). It is fair to say that, as the U.S. has evolved from a natural resource-based or industrial economy to a high-technology and service-based economy, most of the economic value associated with the natural environment has switched from commercial use values to recreational and non-consumptive use values and, increasingly, to non-use values.

Benefit Class	Benefit Category	Benefit Subcategory (examples)
Use	In-Stream	Recreational (water skiing, fishing, swimming, boating)
		Commercial (fishing, navigation)
	Withdrawal	Municipal (drinking water, waste disposal)
		Agriculture (irrigation)
		Industrial/commercial (process treatment, waste disposal)
	Aesthetic	Enhanced near-water recreation (hiking, picnicking, photography)
Enhanced routine viewing (commuting, office/home views)		
Ecosystem	Enhanced recreation support (duck hunting)	
	Enhanced general ecosystem support (food chain)	
Existence	Vicarious Consumption	Significant others (relatives, close friends)
		Diffuse others (general public)
	Stewardship	Inherent (preserving remote wetlands)
		Bequest (family, future generations)

Table A.3 – A Typology of Possible Benefits from an Improvement in Freshwater Quality [from Michell and Carson (1989)]

A.5 Methods of Economic Valuation

We mentioned earlier the tradition in economics of using market prices for valuation. For *small* changes in the supply or demand for marketed goods, this is indeed a valid procedure. However, for *non-marginal* changes, one should measure the economic impact by the change in aggregate consumer's plus producer's surplus. The great English economist Alfred Marshall showed in 1890 that consumer's surplus could be measured by the area under demand curve for the commodity in question, and producer's surplus by the area above the supply curve. This provided a method of implementing the welfare measurement — first estimate demand and supply curves from market data using standard statistical techniques, then calculate the areas under these curves. For large changes, the shift in the area under these curves can diverge substantially from what one would get by multiplying the quantity change by a price.

The approach based on demand and supply curves accounts completely for changes in the price, quality, or availability of market goods. Although it dates back to the beginning of the century, it was not finally established until the 1940s, following an important paper by Hotelling (1938) which proved that it could be reconciled with the theory of ordinal utility that had swept over economic theory in the 1930s. It then quickly became the standard method for measuring economic impacts on market goods. Thus, for example, when benefit-cost analysis was being formalized in the 1950s for use in evaluating federal water resource projects, this was the method used to value marketable project outputs such as hydropower generation, navigation, and the supply of agricultural commodities irrigated with project water.

But, this left unaccounted other project outputs that were *not* marketed, such as recreation at reservoirs, aesthetic factors, or protecting human life and limb through flood control. These "intangibles" as they were called, were considered important but could not be factored into project appraisal because they could not be monetized with conventional techniques. Solving this problem was the major breakthrough in benefit-cost analysis, and led to what is now known as "non-market valuation." There actually were *two* breakthroughs. By coincidence, they were both suggested in the same year, 1947, although they took another decade or more to be implemented.

The one that emerged first is what became known as the *travel cost (TC) method*. It arose out of an effort by the National Park Service (NPS) to measure the economic value associated with the national parks. At the time there were no entrance fees at national parks, so the NPS could not use park revenues as a measure of their value.² The project was assigned to a staff economist who wrote to ten distinguished economic experts for advice. One of them was Hotelling. The others all replied that it was impossible to measure recreational values in monetary terms, but Hotelling disagreed. He saw that, even though there was no entrance fee for a national park, it still cost visitors something to use the parks because of expenses for travel, lodging and equipment. These expenditures were not captured by the NPS but, they still set a price on the park. Moreover, this price would vary among people coming from different points of origin. By measuring the price and graphing it against visitation rates one could construct a demand schedule for visits to the site, and then determine consumer's surplus in the usual manner as the area under this demand curve.

The rest of the story has a California connection. The NPS report (NPS 1949) followed the majority view; Hotelling's response was included along with the others in an appendix, where it lay in obscurity. In 1956 the State of California hired an economic consulting company to estimate recreational benefits associated with the planned State Water Project. This company learned of Hotelling's idea through Harold Ellis, an economics professor at U.C. Berkeley and one of the experts consulted by the NPS in 1947, and decided to apply it. A survey of visitors was conducted at several lakes in the Sierras and data was collected on how far they had travelled and how much they had spent. Using these data, a rough demand curve was traced out, and an estimate of consumer's surplus was constructed. This analysis appeared in Trice and Wood (1958), the first published application of the travel cost method. At the same time, Marion Clawson (1959) at Resources for the Future had begun collecting data on visits to Yosemite and other major national parks in order to apply Hotelling's method to them, which was the second published application. By 1964, there were at least five more applications in various parts of the country and the travel cost method was an established procedure.

The insight behind the travel cost method is that, while people can't buy environmental resources such as clean air, clean water, or a pristine lake in the same way they can buy cans of soup or chocolate truffles, nevertheless there sometimes is a sense in which environmental quality can be bought through the market. This is because there sometimes are private market goods which are *complementary* to the natural environment, i.e., the enjoyment of the private good is enhanced by, or somehow depends on, the presence of the environmental public good. Thus, recreation at a site (the private good) depends on clean water or abundant fish (the public good), and the demand for the former reflects, in part, a demand for the latter. The hallmark of the travel cost

² This still was a common practice among government agencies, although it was known to be inconsistent with economic theory. As we pointed out earlier, it is the park visitors' consumer's surplus, not their expenditures, that measures the economic value of the parks.

method is not the specific application to recreation but rather the general approach of seeking out a private market good whose demand can serve, at least partly, as a surrogate for the demand for the environmental public good.

This same principle is invoked in a method known as the *averting expenditures approach*, often used to value health effects from pollution, which examines people's actions to keep from becoming ill or to treat an illness, for example, by seeing a doctor, buying some type of medication, staying indoors instead of going to work during a smog alert. In effect, this method identifies a demand curve for averting behavior by comparing the use of such behavior with its cost. The area under this demand curve, the consumer's surplus from being able to engage in averting behavior, measures (approximately) their WTP or WTA to avoid or mitigate the illness.

A similar principle underlies another approach to environmental valuation, the *hedonic pricing method*. Here, the private good is houses or real estate more generally. The price of a house reflects not only its physical attributes (e.g., the number of bedrooms, the size of the lot) but also neighborhood amenities (e.g., whether it is in a safe area, whether it is close to transportation) and, sometimes, environmental amenities (e.g. whether it is close to the beach or located in a part of the town with less air pollution). In a landmark study of house prices in Philadelphia and Syracuse, Ridker (1967) was the first to show empirically that air pollution affects property values. However, the general notion of a relationship between the prices of market commodities and their attributes, and the name "hedonic price equation" go back earlier. Ridker's work stimulated a large literature on the correlation between pollution levels and property values. From the perspective of valuation, the assumption was that the derivative of the hedonic price equation, measuring the change in property value per unit change in pollution, could be used to approximate the marginal WTP associated with a change in pollution. In addition to these hedonic property value equations, the same logic has been applied in what are known as hedonic wage equations. These involve the statistical analysis of wage rates for different occupations as a function of the characteristics of those occupations, including the riskiness of the job in terms of the probability of being injured or killed at work. The notion is that the more risky jobs will command a higher wage, and the marginal WTA to accept an increment in risk will be reflected in the derivative of the wage equation with respect to risk. In both cases, it should be emphasized that there are serious problems associated with the use of hedonic pricing equations to value *non-marginal* changes in the characteristics of land parcels or occupations.

The approaches mentioned so far are all based on the concept of *revealed preference* which holds that, since people's preferences motivate their behavior, it should be possible to infer their preferences from their behavior through some appropriate analysis. This was introduced into economics by the nobelist Paul Samuelson in his first paper, published in 1938. While it clearly contains a core of truth, it may oversimplify or mislead in various ways. In addition, for the purpose of valuing nonmarket commodities such as the natural environment, the problem arises that the market commodities being used as a surrogate for the demand for environmental quality may not *completely* capture people's preferences for the environment — people care for the environment *partly* because of their interest in these commodities (e.g., recreation) and *partly* for *other* reasons unconnected with the interest in these commodities. The latter is what we referred to earlier as existence or nonuse value. This value *cannot* be measured by revealed preference approaches such as the travel cost, averting expenditures or hedonic pricing methods, yet it may be an important part of the total value that people place on the natural environmental.

Because they infer preference from externally observed behavior rather than measuring it directly, these revealed preference approaches are sometimes called *indirect valuation*. The alternative, *direct valuation*, is to interview people and elicit their WTP or WTA directly. This approach is known in economics as the *contingent valuation (CV) method*. It was first proposed in 1947 by S.V. Ciriacy-Wantrup, a professor in the Department of Agricultural Economics at U.C. Berkeley in a paper on the economics of soil conservation. He noted that several of the benefits from soil conservation were non-market goods, such as reduced siltation of reservoirs or reduced impairment of scenic resources. He characterized the problem as being how to obtain a demand curve for such goods, and suggested the following solution: "[Individuals] may be asked how much money they are willing to pay for successive additional quantities of a collective extra-market good. The choices offered relate to quantities consumed by all members of a social group... If every individual of the whole social group is interrogated, all individual values (not quantities) are aggregated. The results correspond to a market-demand schedule." While noting the possible objection that "expectations of the incidence of costs in the form of taxes will bias the responses to interrogation," he felt that "through proper education and proper design of questionnaires or interviews it would seem possible to keep this potential bias small."

However, Ciriacy-Wantrup never pursued the idea empirically, and it received no further attention for more than a decade. Perhaps the first CV work was conducted in 1958 for the NPS, which hired a market research company to survey residents of the Delaware River basin about their willingness to pay (WTP) entrance fees for national parks.³ The first significant academic application of CV also dealt with recreation. In 1961, as part of his Harvard Ph.D dissertation on the economic benefits of outdoor recreation in the Maine woods, Robert Davis (1963) surveyed a sample of 121 hunters and recreationists and asked how much more they would be willing to pay to visit the area. The next application came in 1965 when Ronald Ridker (1967) was conducting a hedonic property value study to measure the damages from air pollution and added some questions to a survey about people's WTP to avoid soiling from air pollution. In 1969, a steady stream of CV studies began to appear. Many focused on valuing various forms of recreation, but some applied CV to new topics. In 1970, for his Harvard Ph.D, Acton (1973) conducted a CV survey to value health programs which reduced the risk of dying from heart attacks. In 1972, Alan Randall and colleagues conducted a series of CV studies of residents and visitors in the Four Corners Interstate Air Quality Control Region to value improving the visibility in the area (Randall, Ives and Eastman 1974). In 1973, for their Harvard Ph.D's, Gramlich (1977) and Oster (1977) conducted CV surveys of local residents' WTP to have the Charles and Merrimack Rivers cleaned up. By the mid-1970s, ten years or so after travel cost had become accepted, CV was recognized in the economics literature as a technique for nonmarket valuation.⁴

³ Obviously, both before that time and since, market research firms have conducted what amounts to CV surveys. There is also a direct parallel between CV and the techniques of multi-attribute utility assessment (Keeney and Raiffa 1976) and conjoint analysis (Green and Wind 1973) which are widely used in business decision making and market research, respectively. When monetary cost is one of the attributes for which preferences are elicited, these techniques are a form of CV.

⁴ Travel cost was listed as an approved method in the 1973 edition of the Water Resources Council's Principles and Standards for the evaluation of federal projects., CV was added to the list when the document was revised in 1979.

As more economists became interested, CV techniques were gradually refined. A key factor was the need for expertise in survey research, since CV cannot be done well by economists alone. It took until the 1980s for adequate links to be forged with the other social sciences. An important event in this regard was a 1984 conference in Palo Alto on the state of the art of CV funded by EPA. In addition to contributions by leading practitioners, there was a review panel of eminent economists and psychologists, including Nobel laureate Kenneth Arrow, which identified areas for future research (Cummings et al. 1986). Another milestone was the publication in 1989 of Mitchell and Carson's book on CV, now the standard work, which placed it in the broader context of sociology, psychology, political science and market research as well as economics. By now, the CV literature contains more than 1500 studies and papers from over 40 countries covering a wide range of topics: transportation, sanitation, health, the arts, education, the environment (Carson et al. 1993; Navrud 1992).

APPENDIX B

GLOSSARY

Avoided Cost is the cost of an activity or facility that could be *avoided* by choosing an alternative course of action. For example, avoided water supply costs are the costs of water supply that are avoided by conservation, which reduces the need for new supply projects.

Consumer Surplus is the difference between what a commodity is worth to a consumer and what he or she actually pays for it.

Costs are the resources needed for a course of action—in this case for BMP implementation. Costs are valued by identifying the opportunities forgone by diverting the requisite resources to the BMP. In other terms, “What do we give up to get the BMP?”

Cost-Effective is defined in the MOU as when the present value of benefits exceeds the present value of costs. Cost-effectiveness analysis, then, in the context of the MOU, is analysis that calculates and compares the present value of costs to the present value of benefits. [Note: A textbook definition would distinguish between the terms *cost-effectiveness analysis* and *cost-benefit analysis* (CBA). CBA measures all costs and benefits in dollar terms, whereas CEA measures at least one benefit in its physical units (e.g., acre-feet of water saved).]

Discount Rate is the rate used to calculate the present value of future benefits and costs. Discount rates can be either nominal (not adjusted for inflation) or real (adjusted for inflation).

Escalation Rate is the average rate of increase in the inflation-adjusted future cost of water supply.

External Costs and Benefits. An *external cost* is when one party, as a result of its actions, adversely affects another party either by reducing its productivity or well being, or by raising its costs. An *external benefit* is where one party beneficially affects another party either by increasing its productivity or its well being, or lowering its costs. *Externalities* (external costs and benefits) are distinguished from “pecuniary” effects when the adverse or beneficial affects of the others actions are not market interactions. Rather, one party’s action has a direct *physical* effect on the welfare or costs of others.

Fixed Costs are those that do not change as output level changes over the time horizon being analyzed. These costs typically include capital goods, land, and long-term contract commitments. In the short run, fixed costs do not enter into the calculation of marginal costs. In the long run, all costs are variable.

Incremental Costs and Benefits are the costs and benefits that occur due to a course of action (e.g., BMP implementation) that would not occur otherwise. In other terms, incremental costs and benefits are the additional “increment” of costs and benefits from implementing a BMP.

Inflation is the rate of change in a price index (e.g., the Consumer Price Index) over a certain period of time that reflects a general increase in *all* prices so that relative prices of different goods and services remain the same. Annual inflation, for example, reflects the change in the purchasing power of a dollar over the course of a year.

Life-Cycle Analysis examines the costs and benefits of an action (e.g., a BMP) over its entire expected life span.

Marginal Cost is the additional cost incurred by producing one more unit of output (e.g., the additional costs of supplying one more acre-foot of water).

Market Price is determined in a *market*, which is where individuals, firms or other organizations come together to exchange goods and services. Markets can take many forms, including dealerships, financial asset and stock exchanges, stores, bulletin board listings, and brokerages.

Net Present Value is the present value of benefits minus the present value of costs. Present value refers to the value of a cost or benefit *today* that will be incurred or accrued sometime in the future. The present value of a cost or benefit is determined by discounting the future cost or benefit utilizing a discount rate.

Opportunity Costs are the true costs faced by a decision-maker, measured as the highest valued (best) alternative that is foregone when an action is taken.

Project or Device Life Span. The life span of a *device* is its remaining physical or productive lifetime. It begins when the device is acquired and ends when the device is retired from service. *Project* life span is the remaining physical or productive lifetime of devices (or assets more generally) required for a project. Device or project life span is often not the same as the useful life for tax purposes.

Period of Analysis is the period over which the cost-effectiveness of the BMP is analyzed. The period of analysis does not have to be the same as the project life span, although this is often a convenient assumption.

Real Dollar Value is the dollar value of an item that has been adjusted for inflation.

Sunk Costs have already been incurred and are not reversible. For example, most engineering and design costs are sunk once they have been paid for. Unlike land or equipment, the design cannot usually be sold at a later time (if the design can be sold, then it is not sunk).

Sensitivity Analysis is the process where the assumptions of analysis are tested to determine how much influence they have on the results. In other terms, "How sensitive are the results to alternative assumptions?"

Transfer Payments are direct transfers of money or economic value from one party to another without an exchange of goods or services in return.

Variable Costs are the costs that change in response to changes in level of output by a firm. These costs often include energy, labor, and supplies.

Willingness to Pay is the amount an individual would be willing to pay if he or she could obtain the item by making a payment. The maximum amount he would be willing to pay for the item measures its value to him in monetary terms.

Willingness to Accept is the amount one would have to pay the individual if he or she could be induced by a payment to go without the item. The minimum amount that he should be willing to accept to forego the item is an alternative monetary measure of its value (alternative to willingness to pay).

APPENDIX C

PRESENT VALUE CALCULATION “SHORTCUT”

Calculating the present value of benefits with Equation 2.3 in Chapter 2 is simple with a computer spreadsheet. We recommend that these calculations be automated with a computer so that changes can be made easily. The “shortcut” below can be used to (1) speed up spreadsheet calculations (in particular, the time it takes to program the equations and conduct sensitivity analysis), and (2) make present value calculations with a hand calculator, if necessary. The shortcut saves time by combining several calculation steps together. This method can be used to calculate the present value of a stream of benefits when:

- the benefits are constant in each year of the program or when benefits change at a constant rate each year (e.g., benefits grow by a constant escalation rate, e , each year);
- the discount rate, r , is constant;
- benefits accrue at the end of each year (e.g., year 1 benefits accrue at the end of year 1); and
- the period of analysis is comprised of a total of m years.

A stream of benefits with these characteristics is a *uniform growth series*.¹ The present value of a uniform growth series of benefits can be calculated with the following equation:

$$B^{pv} = B_0 \cdot \left[\frac{(1+a)^m - 1}{(1+a)^m \cdot a} \right] \quad (\text{C.1})$$

Where a , the effective growth rate, is:

$$a = \left(\frac{1+r}{1+e} \right) - 1 \quad (\text{C.2})$$

And where: B^{pv} is the present value of the stream of benefits, B_0 is the annual benefits if accrued immediately (Year 0), e is the escalation rate (growth in annual benefits), r is the discount rate, and m is the total number of years in the period of analysis. With Equation C.1, the present value of benefits is calculated by multiplying the annual benefits B_0 times the expression in brackets.

¹ See Zerbe and Dively 1994, pp. 62-63.

Example: With a discount rate of 6 percent and an escalation rate of 4.5 percent, a is $.0144 [(1.06/1.045)-1]$, using Equation C.2. With a 20 year period of analysis, the expression in Equation C.1's brackets is 17.2785. With water savings of $.02419AF/yr$ per single family ULF toilet replacement, and a marginal cost of new water supply of $\$585/AF$, the benefits if accrued immediately (Year 0) would be $\$14.15/yr/toilet (= .02419*585)$. Using Equation C.1 again, the present value of benefits is $\$244.51/toilet (= \$14.15*17.2785)$. If the entire cost of this program are incurred at the outset (e.g., $\$125/toilet$ in Year 0), then the costs are already in present value terms. We can now compare the present value of benefits ($\$244.51/toilet$) to the present value of costs ($\$125/toilet$). If these estimates are representative of the average of the program, then we can say the whole program will have positive net present value.

There are several variants of the formula to calculate the present value of a uniform growth series. The different variants come from different assumptions about exactly when the benefit accrues (or when a cost is incurred), which determines when discounting begins. One formula results if the benefits are assumed to accrue at the beginning of the year. The formula in Equation C.1 assumes benefits accrue at the end of the year. The end-of-year formula yields a slightly smaller value, which gives a conservative upper bound on the cost-effectiveness of a conservation measure. In the example above, the (end-of-period) formula yields $\$244.5$ in benefits per ULF toilet. Using the beginning of period formula would yield $\$247.63$. Planners desiring neither an upper nor a lower bound can also use the variant of the formula that accrues the value of benefits at mid-year. If the time stream of benefits is well defined and important, greater resolution can be obtained by using a smaller time step, that is, monthly or weekly periods rather than years.

*Printed by
Department of Water Resources
Reprographics*

D - 0 4 6 2 4 2

D-046242