CHAPTER 3

MEASURING THE BENEFITS OF WATER QUALITY PROGRAMS

3.1 INTRODUCTION

What are the benefits of water quality programs? What are the basic benefit principles? What methods are available to measure benefits? What are the key assumptions and features of these methods? What case studies are available to illustrate the use of these methods?

While benefit-cost assessments that use only qualitative information may suffice for clearcut water quality decisions, quantitative information can simplify more difficult decisions by reducing the complexity of the issues and clarifying the central issues. This chapter provides a framework for gathering and organizing this information to measure the benefits of water quality programs.

This chapter briefly reviews the concept of benefits and practical approaches for measuring them. In particular, it discusses the conceptual issues involved in estimating the benefits of water quality improvements, describes techniques for measuring different types of benefits, and presents case studies that show how different practitioners have employed them. Specifically, Section 3.2 summarizes benefit categories, Section 3.3 highlights general issues in selecting a benefits estimation methodology, and Section 3.4 describes approaches for measuring household benefits. Section 3.5 discusses business benefits by summarizing key aspects in studies of agricultural, industrial, and navigational benefits of water quality improvement. Section 3.6 briefly describes public water supply benefits, and Section 3.7 summarizes the issues covered in the chapter. Case studies follow the text in each of the appropriate sections. (The scenarios in Chapter 6 show how the case studies can be applied in new situations.)

3.2 CATEGORIES OF BENEFITS: AN OVERVIEW

Since each household or firm undertakes different types of activities, each is differently affected by water quality changes. A natural starting point in appraising the various types of benefits of water quality programs is to place them in broad classes. Figure 3-1 shows the categories of benefits associated with water quality programs. The top part of the figure aligns each benefit type with the uses made of water bodies. More perspective on these benefit types is given by Table 3-1, which lists them according to households or firms (the type of economic agent likely to receive them) and the methods appropriate for measuring them. For example, the user benefits category separates health benefits from recreation. Contingent valuation and hedonic property value models are potential candidates for measuring both

Potential Water Quality Benefits	Current User Benefits	Direct Use	In Stream	Recreational — fishing, swimming, boating, rafting, etc. Commercial — fishing, navigation
			Withdrawal	Municipal — drinking water, waste disposal Agricultural — irrigation Industrial/Commercial — cooling, process treatment, waste disposal, steam generation
		Indirect Use	Near Stream	Recreational — hiking, picnicking, birdwatching, photography, etc. Relaxation — viewing Aesthetic — enhancement of adjoining site amenities
	Intrinsic Benefits	Potential Use	Option	Near-term potential use Long-term potential use
		No Use	Existence	Stewardship — maintaining a good environment for everyone to enjoy (including future family use—bequest) Vicarious consumption — enjoyment from the knowledge that others are using the resource.

Figure 3-1. A spectrum of water quality benefits.

categories of benefits. In addition, damage functions may be useful for health benefits, while the travel cost and recreation participation survey approaches can measure recreation benefits.

Although they are not directly associated with use, option and existence values are potential sources of economic benefits. Option value is the amount that an individual may be willing to pay (over his expected user values) for the right to use a water body--e.g., a river--in the future because uncertainty exists either in the river's availability or in the individual's use of it. Specifically, if an individual thinks he may want to use the river, but isn't sure, then he may pay some amount each year for the right to use it. When this payment exceeds the benefit the individual would receive from use, the excess is the option value. Existence value is the willingness to pay simply for the knowledge that a resource exists--i.e., the value an individual places on a resource just because he knows it is there. Thus, because of a stewardship or related motive, an individual might be willing to pay something to maintain a river even though he knows he will not use it.

Table 3-1. Classification of Benefit Categories

Type of economic agent	Benefit category	Type of measurement method
Household: User	Recreation	Travel cost model Contingent valuation survey Recreation participation survey Hedonic property value model
	Health	Damage function Contingent valuation survey Hedonic property value model
	Option value	Contingent valuation survey
Household: nonuser	Existence value	Contingent valuation survey
Business and municipality: user	Cost savings	Cost function

For businesses and municipalities, classification is more clearcut: The effects on a firm's cost of production are the primary interest because the role of water quality is exclusively reflected through these effects. Irrigation, nagivation, and process uses are examples of water uses where cost savings may arise.

Benefit classification should not be misinterpreted. In most cases it is impossible to separate all the sources of a benefit estimate. For example, while willingness-to-pay estimates for a water quality improvement derived from a hedonic property value model (discussed below) may be based on both direct and indirect uses of the water body, the contributions of each cannot be shown in practice. Equally important, overlaps should be expected between the methods used and the types of benefits derived. A contingent valuation survey's (discussed below) estimate of willingness to pay for improved water quality may include health, recreational, and nonuser benefits. The exact composition will depend on the water body under study and the nature of the questions used to elicit the information.

The classification scheme offered in this section simply shows possible sources of benefits and may help identify measurement methods. However, because this scheme does not fully define each of the methods or describe how a water quality change is introduced in each, the following sections offer more detailed discussions of the various benefit estimation approaches, including specific case studies that summarize previous work.

3.3 PRACTICAL CONCERNS: SELECTING A BENEFIT ESTIMATION METHOD

One of the first questions about benefit-cost assessment facing the practitioner is how to select a method or set of methods for measuring the benefits of water quality programs. This decision will be influenced by the following conditions:

- The time and financial resources available.
- The types of economic agents affected by the change in water quality regulation.
- The nature and magnitude of the changes in the water quality regulations themselves.
- Data availability.

These conditions largely determine the appropriate level of detail for a study. In most benefit-cost assessments of water quality programs, existing data and results available from other studies will be sufficient. In complex cases, new data and case-specific methods may be necessary. However, even in these cases, when neither time nor resources are available, existing literature and, to a lesser extent, ad hoc methods must be used.*

In practice, the ideal conditions routinely assumed in theoretical analyses of benefit measures simply do not exist. Indeed, many benefit analyses of environmental resources result in compromises that arise from a poor understanding of the exact association between water quality and particular activities of economic agents. However, while compromises may be necessary to measure the benefits of water quality regulations for some water bodies, every effort should be made to measure benefits based on willingness to pay and cost savings--the only definitions for economic benefits that have clear theoretical justifications.

Finally, because resources are limited, benefit-cost assessments of water quality programs require that resources be wisely used--i.e., that they be closely matched with the complexity of specific cases. Whether or not resources are available, however, the practitioner must clearly understand the features of each benefit measurement method to make an intelligent choice among them.

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*For example, while the Water Resources Council's current guidelines for cost-benefit analysis recommend use of the travel cost or contingent valuation approach for estimating economic benefits of outdoor recreation services, they acknowledge that practitioners may have to use ad hoc approximations such as activity-day values--constant dollar values proposed for days of particular types of outdoor recreation (see Water Resources Council [1979])--multiplied by projections of user-days.

3.4 HOUSEHOLD BENEFITS

There are several ways to measure the benefits of water quality programs. However, to compare the accuracy of these measures, the practitioner must also understand how individuals value different goods. Fortunately, economics provides an objective way to measure these values using the basic concept of a demand function.

Theory: The Demand Function

The first organizational guidepost that economics provides is the concept of an individual demand function, shown in Figure 3-2. This function describes for any good, X, the maximum quantity of the good an individual would be willing to purchase for each price of X. The downward slope of the curve indicates that individuals are willing to buy more of X at lower prices than at higher prices. The simple diagram in Figure 3-2 assumes all other factors that might influence demand--including income, the prices of related goods, etc.--do not change. Frequently, there is no need to actually measure a demand curve. What it does is provide a basis from which the benefits to households can be viewed,

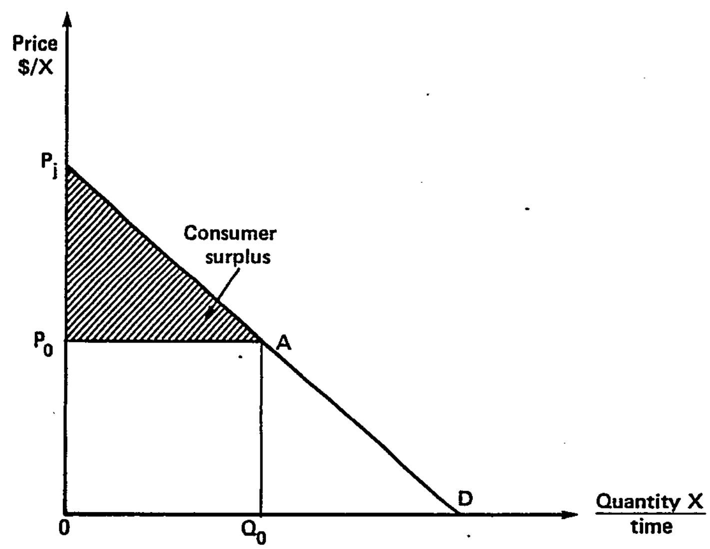

Figure 3-2. The demand function and consumer surplus.

If the market process establishes a price at P_o, the individual will purchase Q_o of X and make a total expenditure equal to P_oAQ_oO. Since the area under the demand curve measures the individual's maximum willingness to pay for each unit of consumption, the total willingness to pay for Q_o is the entire area--total expenditures <u>plus</u> the triangle P_oP_jA. This difference--between what the individual actually pays and the amount he is willing to pay--is the consumer surplus, or the dollar measure of the satisfaction an individual receives from consuming a good or service, less what he pays for it. As a dollar measure of individual welfare, consumer surplus is not ideal, but most. studies have found it to be a good benchmark.

Practice: Methods for Measuring Household Benefits

Household benefits may be measured by using the travel cost method, a contingent valuation survey, a recreation participation survey, the hedonic property value method, or the damage function method. Advantages and disadvantages, data requirements, and key assumptions of each method are highlighted in this section. Case studies show how the methods have been used in recent applications.

Travel Cost Method

One of the most popular approaches to describe demand for the services of recreation facilities, the travel cost model,* has been used to estimate recreational benefits in a wide variety of applications. The logic underlying this model is simple. Recreators at a particular site pay an “implicit” price for using the site’s services through the travel and time costs associated with visiting that site.† Since recreators visit a site from diverse origins, their “travel behavior” can be used to analyze the demand for the site’s services. That is, all else being equal, any person will. continue to travel to the site until the marginal value of the last trip is exactly equal to its full costs (i.e., the travel expenses and the opportunity cost of the time spent traveling).

As a rule, the travel cost model estimates the demand for the representative individual. Therefore, to estimate the aggregate benefits of water quality improvement at a site, the practitioner needs to estimate how many recreators would use it. The solution to this problem will depend upon the data used to estimate individual demand. For example, the visits made by residents of an origin zone, usually during a season, relative to the population of that origin zone is the quantity measure--a rate of use--conventionally used in the travel cost model. Since benefits are for the “representative” rate of use, multiplying by the population of that origin zone will yield its aggregate benefit estimates. Overall benefits would be the sum of the zone benefit estimates.

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*For further details see Dwyer, Kelly, and Bowes [1977], Freeman [1979], Smith [1975], and Desvousges, Smith, and McGivney [1983].

†Most public recreation facilities either have no user fees or have nominal fees that do not reflect the marginal cost of a site’s recreation services. Thus, these fees are not indicative of the equilibrium. prices that would arise if conventional market mechanisms allocated the services of recreation sites.

Travel cost models also can be estimated by surveying users at a specific recreation site. Then, the benefit estimates are for a "representative" recreationist and estimates of total site use estimates must be obtained independently. Possible sources of these estimates include the Corps of Engineers, the Department of Interior, or parks and recreation departments at the State level.

If a travel cost model can be estimated, it can be used to estimate consumer surplus. However, this is only part of the problem that must be solved to appraise the benefits of water quality improvements. In addition, the linkages between the regulations, the changes in water quality, and the recreation decisions of individuals must be known. One possible linkage is a change in demand for the services of a recreation site because individuals wish to use them in one or more activities. A change in the level of water quality may permit a wider range of uses, increase the individual's enjoyment (and hence valuation) of existing uses, or both, which increases the demand for the site's services at each (implicit) price.

Therefore, to evaluate the implications of a change in water quality for an individual's economic well-being, water quality must be linked to the variables in a recreation demand function. Three ways for making this association will be discussed in detail in Volume II. The case shown in Figure 3-3 offers the most acceptable approach for linking water quality to recreation site demand. It incorporates the effects of water quality as a determinant of the demand in the travel cost model for a site's services (see Freeman [1979], Chapter 8). Since little evidence generally exists on the variation in water

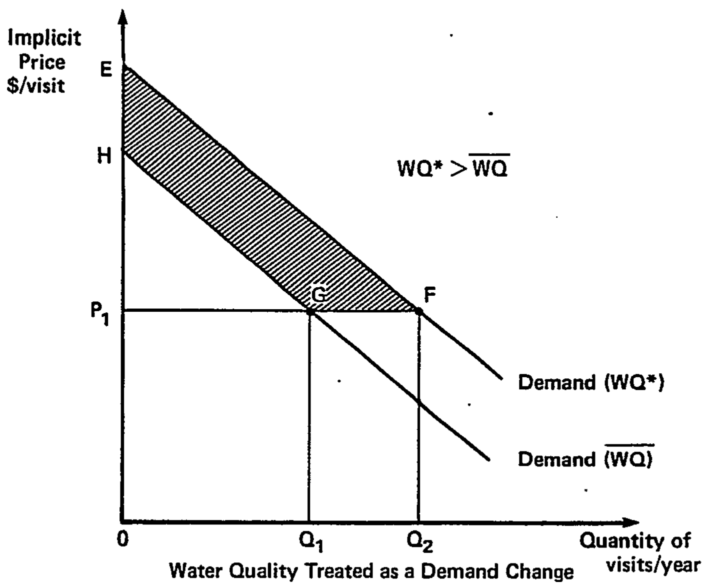

Figure 3-3. Illustration of the treatment of water quality with travel cost demand model.

quality across the same water body, the travel cost model is difficult to implement empirically with a single site. Conceptually, however, a change in water quality is assumed to shift site demand by providing a wider ranger of activities. Thus, in Figure 3-3, the benefits associated with a change from WQ to WQ* would be represented by the area HGFE. The scenario in Chapter 6 shows an existing study that can be applied to new situations (see Chapter 6, Section 6.4).

Data Needs, Key Assumptions/Limitations, and Features

The following checklist outlines the data needs and key assumptions and features of the travel cost model.

Data Needs:

- Origin--county of residence or zip code--for users of the recreation site. These are often available from recreation management agencies for samples of users.

- Population size and summary measures for features of the population in each origin zone (e.g., median family income, median age, and median education). Sources include census data, national and State recreation surveys, and site surveys.

- Round-trip mileage from each origin to site. This information can be calculated from maps.

- Vehicle costs per mile and implicit time costs of travel. Travel costs should be calculated as operating costs per mile for the vehicle. Time costs can be estimated with the approximate wage rate for the household head. One source is a wage and occupation survey.

Key Assumptions/Limitations and Features:

- The model is site specific. It measures the demand for the services of a site, not total or general recreation demand.

- The model measures only user benefits.

- Consistency in the length of stay for each type of trip in aggregate data. For example, all trips are treated as day visits or as weekend visits.

- A site's demand depends on its potential services for the required activities. (For example, a minimum-sized river segment is necessary for power boating, while a river segment with extensive locks and dams is not conducive to canoeing.)

- The cost of time spent at the site is excluded. This suggests that "full-cost" may not be expressed in a demand relationship.

- There are no good substitute sites available. If many substitutes are available, the simple model will overstate the demand for the site.

- The travel cost is assumed to capture all the factors that influence the decision to recreate at the site. (For example, this assumption implies that no changes in access, docks, or other site features occur.)

- The only purpose of the trip is to recreate at the site. If this is not the case, the cost of the trip has a joint cost and benefits are overestimated.

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CASE STUDY: ALTERNATIVE APPROACHES FOR ESTIMATING RECREATION AND RELATED BENEFITS OF THE MONONGAHELA RIVER*

Introduction

The travel cost model for the Monongahela River study assumes that site features or attributes affect the individual's ability to participate in recreational activities at any particular site, as well as the quality of the recreational activities undertaken. It considers the demand for a recreation site as a derived demand. That is, a site's services are desired because of the recreational activities that can be undertaken at that site. Common sense suggests that a recreation site's features or attributes will influence the demand for its services. Since the level of water quality is a site attribute, a basis is established for relating water changes to shifts in demand for a recreation site's services.

Approach

The measurement approach examined numerous water-based recreation sites from the Federal Estate Survey component of the 1977 National Outdoor Recreation Survey. This survey provides specific information on the sample recreationist patterns of use during a single season for each site. The sample sizes for each site ranged from approximately 30 to several hundred respondents and included information on individuals' recreation behavior, socioeconomic characteristics, travel time necessary to reach the site, residential location, and a variety of other factors. This information permitted the estimation of individual travel cost demand models for each of the recreation sites.

Several advantages of this travel-cost model include:

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*This discussion is taken from Desvousges, Smith, and McGivney [1983].

- Deriving individual estimates for the time associated with traveling to the site as well as the roundtrip distance for each trip.

- Using the opportunity cost of time to evaluate travel time and estimating opportunity cost for each individual based on his characteristics, including age, education, race, sex, and occupation.

- Considering for each site the potential effects of individuals' differences in onsite time per visit.

A total of 22 individual site demand functions were estimated based on this survey. For example, Equation (3.1) is a general description of one of these site demand models:

$$\ln V = a + bTC + cY, \tag{3.1}$$

where

$\ln V$ = the natural log of the number of visits by a household to the site in a recreation season.

TC = the travel cost per visit to the site, including out-of-pocket vehicle operating costs and the opportunity cost of the time spent traveling.

Y = family income.

The basic hypothesis of this study is that variation in the estimates of a, b, and c across sites reflects the effects of those sites' characteristics on the representative individual's demand for each site's services. Thus, each estimate provides the basis for describing how a change in any attribute would affect demand.

The second step in the study involved estimating the relationship between variations in the site-specific estimates of a, b, and c and each site's attributes. The site characteristic information was obtained from records of the U.S. Army Corps of Engineers and the water quality data from the U.S. Geological Survey. Table 3-2 reports the site attributes, including the water quality measures used in the model. Many other attributes, such as boat launches, docks, and recreational facilities, were tried, but none was statistically significant. For sites where the information on water quality was incomplete, the average value for all sites was used. This treatment of missing values means that the estimated relationships will rely primarily on sites with observed readings for the water quality variables.

Since precision in the estimates of demand parameters a, b, and c in Equation (3.1) varied, a statistical procedure was used to account for the quality of the estimates. Table 3-3 shows the estimated equations for the demand parameters. As Table 3-3 shows, many of the attributes have statistically significant effects on the demand parameters, particularly on the travel

Table 3-2. Site Attributes Considered in Monongahela River Study

Variable name	Description	Source
SHMILE[a]	Number of miles of shoreline for the site	U.S. Army Corps of Engineers
ACCESS[a]	Number of developed multipurpose recreational areas plus the number of developed access areas on the site	U.S. Army Corps of Engineers
ARSIZE[a]	The ratio of the pool surface acreage during the peak visiting period relative to the total project area in acres	U.S. Army Corps of Engineers
DO[a,b]	Dissolved oxygen based on monthly readings	U.S. Geological Survey

[a]These variables were considered as monthly readings and as 4-month averages in the specification of the demand parameter models.

[b]DOM and DOV correspond to the average value of dissolved oxygen over the four monthly observations and the variance about that average, respectively.

Table 3-3. Estimated Equations for Site Demand Parameter Estimates[a]

Variable	Site demand parameter estmates		
	$\hat{a}$	$\hat{b}$	$\hat{c}$
Intercept term	1.51 (4.08)	-0.0246 (-9.48)	0.000005 (0.308)
SHMILE	0.0003 (1.25)	-0.00001 (-6.76)	9.74×10^{-10} (0.09)
ACCESS	-0.0059 (-1.50)	0.00008 (2.81)	4.69×10^{-7} (2.56)
ARSIZE	-0.395 (-1.75)	0.0033 (2.27)	-1.94×10^{-6} (-0.18)
Average DO	0.0045 (1.07)	0.00018 (5.99)	-1.22×10^{-7} (-0.60)
Variance in DO	0.0005 (1.86)	0.00001 (4.08)	9.39×10^{-11} (0.01)

[a]The numbers in parentheses below the estimated coefficients are the asymptotic (approximate) t-ratios for the null hypothesis of no association--the larger the number, the more likely the null hypothesis is rejected. These equations show how the parameters of the individual site demand equations vary with changes in the site's attributes.

cost parameter. The water quality attribute has a highly significant effect on travel costs, with the most plausible results obtained using the mean value of dissolved oxygen over the 4-month summer period (June through September) and the variance in dissolved oxygen about that mean. However, the small variation in the water quality measures over the sample suggests these findings be interpreted cautiously.

The model was used to evaluate the benefits of a water quality improvement for users of the Monongahela River in Pennsylvania. This site was not included in the 22 used to estimate the model. The model was applied to an independent data set based on a household survey of residents in the Monongahela River Basin (see the case study under Contingent Valuation below for more details). The survey reported sufficient information on the respondents' socioeconomic characteristics, as well as specific portion(s) of the river used, to construct individual demand curves varying by river site (at a total of 13 different sites) and by individual. The benefit calculations were as follows:

- Estimates of consumer surplus loss per user if the river were no longer available for its current use--recreational boating.

- Estimates of the increment to consumer surplus associated with improving water quality from the current level that permits boating, to a level that would accommodate recreational fishing.

- Estimates of the increment to consumer surplus associated with improving water quality from the current level (boating) to a level that would accommodate swimming;

The levels of dissolved oxygen used in the benefit calculations for each of these use designations were the values selected by Vaughan in Mitchell and Carson [1982] in a water quality ladder developed for Resources for the Future (RFF). The variance in dissolved oxygen was held constant at levels corresponding to those generally observed at the 22 sites. Table 3-4 provides the RFF ladder thresholds for each activity.

Table 3-4. Specifications for the Dissolved Oxygen (DO) Levels Associated With Use Designations[a]

Use designation	DO level (percent saturation)
Boatable[b]	45
Fishable[b]	64
Swimmable[b]	83
Drinkable	90

[a]These thresholds correspond to those used in RFF's water quality ladder.

[b]These use designations were considered for benefit analyses.

Benefit Estimation

Figure 3-4 illustrates the model. $D(WQ_1)$ corresponds to the representative individual's demand for the site's services at a water quality level of WQ_1. Since the demand function is specified as semi-log in quantity, there is no maximum price at which visits to the site will be zero. Therefore, the benefit calculation required a maximum feasible price--P*. This was taken to correspond to the largest travel cost incurred by any of the users of the Monongahela River ($22.65 per roundtrip).

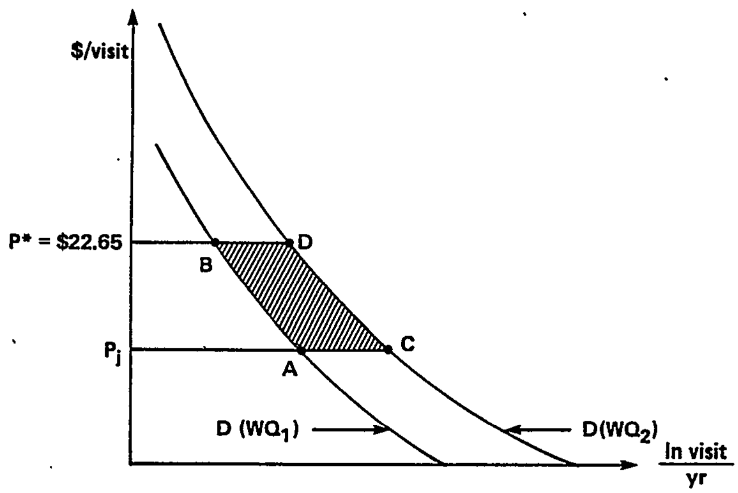

Figure 3-4. General travel cost demand model for a water quality improvement.

The first benefit calculation involves the computation of the baseline area P_jABP*--the loss in consumer surplus if the site could no longer provide the services available with a water quality of WQ_1 to the user with a travel cost of P_j. Incremental benefit estimates were derived by estimating the addition to consumer surplus associated with the increment to water quality. In Figure 3-4, a change from WQ_1 to WQ_2 would be shown as leading to an incremental benefit of ACDB for the user at a travel cost of P_j. Table 3-5 provides a summary of the average benefit estimate for each change and the range of estimates over the survey respondents.

This case study provides a detailed model for incorporating site attributes into estimating the demand for water-based recreation sites and, in turn, for evaluating the benefits from changing one or more of those attributes. Since it was developed from data primarily on flat-water recreation sites, the model can be used to predict benefits for changes in attributes for a sizable range of recreation sites. However, the actual estimates of the benefits of water quality improvements in the study must be regarded as tentative because of the limited available information on water quality. The approach illustrated by this case study could be used in a wide variety of applications. For one example, see Chapter 6, Section 6.4.

Table 3-5. Benefit Estimates from Generalized Travel Cost Model With the Monongahela Survey Respondents

Use designations	Benefits[a] Mean	Benefits[a] Range
Benefits lost as a result of the loss of ability to undertake boating activities	$53.35	0 to $70.80
Incremental benefits gained as a result of water quality improvement changing use designation from boatable to fishable	$ 4.52	0 to $8.60
Incremental benefits gained as a result of water quality improvement changing use designation from boatable to swimmable	$ 9.49	0 to $18.30

[a]The benefits are measured as the consumer surplus per user for the use of the river during a single recreational season.

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Survey--Contingent Valuation

The contingent valuation survey approach for estimating the benefits associated with a nonmarketed commodity such as water quality improvements involves asking individuals about their willingness to pay for different levels of the commodity involved. Use of the survey approach requires that the practitioner determine the aspects of changes in environmental quality individuals value and convey these aspects to the respondent. The approach assumes that individuals will accurately reveal their valuation of potential behavioral responses in hypothetical market experiments. These experiments depend on a survey procedure and a survey instrument. The survey procedure determines the appropriate sampling plan and specifies the general requirements of the survey instrument. The survey instrument is the questionnaire used to elicit the respondents' answers.

A survey instrument is the cornerstone of the hypothetical market used in the contingent valuation survey approach. It will generally consist of the following sections [Rowe and Chestnut, 1981]:

- Introduction and statement of purpose
- Nonvaluation questions

- Scenario development and market definition
- Bidding or valuation questions.

The first two sections are self explanatory and will not be discussed further. The scenario development and market definition section is considered the most critical aspect of survey instruments because it must carefully present the alternative levels of environmental quality. In the case of water quality, scenario development describes the linkages between the regulatory action and the resulting change in water quality. Verbal or written descriptions, supplemented by visual props, are used in this activity. Scenario development must be informative and realistic. It must portray the probabilities of the effects, as well as the effects themselves.

After the hypothetical scenario is developed and the market is defined, the bidding or valuation of the environmental commodity takes place. Several questioning formats can be used:

- Direct Question--The interviewer directly asks the individual's willingness to pay for a specified change in the amount of a commodity--water quality--that has been carefully defined. No cards or other aids are used to obtain the amounts.

- Bidding Game--The interviewer defines the change to be evaluated, suggests to the individual an amount representing the value of the change (the starting point), and asks whether he would be willing to pay that amount. Based on the response, the interviewer raises or lowers the suggested value by a fixed amount and repeats the process until the individual agrees no further change is necessary.

- Payment Card--This approach also does not directly ask about willingness to pay. The interviewer explains the specified change to be evaluated, provides the individual with a card displaying an array of potential values, and asks him to select a value or give any value for willingness to pay. These numbers range from zero to values judged to be outside the range of responses. Some surveys (notably Mitchell and Carson [1981]) have adjusted the upper bounds of values on the cards for higher income respondents. In addition, in an anchored payment card format, some responses have been identified as reflecting the share of an individual's taxes associated with specific public programs, such as education and defense (see Mitchell and Carson [1981]).

- Bidding Game With Budget Constraint--This approach is a very recent innovation for the bidding game format discussed in Brookshire et al. [1982]. Before requesting a bid in the format explained above, the interviewer asks the individual to estimate his after-tax monthly income and allocate it into expenditure categories--for example, electricity, shelter, entertainment, savings, and a residual. After this information is acquired, the interviewer conducts a bidding game with an additional question: "Which of the categories of expenditures would be reduced in order to make the proposed payment?"

- Ranked Choice and Willingness to Pay--In this approach, introduced, by Rae [1981a, 1981b], the interviewer provides individuals with different hypothetical market outcomes--proposed payments and a specified level or change in water quality, for example, to be ranked. These ranks are then used in a statistical analysis to estimate the individual's willingness to pay.

The question format and description of the hypothetical market are important determinants of the quality of the estimates derived from a contingent valuation experiment. The results of a comparative analysis of the direct question, payment card, and bidding game formats in Desvousges, Smith, and McGivney [1983] suggest that, for questions associated with water quality, the question format has some effect on the average willingness to pay. The starting point for the bidding game appears to influence the average values.

Two basic types of biases can arise in designing the format of a contingent valuation study. Since Schulze, d'Arge, and Brookshire [1981], Rowe and Chestnut [1981], and Mitchell and Carson [1981] have all discussed these biases in detail, a brief overview of their conclusions is provided in Table 3-6, which defines the bias, identifies the studies that considered its potential effects, and summarizes the current understanding of its effects.

Overall, the results seem to suggest that starting point bias may be the most important consideration (aside from the hypothetical nature of the questions, which has not received sufficient testing to fully gauge its implications) in using the contingent valuation framework. Most of the other potential sources of bias can be controlled in the structuring of the instrument and the explanations provided to sample respondents. Several additional technical assumptions are highlighted below in a summary of data requirements and key assumptions of the approach.

Data Needs, Key Assumptions/Limitations, and Features

The following checklist outlines the data needs for the contingent valuation survey approach, along with its key assumptions and features.

Data Needs:

- Survey of individuals designed to be representative of affected population.
- Clearly defined and pretested survey instrument. In-person interviews are generally more reliable than telephone or mail surveys.

Table 3-6. Summary of Biases in Contingent Valuation Experiments

Type of bias	Definition	Studies that have tested for bias	Summary of current results[a]
General			
Hypothetical	Error introduced by posing hypothetical conditions rather than actual conditions to an individual; response may not be a good guide to actual actions individual would take	One known test-- Bishop-Heberlin [1979]	Some indication that hypothetical nature of question did influence responses, but could not distinguish this effect from instrument-related biases
Strategic	Attempt by respondents to influence outcome of study by systematically over- or under-bidding so action favors their true interests; strategic responses depend on how payment scheme is defined and whether it is believed	At least eight tests (see Schulze, d'Arge, and Brookshire [1981] for summary; Cronin [1982])	Very little evidence of strategic bias except for Cronin [1982]
Instrument Related			
Starting point	Contingent valuation experiments using bidding game format have started with suggested payment and use yes or no responses to derive final willingness to pay; suggestion may be perceived as appropriate bid	At least five tests (see Schulze, d'Arge, and Brookshire [1981] and Rowe and Chestnut [1981])	Some differences in opinion over importance of starting point bias; Mitchell-Carson feel starting point bias is important, and Desvousges, Smith, and McGivney [1983] provide some support; Schulze, d'Arge, and Brookshire [1981] feel it is more limited
Vehicle	Characteristics of proposed mechanism. for obtaining respondent's willingness to pay may influence responses	At least four tests (see Schulze, d'Arge, and Brookshire [1981] and Mitchell and Carson [1982])	Some evidence of effects in at least two studies
information	Effect of information provided to respondent on costs of action under study or other dimensions of problem may affect responses	At least four tests (see Schulze, d'Arge, and Brookshire [1981] and Mitchell and Carson [1981])	Limited evidence of effects
Interviewer	Responses vary systematically according to interviewer	Two tests-- Desvousges, Smith, and McGivney [1983] and Cronin [1982])	No evidence of bias Bias present

[a]The definitions and results summarized in this table are based on Schulze, d'Arge, and Brookshire [1981], Rowe and Chestnut [1981], and Mitchell and Carson [1981].

Key Assumptions/Limitations and Features:

- Individuals' responses to hypothetical questions are assumed to be indicative of their actual valuations of the changes described in the questions.

- Careful tests are required to determine starting point effects, appropriate mechanisms for payment, and consistency of responses with other budgetary requirements.

- Careful control is required over information given respondents so answers are based on the same information in each interview.

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CASE STUDY: RECREATION AND RELATED BENEFITS OF WATER QUALITY IMPROVEMENTS OF THE MONONGAHELA RIVER*

Introduction

This contingent valuation survey measured the recreation and related benefits of water quality improvements in the Monongahela River Basin in Pennsylvania. It compared alternative question formats for asking individuals' willingness to pay and measured both user and nonuser values. In a household survey conducted by 9 professional interviewers from the five-county area, an 80 percent response rate was obtained from a clustered random sample of 393 households.

Approach

In any contingent valuation study, the survey questionnaire is the key element for providing plausible results. By dividing the questionnaire into a version for each question format and distributing each version equally among the interviewers, the Monongahela study compared the techniques.

A water quality ladder, developed by RFF (see the travel cost case study for more detail), was used to establish a linkage between levels of water quality and the associated uses for recreation. Tied to scientific measures of water quality, the ladder steps permit the respondent to give his willingness to pay for the various levels of water quality.

The contingent valuation method requires a way to make the hypothetical payment for water quality improvements. User fees, increases in sales taxes, and increases in water bills are among the alternatives used. This study expressed the additional annual amounts as taxes and higher consumer prices. Also used by Mitchell and Carson [1981], this method corresponds roughly with how a respondent actually pays for water quality improvements.

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*This discussion is taken from Desvousges, Smith, and McGivney [1983].

Each version of the questionnaire used a different technique to elicit the respondent's willingness to pay. The iterative bidding technique was used in two versions, with the interviewer starting the bidding at $25 in one version and at $125 in another. The direct question techniques and the payment card were also used. The payment card contained values arrayed from $5 to $775, but no other information.

All versions of the questionnaire required the respondent to place a value on a degradation in water quality in the Monongahela from its present overall level of boatable to a level where the river was unsuitable for any recreation. Additional amounts were elicited for water quality improvements to support fishing and swimming. These amounts reflected actual use and potential use in the future, with a followup question requiring the respondent to break down the amounts into actual and potential use.

Benefit Estimation

For each version of the questionnaire, Table 3-7 presents the average amounts users and nonusers of the Monongahela River were willing to pay for

Table 3-7. Willingness to Pay for Three Levels of Water Quality[a] ($/yr)

	Users	Nonusers	Combined
	Payment card		
Mean	117.9 (47.1)	82.8	93.8 (71.6)
Standard deviation	117.0 (53.8)	104.7	108.9 (92.8)
Number of respondents	17	37	54
	Direct question		
Mean	98.2 (47.4)	34.5	55.7 (38.8)
Standard deviation	103.5 (81.5)	66.4	85.2 (71.8)
Number of respondents	17	34	51
	Bidding Game: $25 starting point		
Mean	59.5 (42.4)	51.4	54.1 (48.4)
Standard deviation	38.1 (31.9)	53.1	48.5 (47.1)
Number of respondents	19	39	58
	Bidding Game: $125 starting point		
Mean	194.4 (109.4)	79.2	117.6 (89.3)
Standard deviation	136.5 (129.2)	102.5	126.0 (111.6)
Number	16	32	48

[a]As defined in Section 3.2, numbers in parentheses are individuals' estimated mean option values and corresponding standard deviations.

avoiding a decrease in water quality and for raising it to swimmable levels.* Several conclusions can be drawn from the results in Table 3-7. The estimates of willingness to pay--regardless of method used to elicit the amount--are quite substantial, ranging from $35 to $195 per year. The results are sensitive to the method used; the payment card with the $125 starting point bidding game gave higher amounts than the direct question with the $25 starting point bidding game. There is some indication of a starting point bias, but the evidence is not conclusive.

Users of the Monongahela generally were willing to pay higher amounts than nonusers, with their average values ranging from $59 to $194 compared to a nonuser range of $34 to $83. Estimates of option value are about half the user's willingness-to-pay values and are statistically significant for both users and nonusers. The results imply that benefit estimates based solely on recreation use may substantially understate the total benefits of water quality improvements. The approach illustrated by this case study could be used in a wide variety of applications. For one example, see Larson [1981].

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Survey--Recreation Participation Models

Many State and Federal agencies undertake surveys of the general population in an effort to identify household participation patterns for recreational activities. As a rule, these surveys provide detailed information on household characteristics and on the types and amounts of participation in outdoor recreation. These surveys have been used to estimate recreation participation models. Such models are neither demand nor supply relationships but summaries of all the determinants of the likelihood that an individual will participate in recreational activities--for example, boating, fishing, or swimming--as well as of the level of participation in these activities. Generally, these models divide the participation decision into two steps: determining whether a person participates in a particular activity and modeling the expected number of days (or trips) he spends at the activity over a season.

These models have been developed from a framework that views the individual as maximizing well-being by selecting levels of service flows for his consumption. Individuals produce these service flows by using time and/or purchased goods and services. For example, the level of participation in a recreation activity is one measure of recreation service flow that requires the person's time, any equipment associated with the activity, and the services of a recreation site as inputs. Participation models, which describe the final result of the activity, are influenced by each element in the production of service flows.

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*These mean amounts are calculated exclusive of the respondents who rejected the approach and those who were shown to be outliers by a statistical analysis. For a complete discussion of the procedures used to make these determinations and the small differences that result from the exclusions, see Desvousges, Smith, and McGivney [1983].

This perspective is important because it establishes a natural association between participation and travel cost models. Travel cost models are demand models for the services of a recreation site. These services add to the production of the recreation service flows. In addition, benefits measured by a participation model should, for consistency, use the demand for the recreation service flow and not for the recreation site, but these demands are difficult to isolate.* This often makes assignments of benefit estimates resulting from a change in water quality arbitrary (see Davidson, Adams, and Seneca [1966]).

Instead of identifying the recreation facilities used by the survey respondents, participation surveys have, as a rule, required crude measures of recreation supply characteristics to be merged. In principle, this merging permits the use of summary measures of water quality for regional areas as determinants of the likely participation and the level of participation of the representative household. Yielding crude approximations at best, this practice reflects the paucity of data in this area.

However water quality is introduced, it should be emphasized that the results of these models are estimates of the levels of use of recreation activities and not economic benefits. Methods for measuring these values must be developed independently.

Data Needs, Key Assumptions/Limitations, and Features

The following checklist outlines the data needs for the participation survey method, along with its key assumptions and features.

Data Needs:

- Survey of recreation patterns of the general population, with socioeconomic detail and identification of residential location (preferably in more detail than State of residence).
- Identification of sites used for recreation activities, or at least some measure of the supply of recreation facilities, is highly desirable.
- Measures of water quality for sites used by respondents, or linkage between water quality and capacity-related measures for recreational activities.

Key Assumptions/Limitations and Features:

- An independent estimate is required of an individual's willingness to pay for a day or a trip spent in each recreational activity.

*See Deyak and Smith [1978] and Bockstael and McConnell [1981].

- The demand and supply relationships are assumed to remain stable.

- Model specification (i.e., two-step partition of participation decision and level of participation) is assumed to be correct, and functional forms are assumed to be adequate approximations.

- Measures should be provided at a general level, not on a site-specific basis.

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CASE STUDY: A PARTICIPATION SURVEY APPROACH TO VALUING WATER QUALITY IMPROVEMENTS*/

Introduction and Basic Logic

The Vaughan-Russell [1982] study, the most ambitious and detailed application of a recreation participation model to date, focused on the recreational fishing benefits that arise from a change in water quality. It used the fact that more "desirable" freshwater sport fish--coldwater and certain warm-water species--require better water quality. Improved water quality may alter the types of fish that can be supported in a water body. Assuming the supporting recreation facilities are available, Vaughan-Russell suggest that there will be a change in the type of fish (and perhaps a net increase in the level of fishing participation) from less desirable to the more desirable varieties. The sources of benefits from the water quality change arise from:

- The change in the composition of fishing activities

- Any net increase in the level of participation in fishing.

To implement this logic on a national scale, the Vaughan-Russell objective, requires the following:

- Measuring the availability of freshwater bodies for fishing and their water qualities at a geographically disaggregated level.

- Modeling and measuring the influence of water quality on participation in recreational fishing and on fishing activities by type of fish sought.

- Measuring the economic benefits according to the type of fish sought.

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*This study is taken from Vaughan and Russell [1982].

This review highlights some of the key elements in this application of partici-pation models.

Approach

The first step in the analysis was to estimate the available "fishable" waters. Using dissolved oxygen and suspended solids criteria, Vaughan-Russell projected total fishable water on a pre- and post-policy basis. For each policy scenario; they used the following steps:

1. Calculate the percentage increase from baseline levels of total fishable water as represented in the RFF water quality network model.

2. Estimate the policy impact by applying the improvement factors from Item 1 above to a national baseline of fishable acres per capita.

3. Estimate the change in composition of fishing activities by using the water quality network model to calculate fishable water by species type.

These steps are based on a recreational fishing participation model that divides a person's participation choices into three decisions:

1. "Decide whether or not to fish"

2. "Decide what to fish for"

3. "Decide on a level of participation."

The model implies that the amount of fishable water available affects the probability of an individual's being a fisherman. Then, the suitability of water quality to support a class of fish (e.g., coldwater, warmwater, game, and rough) affects the type and level of fishing activity. Policies that change water quality affect the availability of each type of fishable water. In the Vaughn-Russell study, this relationship established the necessary technical linkage between water quality and behavior (see Chapter 1).

The empirical analysis of participation was based on the 1975 National Survey of Hunting, Fishing, .and Wildlife Associated Recreation. For Parts (1) and (2) of the fishing decision, probability models were estimated using several statistical techniques. The models included a wide array of socio-economic variables (e.g., age, sex, income, region, residency in metropolitan area, residency in State with coastline, and total acres of fishable water in the State per capita). The estimated effect of acres of fishable water per capita on the likelihood of participation in fishing was positive and statisti-cally significant.

Several methods were considered for estimating the second-stage probability models--i.e., for the particular type of fishing selected. The final set of models for these probabilities was based on three overlapping fishing choices--some trout, some bass, and some rough fish. The most significant effect of the fishery-specific water quality variable was the coldwater gamefish category. Nonetheless, the signs of the effects of the water quality variables generally agree with a priori expectations for all categories of fishing.

In the last component of the model, the number of days spent fishing in each category were estimated. The participation model requires the use of all three components to evaluate the implications of a change in water quality on the types of fishing chosen. Table 3-8 illustrates the results of one of the Vaughan-Russell scenarios--adoption of Best Practicable Technology (BPT) for the predicted changes in the mix of fishing activities undertaken. The last three lines in Table 3-8 provide the "bottom line" implications of the model in physical terms. They are not benefit estimates but, rather, increases in the number of fishing days of various types. If benefit estimates are to be derived from the model, these fishing days must be valued.

Table 3-8. Vaughan-Russell Model--Predicted Effects of BPT Regulations on Participation

Change from base case	Change in relevant variable BPT/BASE[a]
Probability of being a fisherman	+0.0001 [b]
Probability of doing some:	
Trout fishing	+0.0076
Bass fishing	-0.0142
Rough fishing	-0.0039
Days per capita per year:	
Trout	+0.02
Bass	+0.34
Rough	+0.51
Total days per year:	
Trout	$+7.2 \times 10^6$
Bass	-1.3×10^6
Rough	$+5.6 \times 10^6$

SOURCE: Vaughan and Russell [1982], Table 6-1.

[a] The logit estimates using a sample size of 5,000 were used for these estimates.

[b] This may seem an inconsequential change in the probability of being a fisherman, but it implies an increase of 20,000 fishermen per year.

Benefit Estimation

To value these fishing days, Vaughan-Russell conducted a separate survey of fee fisheries in the United States and used the results of the survey to estimate a travel cost model, accounting for the effects of a number of characteristics of the individual fisheries.* Separate models were estimated for trout and catfish (as a basis for valuing the rough fishing). The estimates of consumer surplus were converted to a per day per person basis. Considering the differential in these values between trout and catfish, the estimates ranged from $1.77 to $8.06 in the final models. These estimates provided the basis for valuing the increments to fishing days projected in the participation model. When the relevant daily per capita consumer surplus is applied to the estimated increments in fishing days, the incremental benefits can be calculated from the Vaughan-Russell model.

One of the most important potential limitations to the Vaughan-Russell methodology is the procedure used to value fishing days. The relevant benefit measure is the demand for fishing as a recreational service flow, not the measure estimated from the demand model for a site's services. While there is a correspondence (see Anderson [1974] or Carlton [1979]), the relationship between the two will depend on the nature of the other inputs to fishing and the activities undertaken at the site. Since the Vaughan-Russell model relies on a very specific definition of the recreational activity and treats trips to the fisheries as single-day visits, the discrepancies may not be great. However, the transfer of the relationship between travel cost and participation models implied by their framework may not be possible in other applications.

There should be little doubt, even with this cursory review, that the Vaughan-Russell model represents an enormous undertaking and is the best effort available to date for modeling recreation participation. The approach illustrated by this case study could be used in a wide variety of applications. For one example, see Chapter 6, Section 6.4.

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Hedonic Property Value Method

Two types of recent models use market data on either property values or real wages along with quantitative measures of environmental amenities to estimate individual willingness to pay for a change in one or more amenities. Researchers have applied both property and wage models to value air quality but have used only property value models in the case of water quality.

These models, known as hedonic models, use two assumptions: (1) participants in a market accurately perceive the characteristics of different hous-

*The characteristics did not include water quality because the fisheries were separated by the type of fish.

ing sites--including water quality--and, in making their location decisions, will consider them along with the prices for the housing units; and (2) there exists a continuous array of combinations of these characteristics across different housing sites within the market. An ideal market process will ensure that equilibrium housing prices and rents will reflect the marginal valuations of the characteristics.

Data Needs, Key Assumptions/Limitations, and Features

Only a checklist on data needs, key assumptions, and features is presented because the resources required to use this method would exceed those available in most States. A detailed discussion and a related case study will be presented in Volume II.

Data Needs:

- Property values (preferrably sale price) for residential sites around water bodies with different water qualities in the same housing market.
- Information on other site and neighborhood characteristics that may affect property values.
- Information on individuals' perceptions of water quality and relationship to available physical measures of water quality.

Key Assumptions/Limitations and Features:

- Market equilibrium
- Full knowledge of the implications and effects of water quality
- Ability to determine extent of market and specify relationships for hedonic price and demand functions
- Full adjustment and ease of mobility.

Damage Function Method

The damage function method applied to valuing the benefits from water quality improvement is most relevant for the effects of water quality on human health. In principle, this approach examines all the possible physical effects of each type of emission into a water body. However, usually only the health effects are considered.

To use this approach it is necessary to estimate, for each class of effect (i.e., chronic versus acute), health impacts that stem from the relationship between the physical effect and the concentration of the relevant water pollutant, as well as any other factors that might influence the pollutant's impact. These relationships are the damage functions. They are used to estimate the physical effects of specified changes in water quality as measured by the concentrations of each of the individual pollutants. The method does not provide a way to value the physical effects so that independent estimates of the health benefits must be developed.

Data Needs, Key Assumptions/Limitations, and Features

The following checklist outlines the data needs for the damage function method, along with its key assumptions and features. A detailed case study will be presented in Volume II.

Data Needs:

- Measures of concentration of relevant pollutants in water used by population over time and over the geographic location.
- Measures of features of population and health patterns.
- Measures of other exogenous factors that may also affect observed health patterns of population.

Key Assumptions/Limitations and Features:.

- Provides largely statistical summaries of data on existing population experiences.
- Assumes no behavioral substitition on the part of populations in response to levels of each pollutant.
- Produces results sensitive to the statistical procedures used to estimate the models.
- Maintains the primary advantage allowing classification of effects according to physical impacts.

3.5 BUSINESS BENEFITS

Benefits from the water quality programs can accrue to firms as well as to households because many provide for a wide spectrum of uses for rivers and streams, including industrial/commercial, agricultural, navigation, and municipal water supply uses. Measurement of business benefits are often easier because market prices are usually available to value these benefits.

Theory: The Supply Function*

In addition to the demand function discussed earlier, economics provides a second organizational guidepost for measuring benefits--the supply function,

*This discussion is a summary of the discussion in Just, Hueth, and Schmitz [1982], Chapter 4.

shown in Figure 3-5. The supply curve shows the maximum quantity of output of good X the firm is willing to supply at each relevant price. If the market establishes the price at P the firm will produce the quantity Q_o. The upward slope of the curve in Figure 3-5 indicates that the firm is willing to sell more at higher prices than at lower prices, assuming that factors influencing the supply function--the prices of inputs, such as labor, energy, machinery, and technological improvements--do not change.

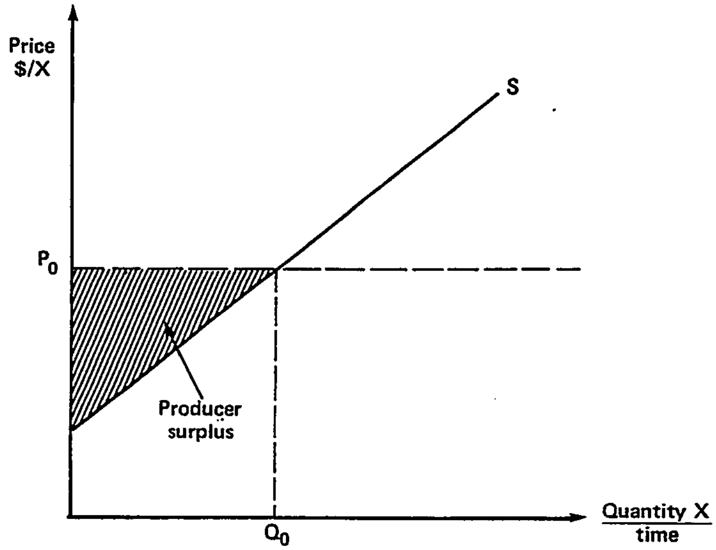

Figure 3-5. Supply function and the producer surplus.

The concept of producer surplus is used as the general measure for a change in the welfare of a firm. In Figure 3-5, producer surplus is shown as an area equal to the area above the supply curve and below the price line for the firm or industry. Whether a producer is better off can be determined by examining the change in producer surplus. Producer surplus provides a measure of a change in welfare for a firm because its welfare is measured directly in dollars of cost savings. This view of a firm is a simplified model that does not include important differences among firms or the distribution of profits among owners and resource suppliers.

<u>Practice: Cost Savings Method for Measuring Business Benefits</u>

The estimation of a firm's benefits from water quality has been much less sophisticated than the estimation of household benefits. The primary focus has been on estimation of the cost savings associated with the water quality change. The estimates are derived largely from engineering cost estimates. In principle, economic cost functions could provide the basis for these estimates, but, in practice, they have not.

The hypothetical example for business benefits is for irrigation, but the same method could be adapted to the other situations. The incremental producer benefits that might arise from water quality programs are:

- Reductions in industrial cost--firms using water in processes may have reduced production costs because either less treatment of water is required or less maintenance is required for pumps, pipes, and other parts of the production process.

- Reductions in agricultural costs--farmers using water for irrigation may have reduced production costs because less maintenance of irrigation equipment is required or less fertilizer per bushel of crop is needed.

- Reductions in navigation costs--barges and other water transport conveyances may have reduced risk of accident. Ship maintenance may be reduced.

From these simple examples two major points arise. The first is that the focus on incremental benefits of water quality decisions will mean these benefits are considerably smaller than they would be if measuring the total benefits of all water regulations were the primary objective of the benefit-cost assessment. That is, the baseline is important in measuring the benefits of a particular decision. The second point is that the relative orders of magnitude of these benefits will be very specific to the individual water bodies evaluated. For example, the complementary attributes necessary for recreation, such as access and overall surroundings, might be at very low levels in some instances, while the potential for producer benefits from other designated uses is very large. This point emphasizes the importance of the focus in the proposed water quality standards program on selecting key segments and considering each on a specific basis.

Data Needs, Key Assumptions/Limitations, and Features

The following checklist outlines the data needs of the cost savings approach, along with its key assumptions and features.

Data Needs:

- Cost data for firm (see Chapter 4 for details)

- Demand information such as market prices and responsiveness of sales to price changes.

Key Assumptions/Limitations and Features:

- All products and inputs (labor, machines) are bought and sold in markets that are perfectly competitive; that is, no buyer or seller has influence over market prices.

- The supply curve reflects the marginal social cost of producing the product or service. This implies that neither external costs nor subsidies are present in the market. (This is unlikely for the irrigation example because of the various legal and regulatory influences in the market, but it is a useful assumption to simplify exposition.)

A shift in the supply of a producer's services will not affect the price at which they are sold in the market.

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CASE STUDY: IRRIGATION BENEFITS

Suppose that a State is considering a change in the designated uses of a river segment to provide for fish and wildlife propagation. As a byproduct of this use designation, the quality of water available for irrigation is assumed to improve, thus shifting the supply of irrigation services--because more high-quality water is available for irrigation--outward from S_1 to S_2, as shown in Figure 3-6.* In an application, the practitioner may have limited data on some costs, but seldom enough to estimate the entire supply function. By supplementing the available data (e.g., from the Bureau of Reclamation or the U.S. Department of Agriculture [USDA]) with assumptions based on common sense, a rough cut at the problem can be obtained. For example purposes, the entire supply curve is drawn.

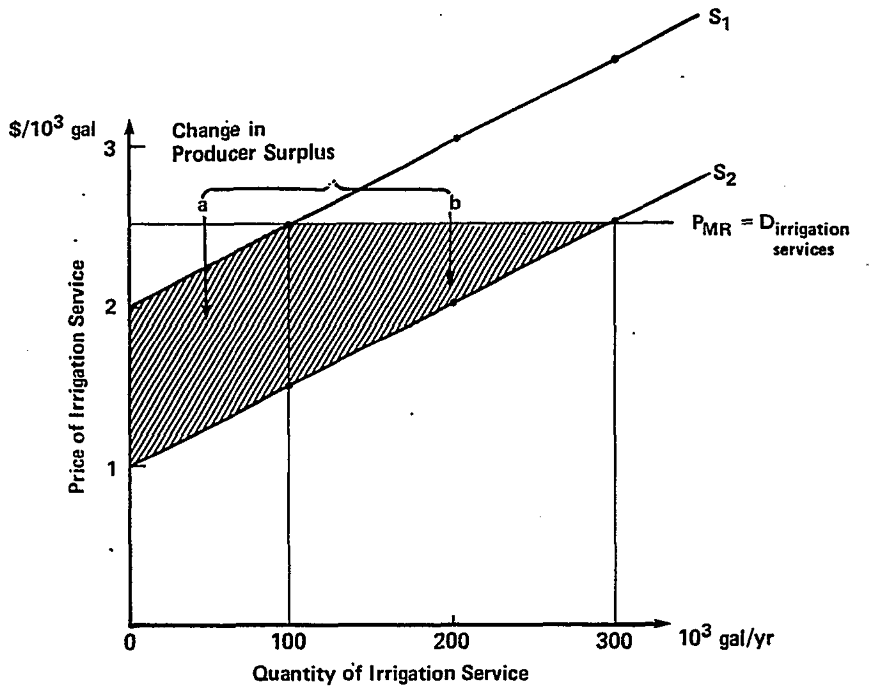

Figure 3-6. Irrigation benefits.

*The stream's flow is assumed to be strong enough that the increases in irrigation will not noticeably reduce it. Prior to the change in use designation, the limiting factor is assumed to be water quality rather than flow.

The task is to calculate the irrigation benefits from this shift in supply--the change in producer surplus attributed to the implementation of the new designated use. The crosshatched portions of Areas a and b in Figure 3-6 are the two components of the change in producer surplus. Area a is the new producer surplus resulting from reduced cost of the original volume of irrigation services (100). Area b is the new producer surplus on the additional volume of irrigation attributable to the reduced cost resulting from the water quality standards.

As drawn, Area a is a parallelogram showing the cost savings on the original irrigation volume. Using the formula for the area of a parallelogram:

Area a = (side) x (perpendicular distance to parallel side)

Area a = $(2-1) x (100-0)

Area a = $(1) x (100)

Area a = $100/year.

Area b is the additional irrigation induced by the decrease in costs due to the water quality standards. Using the formula for the area of a triangle:

Area b = ½(base) x (height)

Area b = ½$(2-1) x (300-100)

Area b = ½$(1) x (200)

Area b = $100/year.

Thus, the change in producer surplus--the measure of firm benefits--attributable to the cost savings from the additional river uses in the water quality standards is $200 a year.

There are several important caveats to the forgoing simple example for estimating firm benefits:

- The costs are not quite as simple as in this example. However, the basic measurement concept still applies.
- The assumptions required for the example are stringent ones, but they do provide a workable approximation for many individual river segments.
- In the cases of agriculture and nagivation, institutional factors in those markets may distort the true social cost. For example, the subsidization of waterway activities and the regulated rates in railway and highway transportation may violate the assumptions of perfect competition in those markets.

- If the assumption of perfect competition in the input markets does not hold, the producer surplus may actually accrue to providers of labor or capital services.

- Market power resulting in control over market prices and outputs will distort the supply relationships and make prices higher than in competition.

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3.6 PUBLIC WATER SUPPLY BENEFITS

Reductions in treatment requirements for municipal water supplies constitute another potential source of benefits from water quality program decisions. By having a use designation that provides for fish and wildlife propagation, a city that uses a river as a water supply source may be able to provide water with less treatment than if the use designation were agricultural or industrial. Once again, it is essential to remember that the focus of the benefit measurement should be the incremental benefits attributable to the particular policy, not total benefits from all water regulations.

Since calculation of these benefits could proceed exactly as in the case of business benefits, no case study is provided. The same key assumptions apply as with business benefits.

The critical issue of toxic substances or toxic pollutants, which would apply to a public water supply, is not considered in this handbook. As more information becomes available on the extent and effects of toxics and their relationships to the water quality regulations, a change in this focus may be warranted. This is an issue that bears future scrutiny because of potential health benefits from reducing toxic pollutants.

3.7 SUMMARY

This chapter has reviewed basic benefits concepts and the approaches used to measure them. An individual's willingness to pay is the central tenet underlying all the methods discussed in this chapter. Even though all assessments may not require the practitioner to use measurement methods, willingness to pay provides an organizing principle for even qualitative assessments of benefits.

Major points developed in the chapter include:

- The assessment should be tailored to balance the complexity and importance of the policy action to the available resources.

- The change in consumer surplus should be used as the measure of willingness to pay for improvements in the well-being of households.

- The travel cost method can provide willingness-to-pay-based measures of water quality changes under many conditions. It measures only user benefits and is sensitive to the treatment of time costs and substitute sites. The travel cost method estimates demand for site services.

- The contingent valuation survey method also provides willingness-to-pay-based measures of water quality changes under many conditions. It can measure both user and intrinsic benefits and is sensitive to questionnaire design and administration.

- The participation survey method provides measures of changes in level of use--visitor days--for a recreation activity and often requires ad hoc valuation of use to develop benefits.

- Cost savings can provide estimates of willingness-to-pay-based measures (producer surplus) of changes in the economic well-being of firms.

CHAPTER 4

MEASURING THE COSTS OF WATER QUALITY PROGRAMS

4.1 INTRODUCTION

Why is opportunity cost the basis for measuring costs? What types of approaches are available to measure costs? What practical problems arise in measuring costs? Are there any examples of cost measurement?

This chapter focuses on determining the incremental costs of a water quality program. It defines various cost categories, discusses their relationships, and reviews costing methods relevant for users of this handbook. It covers costs for both industry and publicly owned treatment works (POTWs) and presents several case studies to illustrate how the general principles are applied. Although the examples are oriented toward potential water quality standards decisions, they are general enough for use in other applications.

Throughout this chapter, opportunity costs--the value to society as a whole of a resource's best alternative use--provide the measurement basis for costing in a benefit-cost assessment. Engineering and accounting cost estimates may differ from opportunity costs because of cost-sharing mechanisms such as taxes and subsidies. In these cases, the practitioner faces the difficult task of determining the value of opportunity costs.

This chapter suggests practical approaches to costing and highlights some of the more difficult issues, which will get more detailed treatment in Volume II. Specifically, Section 4.2 presents the basics underlying the measurement of costs, and Section 4.3 describes two general approaches, engineering and econometric, to measuring costs. Section 4.4 defines types of cost and major cost categories to be used in an assessment. Section 4.5 discusses the practical aspects of determining costs--including data sources, the use of indexes, and major factors influencing cost estimates--and concludes with a sample data form. Section 4.6 describes the engineering methods for estimating costs, and Section 4.7 provides examples using the engineering methods. Section 4.8 offers some general cautions for measuring costs. Finally, Section 4.9 summarizes the chapter's major points.

4.2 MEASURING COSTS: THE BASIC CONCEPTS

This section reviews the fundamental economic principle of cost: opportunity cost, which measures the cost of any resource in terms of its next best alternative use. That is, the value of forgone alternative uses for any resource provides the basis for estimating the cost of any specific use of that resource.

For a water quality decision, opportunity costs include both explicit costs (e.g., wages and salaries, or payments for materials and energy) as well as implicit costs (what self-owned and employed resources could have earned in their best alternative uses). For example, the implicit cost of labor is the highest wage the owner could receive for his labor services.

For firms and households, the opportunity costs are the private costs of a regulatory action. If the action also negatively affects others, either households or firms, additional costs are incurred--in technical terms, external costs. In a benefit-cost assessment, the opportunity cost to society is the relevant measure of cost, the sum of private and external costs.

The economic guideposts of supply and demand functions described in Chapter 3 can be used to view the opportunity cost concept. These functions are combined in Figure 4-1, which illustrates a market for good X. The demand curve, D, shows the amount demanders are willing to buy at each of several prices, while the supply curve, S, reveals the amounts suppliers will provide at various prices. Market forces will cause the price to settle at P_0, with the resulting quantity at Q_0.

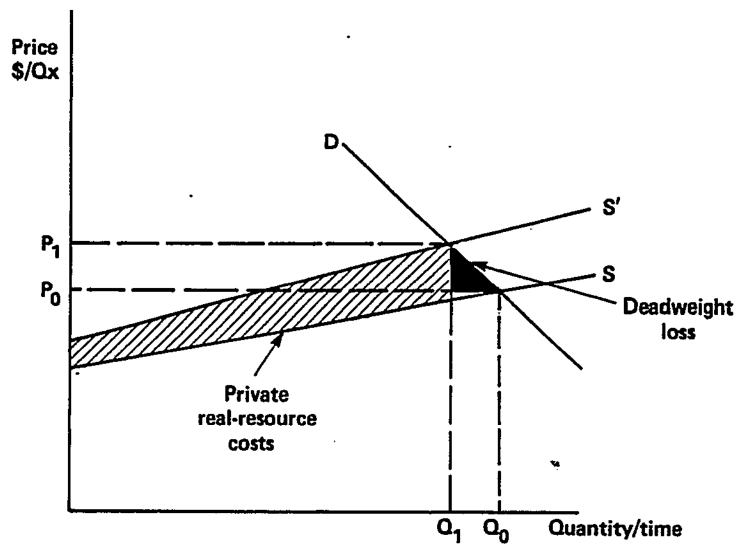

Figure 4-1. Measurement of opportunity/costs.

One way to view the cost of a regulatory action is to suggest it will impose costs on firms, resulting in a shift of the industry supply curve from S to **S'**. In this case, the regulation causes a shift in the curve by an amount that recovers the costs of compliance--shown by the hatched area in Figure 4-1. These costs constitute one element in the opportunity cost of the regulation--the additional opportunity costs (e.g., extra operation and maintenance) required to meet the regulatory standard. The second element of opportunity cost is shown by the shaded triangle--the loss to society because the produced and purchased quantity of X is reduced from Q_0 to Q_1 when supply shifts. In technical terms, some producer and consumer surplus is lost (dead weight loss).

In practice, it is usually impossible to construct the supply curve for an industry. Instead, the practitioner can use the available cost information, often for an "ideal" plant, and assume the supply curve is horizontal. In most cases, the loss in accuracy caused by making this assumption is not a severe limitation because the estimated compliance costs, the largest component of opportunity cost, are less affected than the dead weight loss to society.

Under most circumstances, market prices of goods and services provide a good estimate of their social opportunity costs. However, in some cases, there can be significant differences between market price and social cost. As noted in Chapter 2, the most significant case relevant to water quality programs is the difference between social and private rates of return on capital due to corporate income taxation. In addition, subsidies and grants may cause the financial costs to participants to differ from social costs.

4.3 MEASURING COSTS: TWO GENERAL APPROACHES

Evaluating the costs of regulatory actions requires the collection and analysis of relevant industry and municipal cost data. A thorough accounting of costs for potentially affected firms and cities is desirable. There are two main approaches to estimate these costs: econometric cost estimation and engineering cost estimation.

Econometric cost estimation, sometimes referred to as the statistical approach, uses cost-output relationships that are identifiable through empirical testing. Sometimes, statistical cost estimation offers a way to determine the costs of proposed alternatives. It is possible that data can be gathered for actual firms, most of which have identifiably different production processes and some of which already meet regulatory alternatives of the type under consideration. Given sufficient data, production relationships representative of complying and noncomplying firms can be estimated. Then, if the prices of labor and equipment are known, it is possible to establish cost-output relationships known as cost functions. These cost functions, in turn, can be used to evaluate the cost of regulatory alternatives.

Unfortunately, empirical studies of this type are rarely practicable for regulatory analyses. The major difficulty usually is that sufficient technical data are not available. In particular, published data are usually scarce, and potentially useful data, available only from firms, are typically considered proprietary.

The second approach to cost estimation is the engineering cost approach. This approach offers a viable alternative to statistical cost estimation because it does not rely on the availability of a firm's actual data. Rather, engineers familiar with relevant industrial processes use a wide variety of information to establish relationships between inputs, outputs, and costs. These relationships are presented for hypothetical facilities both with and without proposed regulatory controls. The practitioner uses the facility data to determine the costs of the regulatory alternatives. This general approach is the focus of this chapter.

4.4 TYPES OF COSTS

This section defines the major categories that can be used in assessing costs. The basic types of cost are capital costs, operating and maintenance costs, reinvestment, and salvage costs. The discussion is oriented toward the incremental costs of a regulatory action that affects water quality. In many situations, this orientation will mean upgrading an existing facility rather than constructing a new facility.

Incremental costs may include both additional end-of-pipe treatment units and modification of existing production or treatment units. Most documents relating to treatment costs are concerned with the former because the set of unit treatment processes is fairly well defined, allowing cost estimation to be more standardized. Changes in production processes (or manufacturing) are more difficult to analyze and are not discussed.

Capital Costs

Capital costs (K) represent initial costs associated with the construction or upgrading of a facility to meet the treatment requirements plus periodic reinvestments as individual components wear out and must be replaced. Table 4-1 shows the kinds of costs that should be included in a capital cost estimate. They are divided into three main categories: component installed construction costs, noncomponent construction costs, and nonconstruction costs. The first category includes physical treatment units (e.g., activated carbon, chemically assisted clarification) and miscellaneous structures. The second category includes construction items not necessarily associated with individual structures, such as site preparation. The last category includes all the miscellaneous costs in addition to construction costs, including contractor fees and interest payments. Care must be taken to identify incremental costs associated with the particular water quality decisions. For example, upgrades of existing facilities may not require any additional or miscellaneous structures.

In addition to initial capital costs, replacement costs or reinvestment costs are required over the life of the project as individual pieces of equipment reach the end of their useful life. Although the line between replacement and repair can be a fuzzy one, the definition is quite operational. Items that are depreciated over a number of years rather than expensed immediately as costs are considered to be capital items and are treated as reinvestment.

In most cases, no adjustment is required to use engineering cost estimates as measures of social cost as long as they are based on market prices. This includes the proper allocation of interest and contractor's fees. Some caution is required in dealing with reinvestment because the available measures are based on what tax laws allow and not on the actual social cost. Volume II will cover this in more detail.

Table 4-1. Components of Capital and Operation and Maintenance Costs

A. Capital Costs

(1) Component installed construction costs
- unit processes
- miscellaneous structures

(2) Noncomponent construction costs
- site preparation
- piping
- electrical
- instrumentation

(3) Nonconstruction costs
- land costs
- engineering and construction supervision
- contingencies
- administrative and legal
- miscellaneous nonconstruction labor (testing, etc.)
- design
- fees
- interest during construction

B. Operation and Maintenance Costs

(1) Variable operating costs
- labor
- materials
- chemical
- energy

(2) Byproduct, other credits

(3) Overhead items
- insurance
- taxes
- administrative and other allocations

Operation and Maintenance Costs

Operation and maintenance (O&M) costs represent the annual costs of running and maintaining the facility after its construction (see Table 4-1) and are divided into three groups: variable operating costs (labor, materials, energy, etc.), byproduct and other credits, and overhead items. Control efforts resulting from in-plant process changes may also affect revenues or production costs; these are included in the byproduct credits.

To be consistent with the definition of incremental costs, the overhead items should include only the additions required by the project, not a pro rata allocation based on overall costs. The treatment of taxes in a benefit-cost assessment raises some questions. Although taxes are not costs from the point of view of the nation as a whole, tax receipts that leave a particular State may be regarded by that State as a real cost in its benefit-cost assessment. State and local taxes should not be counted as social costs in any case; they are simply transfers.

Annual O&M costs may vary over the life of the facility. For example, growth in population or water use will increase the flow to a POTW over time, causing O&M costs to increase. If the growth rate is high, using the first year's O&M costs may significantly underestimate average annual O&M costs over the life of the project.

Reinvestment Costs

Reinvestment costs (RC) represent periodic replacements of individual units whose lifetime is shorter than that of the overall project. Depending on data availability, it may be more convenient to represent this process as either the replacement of particular units at discrete intervals or as a constant fraction of initial investment costs each year. Table 4-2 shows the formula for each. If the first approach is used, capital costs may be broken down into groups with different average ages and the formula applied separately to each group using the lifetime applicable to that group.

Salvage Value

Salvage value (SV) is the market value of the facility at the end of the planning period. A wide range of values is possible depending both on what that alternative use is and on what assumption is made about reinvestment (see the previous subsection). One extreme case is that the facility is expected to continue operating beyond the end of the planning period in the same fashion as before. In that case, the salvage value depends on the initial investment cost and the remaining useful life after the planning period. If the reinvestment process is best characterized as a series of periodic reinvestments, the value of the facility is proportional to the ratio of its useful life at the end of the planning period and its total useful life.

If the reinvestment process is better represented as an average reinvestment of amount dK each year (see Table 4-2), the expected lifetime of the facility has no end as long as the annual reinvestments are made. Therefore, the salvage value at the end of the planning period is still K if the facility is expected to continue in the same use as before.

If the facility is not expected to continue in its present use after the planning period, its scrap value must be determined. Any permanent fixtures

Table 4-2. Variables and Definitions for Measuring Costs

	Variable	Symbol	Source
1.	Planning period	N	Parameters
2.	Real social discount rate	s	Parameters
3.	Investment costs	K	Project costs
4.	O&M costs	OM	Project costs
5.	Investment lifetime	L	Project costs
6.	Physical depreciation rate	d	Project costs
7.	Number of replacements in planning period	M	Greatest integer N/L
8.	Growth rate of O&M costs	g	Parameter
9.	Reinvestment costs	RC	K every L years; or dK every year
10.	Fraction. of salvageable value	q	Project costs
11.	Salvage value	SV	qK
12.	Present value of stream of payments for N years at discount rate s	PV(N,s)	$(1-(1+s)^{-N})/s$
13.	Present value of reinvestment costs[a]	PVRC	$RC \sum_{j=1}^{M} (1+s)^{-jL}$; or $RC \cdot PV(N,s)$
14.	Present value of salvage	PVSV	$SV(1+s)^{-N}$
15.	Present value of O&M costs	PVOM	$OM \cdot PV(N,s)$
16.	Present value of all capital costs	PVK	K + PVRC - PVSV
17.	Present value of all project costs	TPV	PVK + PVOM
18.	Total annual cost of project	TAC	TPV/PV(N,s)

[a]First definition in the right-hand column represents periodic reinvestments, where RC = K; the second definition represents annual reinvestments, where RC = dK.

such as concrete tanks or structures are likely to have no salvage value.* Machinery and equipment items may have 25 to 50 percent of their original value. Cash or natural resources on hand can be valued at 100 percent of current value, and other current assets may be valued at 70 to 100 percent of their current value, depending on their salability.

Summary Cost Measures

Discounting allows the four types of costs to be combined to obtain. a single overall cost estimate for a project. Based on the discussion given in Chapter 2, the use of the discount rate is summarized below. Specifically, discount rates are used to construct two kinds of summary measures: present value (PV), where O&M costs are capitalized, and total annual costs (TAC), where capital costs are annualized. Table 4-2 shows these two. methods along with the variables used to develop measures of social cost. In addition, Table 4-2 summarizes the formulas for the components of the total present value of the costs of a project.

The present value of all capital and O&M costs (TPV) is obtained by adding the present values of the cost components (salvage value is subtracted):

$$TPV = K + PVRC - PVSV + PVOM \ . \qquad (4.1)$$

The total annual cost (TAC) of the project is a constant amount whose present discounted sum over the project period is equal to the present value of project costs TPV. By the definition of the present value factor (PV) given in Table 4-2,

$$TAC = TPV/PV(N,s) \ . \qquad (4.2)$$

4.5 PRACTICAL ISSUES IN MEASURING COSTS

This section discusses the practical aspects of measuring costs. It covers sources of data, the use of cost indexes, and major factors affecting cost estimates. A sample data form, one method of organizing the costing process, concludes the section.

Sources of Cost Data

There are three commonly used sources of cost data: vendor information, estimating manuals, and industry information. In the past, many prac-

*Firms can write off such assets as tax losses. However, these writeoffs are not appropriate for measuring social costs because society still bears the full cost of the resources. The distribution of who in society bears the cost is different. Taxpayers and the firm bear the costs when they are written off, and the firm and consumers of its product bear the cost when they are not written off.

titioners have been successful in obtaining cost estimates for both installed capital costs and annual operating costs from equipment vendors. These estimates are generally solicited in writing along with operating features of the model plants for which cost estimates are needed.

Estimating manuals have also been useful in developing cost estimates. Two popular manuals are published by Richardson Engineering Services, Inc. [1977] and R. S. Means Company, Inc. [1981]. Richardson's manual is useful in preparing cost estimates for process industries, and Means' manual is geared to the construction industry. Both manuals are written to provide costs for individual components rather than total systems and thus require some skill and care in their use. Estimates can also be obtained by the use of cost factors. In this procedure, major equipment costs are multiplied by appropriate factors to estimate other cost elements. The factors are derived from experience with previous plant construction costs. Some procedures use a single factor to estimate total capital investment, but greater accuracy can be achieved from a method such as Guthrie's [1974], which separates labor and material costs and applies individual factors to each major process item.

Information supplied by the controlled industry may be useful in estimating costs. If plants can be identified that are already controlled to the level under investigation, both total installed costs and annual operating costs can be obtained from this source. Obtaining estimates of each cost element from more than one source is a way to validate estimates.

The Use of Cost Indexes

Treatment cost indexes allow cost estimates from different years to be converted to dollars of a single year to yield a valid comparison. Costs of various components included in both capital and O&M costs change over time due both to overall changes in the price level (inflation) and to changes in relative prices. The problem of forecasting general price inflation can be avoided by expressing all costs in constant dollars of a given year, but changes in relative prices. still need to be predicted. Unless there are compelling reasons to do otherwise, it is simplest and reasonably safe to assume constant real costs in future years. Of course, this assumption must be applied to all components of the benefit-cost assessment to ensure consistency.

Cost indexes are usually represented as a number showing the ratio of the cost of a unit in dollars of a given year to the cost of the same unit in dollars of the base year multiplied by 100. In adjusting these costs to constant dollars in a given year, the practitioner must take account of the change in the index and the overall change in the price level. For example, if the cost of a treatment plant is given for 1975 in current (i.e., 1975) dollars and must be converted to 1977 costs in 1977 dollars, the U.S. Environmental Protection Agency's (EPA) Sewage Treatment Plant Construction Cost (STPCC) Index [Michel] can be used as follows:

$$\text{Cost}(77) = \text{Cost}(75) \times \frac{\text{STPCC}(77)}{\text{STPCC}(75)}$$

$$= \text{Cost}(75) \times \frac{278.3}{250.0}$$

$$= \text{Cost}(75) \times 1.11 .$$

If the costs for a given year are to be expressed in the constant dollars of another year, then the gross national product (GNP) deflator or another general price index must be used. For example, costs shown above for 1977 may need to be converted to 1976 current dollars. Using the convention that PGNP (N) is the GNP deflator* in year N and that the notation cost (m, n) refers to costs corresponding to year m expressed in constant dollars of year n gives:

$$\text{Cost}(77, 76) = \text{Cost}(77, 77) \times \frac{\text{PGNP}(76)}{\text{PGNP}(77)}$$

$$= \text{Cost}(77, 77) \times \frac{1.321}{1.398}$$

$$= \text{Cost}(77, 77) \times 0.945 .$$

Cost indexes are available for both capital and O&M costs. One index to use for O&M costs is the U.S. Environmental Protection Agency's (EPA) Municipal Wastewater Treatment Plant Operation and Maintenance Cost Index [Michel]. This index is a weighted average of cost indexes for labor, chemicals, power, maintenance, other costs, and a "quality added" factor. Although developed primarily for secondary treatment plants, the mix of inputs for O&M costs of advanced treatment plants should not differ much.

Several construction cost indexes are available for adjusting capital costs. These include EPA's STPCC index used earlier, the Engineering New-Record Cost Index (ENR),† and the Chemical Engineering Plant Construction Cost Index (CE).‡ The nature of the treatment system being examined determines which of these indexes is most suitable to use. Both the STPCC and ENR indexes are more oriented to secondary treatment plants, where large concrete tanks play an important role, but they are also appro-

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*The GNP deflator is published by the U.S. Bureau of Economic Analysis. The wholesale price index (WPI), another useful index, appears in the U.S. Bureau of Labor Statistics, Producer Prices and Price Indexes.

†Appears weekly in the Engineering News-Record, published by McGraw Hill.

‡Appears in Chemical Engineering, published by McGraw Hill.

priate for some advanced treatment (AT) processes (such as chemically assisted clarification), which rely on large tanks. The CE index is more suitable for processes where equipment plays a large role in costs, such as use of activated carbon. However, it is difficult to make hard and fast rules. The cumulative percent increases of the STPCC and ENR indexes are close, while that of the CE index is somewhat lower.

To arrive at a cost figure more accurate than one. that results from the use of the national average indexes alone, locality factors can be applied to an estimated cost or cost index. The use of locality factors, which have been calculated from generally available statistics, permits the localizing of national average cost data on various cost items. Locality factors are available from the U.S. Environmental Protection Agency's (EPA) Sewage Treatment Plant and Sewer Construction Cost Index [Michel].

Major Factors Affecting Cost Estimates

The cost of a treatment process is influenced by a multitude of factors. Among the important ones are wastewater flow rate, pollutant loadings, plant location, and performance (i.e., amount of pollutant removed and effluent concentrations). Most treatment technologies show economies of scale; i.e., costs increase at a slower rate than flow size. Thus, the cost per gallon of wastewater treated in a large plant is less than that treated in a smaller plant that meets the same treatment performance criteria. In general, the scaling factor* varies with size of flow and technology. For preliminary planning purposes, the following values are useful for extrapolating the treatment cost of a given treatment plant size to others:

Cost Item	Scaling Factor
Capital	0.6 to 0.9
O&M	0.7 to 0.9
Labor	0.5 to 0.7
Utilities and chemicals	1.0

The upper end of the range for the scaling factors (implying less economy of scale than the lower end) is associated with the more advanced treatment technologies, such as carbon adsorption and electrolysis, to which this handbook is oriented. Economies of scale also appear in the relationship of cost to waste loading but are less prevalent than in the cost-to-flow-size relationship.

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*As used here, scaling factor refers to x in the following equation:

$$C_2 = C_1 \left(\frac{Q_2}{Q_1}\right)^x,$$

where C_1 is a cost for a treatment plant with flow Q_1 and C_2 is the estimated cost for a plant with flow Q_2.

Because wastewater flows and loadings tend to show greater variability in a POTW than they do in an industrial plant, equalization is commonly used to smooth out fluctuations. Even so, the POTW customarily is designed with some excess capacity to accommodate variations in flow and waste loading.

In some cases, more intensive treatment effort in the treatment plant--such as additional chemicals or energy input--can result in enhanced performance or accommodation of a greater volume of wastewater without sacrificing design performance. However, the incremental cost usually is high. Therefore, it is less costly in the long run to upgrade or expand the treatment facility if actual flow, loading, or performance is expected to change appreciably from initial design conditions.

It is generally more costly to upgrade an existing plant by retrofitting than it is to use the same treatment train in a new plant. The treatment in place at a plant may limit the choice of higher treatment technologies that can be selected to upgrade the plant. Upgrading usually requires engineering effort, rewiring, and additional piping at the existing facility. The additional cost attributed to retrofitting a plant is sensitive to the specific features of the plant and the site, so these factors should be considered in developing retrofit cost factors. Based on limited observations, costs of retrofitting an existing plant can range from 1 to 15 percent higher than the cost of incorporating the same treatment train in the initial design of a new plant [U.S. EPA, 1976]. The added cost of retrofit in percentage terms is inversely proportional to the capacity of the treatment facility.

Sample Data Form

A “model plant form” can be used to compile parametric and cost estimates in an orderly fashion. The form can be continually revised to meet the needs of the specific data requirements of an assessment. A model plant questionnaire of this type is applicable only for regulatory alternatives that involve engineering controls. Figure 4-2 presents a version of the mod’ plant questionnaire.

4.6 COST ESTIMATING TECHNIQUES

This section on cost estimating techniques defines the components of treatment systems and describes several variations on the basic costing techniques. Finally, the question of how to proceed when no directly relevant cost sources are available is discussed. The techniques described here are appropriate for costing both POTWs and industrial dischargers.

Components of Treatment Systems

To analyze the costs of a particular proposed treatment system, it is useful to break it down into its components. Although each treatment system has its unique aspects, the individual components are more standardized and hence more easily costed using standard references, where costs are defined in terms of a few major parameters. The detail of the breakdown depends on the accuracy of the estimate required. It is useful to understand the relation-. ships of the following three levels of treatment units:

MODEL PLANT FORM

1. **Model Plant Number and Description**
   Number ______
   Description ______
2. **If new, state design life (years)** ______
   If existing, state plant age (years) ______
   and remaining life (years) ______
3. **Legal Depreciation Period (years) and Usual Depreciation Method**
   Plant ______
   Compliance Equipment ______
4. **Discuss what relationship exists, if any, between existing plant age and model type. Discuss age distribution of existing plants.**

______

______

______

	Alternative 1 (Baseline)	Alternative 2	Alternative n
5. Product Names, Annual Capacity Outputs			
Primary Product			
Name ______			
Annual Physical Output Capacity Units Specified ______	______	______	______
Producer Price, 19__ dollars per unit ______			
Secondary Product			
Name ______			
Annual Physical Output Capacity Units Specified ______	______	______	______
Producer Price, 19__ dollars per unit ______			
Marketable Byproduct			
Name ______			
Annual Physical Output Capacity Units Specified ______	______	______	______
6. Annual In-Plant Consumption of any of the Products Listed in (5).			
Name ______ Quantity	______	______	______
Name ______ Quantity	______	______	______
7. Installed Capital Cost 19__ dollars OF NEW PLANT	______	______	______
8. Installed Capital Cost of Compliance Equipment for Existing Plant 19__ dollars	XXX	______	______

Figure 4-2. Sample model plant data form.

Model Plant Form (con.)

	Alternative 1 (Baseline)	Alternative 2	Alternative n
9. Expected Life of Compliance Equipment for Existing Plant (years)	XXX	____	____
10. Lost Productive Time While Compliance Equipment Is Installed in Existing Plant (days)	XXX	____	____
11. Salvage Value, if any, of Compliance Equipment When Plant Is Closed 19___dollars	XXX	____	____
12. Total Annual Operating Costs 19___dollars	____	____	____
13. Annual Fixed Operating Costs			
Total Fixed Operating Cost 19___dollars	____	____	____
Labor			
Number of labor hours	____	____	____
Annual Wage per labor hour 19___dollars	____	____	____
Labor Cost 19___dollars	____	____	____
Energy Costs 19___dollars	____	____	____
Materials Costs 19___dollars	____	____	____
Overhead Costs 19___dollars	____	____	____
Other Fixed Costs 19___dollars	____	____	____
14. Annual Variable Operating Costs			
Total Variable Operating Costs 19___dollars		____	____
Labor			
Number of labor hours	____	____	____
Annual Wage per labor hour 19___dollars	____	____	____
Labor Cost 19___dollars	____	____	____
Energy Costs 19___dollars	____	____	____
Materials Costs 19___dollars	____	____	____
Overhead Costs 19___dollars	____	____	____
Other Variable Costs 19___dollars	____	____	____
15. Current Salvage Value of Plant 19___dollars ____________			
16. Salvage Value of Plant at End of Life 19___dollars	____	____	____
17. Residuals Discharged to Environment			
To Atmosphere			
Name ____________			
Quantity	____	____	____
To Water			
Name ____________			
Quantity	____	____	____
To Land			
Name____________			
Quantity	____	____	____

Figure 4-2. (con.)

- Unit process: A unit process corresponds to a single treatment operation. Examples of unit processes are secondary clarification, filtration, and cyanide destruction.

- Treatment process: A treatment process is a sequence of one or more unit processes linked together to support a particular pollutant-removal process. For example, the activated sludge process involves the decomposition of organic pollutants by microorganisms. This operation requires a number of unit processes including aeration, sedimentation, and sludge reactivation.

- Treatment train: A treatment train is a sequence of treatment processes. For example, an advanced treatment train may consist of the following treatment processes: preliminary screening, primary settling treatment, secondary biological treatment, and nutrient removal by chemical addition.

As discussed below, cost estimates for benefit-cost assessments of water quality programs should be broken down at least to the treatment process level and, in some cases, to the unit process level.

Estimating Treatment Costs

Cost estimation requires a specification of the treatment train to be used. A waste treatment train can be described by a flow diagram showing the relation and function of the various treatment and unit processes. One way to proceed is to (1) specify the important design parameters (such as flow, influent and effluent concentrations, and contact time) of each unit in the treatment process, (2) calculate the resource requirements (for example, for site preparation and construction and for purchased equipment, energy, and labor) of each unit, (3) estimate the indirect costs, and (4) sum to obtain a total cost. This calculation is carried out separately for a total capital and a total O&M cost before they are combined into a present value or annualized cost.

Before illustrating how different sources of cost information can be applied in particular situations, it is useful to distinguish among four different approaches that are employed to make cost estimates:

- A total system estimate

- A planning level estimate

- An engineering estimate

- A contractor estimate.

The cost estimates produced by these techniques range from gross to refined, depending on the different stages of a project, which range from project conceptualization to request for contractor bids. The four costing techniques provide a convenient frame of reference for discussion purposes but do not imply that rigid distinctions can always be made in using one technique versus another in a specific situation.

The use of site-specific information should result in more accurate results than use of generalized information. While it is, of course, desirable to develop accurate estimates, the practitioner is always confronted with deciding how much accuracy is needed for a particular phase of project planning and what level of effort to commit to the development of the estimates. For the purposes of water quality standards planning, the planning level estimate is generally the most appropriate one to use, and the examples focus on that level.

- Total System Estimate. In contrast to the other three costing techniques, the total system approach does not attempt to partition a treatment train into treatment or unit processes. Usually only one parameter of the treatment system--for example, plant capacity expressed as daily flow--is used with a set of cost curves to obtain total capital and annual O&M costs. The accuracy is ±40 percent.

- Planning Level Estimate. This approach is based on prior analyses of treatment system components or unit processes in which costs of the units have been related to important design parameters. The purpose is to allow recombination. or synthesis of total costs resulting from any combination of the unit processes using specified values of the design parameters. This level of estimate is appropriate for most water quality program planning purposes. Application of this technique requires that the practitioner identify the major components in the wastewater treatment train, the associated design parameter values, and the access to generalized cost functions for the components. The accuracy of this costing technique is within ±30 percent. The practitioner may be able to improve the accuracy of the estimate if judgments can be made about how site-specific characteristics differ from average conditions embodied in the generalized cost functions.

- Engineering Estimate. Like the planning level estimate, the engineering estimate is calculated using unit process data but goes into more detail on the unit processes in the system to adjust specific costs. This technique should yield a cost estimate within ±15 percent.

- Contractor Estimate. The contractor estimate is based on specific engineering designs--or design approaches coupled with specified performance requirements--for the treatment system and its unit processes. The precision of the contractor's estimate should be within ±5 percent.

4.7 EXAMPLES USING COST TECHNIQUES

Detailed engineering cost estimates are unlikely to be available for analyses of the type described in this handbook. Therefore, this section explores a range of techniques, from fairly sophisticated costing models (CAPDET) to process handbooks and EPA development documents, and presents specific examples to show how they are applied. Their applicability depends on both the amount of information and the time and resources available to the analyst. States may have their own techniques that are equally applicable. Even if specific information is not available, there are basic similarities in the approaches to water treatment problems taken by different industries. Therefore, the experience of other industries with similar processes or pollutants may provide a reasonable guide for estimating costs.

A library of cost information* is available to the practitioner, including documents and computer programs. The purpose of the following examples is to illustrate the use of various information sources to estimate costs, particularly planning level estimates.

Example 1: Pulp Mill Using EPA Development Document

This example illustrates the use of an EPA Development Document [U.S. EPA, 1980b] for a specific industry and the planning level costing approach. Assume that more stringent effluent standards will be imposed on a 900-ton-per-day kraft pulp mill to meet water quality standards. Based on a wasteload allocation, the effluent concentrations required to meet the water quality standards are 15 mg/L for both biochemical oxygen demand (BOD) and total suspended solids (TSS). The costs are to be estimated for October 1981.† The practitioner determines that the mill belongs to the "Market Bleached Kraft" subcategory (described as one of the industry subcategories in the Development Document) and that concentrations of BOD and TSS in the plant's effluent stream currently are 20 mg/L and 30 mg/L, respectively, which meet Best Practicable Technology (BPT) standards.‡ The Development Document identifies three treatment options that might possibly be used to meet the new BOD and TSS targets, but only Option 3, which consists of additional in-plant process controls together with chemically assisted clarification of the final effluent, can achieve the BOD and TSS targets of the water quality standards.

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*Important sources include: (1) EPA Development Documents for effluent limitations guidelines and standards (issued by the Effluent Guidelines Division of EPA to provide the technical background for the development of waste treatment rules for particular industries); (2) Areawide Assessment Procedures Manual [U.S. EPA, 1976]; (3) Innovative and Alternative Assessment Manual EPA, 1980a].

†The examples in this guidance use historical values of treatment cost indexes. For planning purposes it may be necessary to estimate future values.

‡BAT standards for the pulp, paper and paperboard industry have not yet been promulgated.

The next step is to estimate the cost for Option 3. Table 4-3 shows the costs of meeting Option 3 for three model mills with sizes of 350, 600, and 1,600 tons per day. Note that energy costs are presented separately, so they must be combined with O&M costs to obtain the definition of O&M costs used here. Two costs are shown for each category of cost based on alum concentration. As a first approximation, an average cost for the two alum concentrations is used. Next, because none of the three model mill sizes is

Table 4-3. Example 1: Cost Summary--
Market Bleached Kraft, Subcategory

	Mill size (tons/day)	Incremental compliance costs from BPT: Option 3[a,b]
Capital cost	350	6,662 7,010
	600	8,974 9,446
	1,600	16,590 17,410
Annual O&M cost	350	947 1,327
	600	1,327 1,953
	1,600	2,974 4,550
Annual energy cost	350	212 217
	600	351 358
	1,600	897 917

SOURCE: U.S. EPA [1980b], p. 468, Table IX-7.

[a] First quarter 1978 thousands of dollars.

[b] Dollar value shown above the line is based on chemical assisted clarification dosage of alum at 150 mg/L; the value below the line is for dosage at 300 mg/L.

for a 900-ton-per-day plant, a linear interpolation based on mill size is made between the values for the 600- and 1,600-ton-per-day plants.* This yields a capital cost for Option 3 of $11.5 million. Annual O&M cost is $2.3 million, and energy cost is $0.5 million; these are added for a total O&M cost of $2.8 million.

The following steps show the results for various measures of social cost derived from the basic costs, which are used as part of the benefit-cost assessment. The following parameter values are used:

ENR index (1st Qtr 1978) = 2,683

ENR index (Oct 1981) = 3,679

EPA O&M index (1st Qtr 1978) = 2.30

EPA O&M index (Oct 1981) = 3.34

s = real social discount rate = 0.10 or 0.05†

L = average equipment lifetime = 15

d = depreciation rate = 1/L = 1/15

N = planning period = 30 years

The indexes are historical values, the other parameters are assumed values. The results are (all quantities in thousands of 1981 dollars unless otherwise noted):

1. Capital treatment costs:

   K = 11,500 (1st Qtr 1978 $)

   $$K = 11{,}500 \times \frac{3{,}679}{2{,}683}$$

   K = 15,800 (Oct 1981 $)

2. O&M treatment costs:

   OM = 2,800 (1st Qtr 1978 $)

---

*Another method for estimating the value for the 900-ton-per-day plant size is to fit a cost curve to the three data points to determine if there are economies of scale of treatment costs instead of assuming a linear relationship between mill size and cost for the two larger model mills.

†These are just sample values chosen to show the effects of different values on the results. See Chapter 2 for discussion of which discount rate to use.

$$OM = 2{,}800 \times \frac{3.34}{2.30}$$

OM = 4,100 (Oct 1981 $)

3. Present value factor (equals present value of payment of one dollar per year for N years at discount rate s):

   PV(30, 0.10) = 9.43

   PV(30, 0.05) = 15.37

4. Present value of O&M costs:

   $$PVOM = OM \cdot PV(30,\ 0.10) = 4{,}100 \cdot 9.43 = 38{,}700$$

   $$= OM \cdot PV(30,\ 0.05) = 4{,}100 \cdot 15.37 = 63{,}000$$

5. Reinvestment cost (assume the entire facility is replaced in 15 years at the same original real cost):*

   RC = K = 15,800

6. The present value of the reinvestment cost is found by discounting at rate s over 15 years:

   $$PVRC = RC \cdot (1+s)^{-L} = 15{,}800 \cdot (1.1)^{-15} = 3.800\ (s = 0.10) \text{ or}$$

   $$= 15{,}800 \cdot (1.05)^{-15} = 7{,}600\ (s = 0.05)$$

7. Salvage value (assume zero salvage value):

   sv = 0

8. Present value of salvage (salvage occurs at end of planning period, N):

   $$PVSV = sv\ (1+s)^{-N}$$
   $$= 0$$

9. Present value of salvage (salvage occurs at end of planning period, N):

---

*Not all structures would need to be replaced. Fifteen years is assumed to represent the average lifetime of the facility.

$$PVSV = SV\ (1 + s)^{-N}$$
$$= 0$$

10. Total present value of investment cost:

$$PVK = K + PVRC - PVSV$$
$$= 15{,}800 + 3{,}800 - 0 = 19{,}600 \quad (s = 0.10)$$
$$= 15{,}800 + 7{,}600 - 0 = 23{,}400 \quad (s = 0.05)$$

11. Total present value of project cost:

$$TPV = PVK + PVOM$$
$$= 19{,}600 + 38{,}700 = 58{,}300 \quad (s = 0.10)$$
$$= 23{,}400 + 63{,}300 = 86{,}400 \quad (s = 0.05)$$

12. Annualized capital costs:

$$KANN = PVK/PV = 19{,}600/9.43 = 2{,}080 \quad (s = 0.10)$$
$$= 23{,}400/15.37 = 1{,}520 \quad (s = 0.05)$$

13. Total annualized costs:

$$TAC = KANN + OM = 2{,}080 + 4{,}100 = 6{,}180 \quad (s = 0.10)$$
$$= 1{,}520 + 4{,}100 = 5{,}620 \quad (s = 0.05)$$

The total present value of project costs calculated in Item 11 above is the amount that would be included in the benefit-cost assessment. Alternatively, the total annualized cost (Item 13 above) would be used if the rest of the assessment were also expressed in terms of annualized costs.

Example 2: POTW Using CAPDET

Over the past decade a number of computer-based treatment cost estimating models have been developed; CAPDET is one of the more widely used models [U.S. EPA, 1981].* CAPDET is not a mathematical optimization model; the CAPDET approach is to prepare cost estimates for alternative treatment trains specified by the user. With reference to the four costing techniques discussed earlier, the CAPDET method is probably best described as an intermediate method between the planning level approach and the engineering esti-

*To obtain access to CAPDET programs and documentation, contact the Systems Analysis Group of EPA regional offices or the Facilities and Requirements Division, Office of Water Program Operations, EPA in Washington, D.C.

mate approach. CAPDET contains cost and performance equations for 35 unit processes such as activated sludge, carbon absorption, lagoons, incineration, etc. For some unit processes, alternative design approaches are included; for example, the activated sludge process is described by 13 different methods of aeration. Two separate cost estimating methods are incorporated in CAPDET. First, parametric cost estimating is based on statistical analysis of the cost of facilities of similar size and characteristics at other locations. Second, unit cost estimating is based on identification of cost elements to which input prices are applied--e.g., cubic yards of concrete in a clarifier are quantified and an input cost value for reinforced concrete is applied to obtain a construction cost.

After recent revisions, CAPDET can be used to estimate costs of upgrading an existing POTW even though the program was developed originally to estimate new plant costs. Its capabilities have also been expanded to provide estimates of financial impacts on households from the construction of a POTW facility.

In this example, an existing municipal POTW has an average daily flow of 5 Mgal/d, a maximum flow of 10 Mgal/d, and effluent concentrations of 15 and 20 mg/L for BOD and TSS, respectively. Current secondary treatment uses plug flow for the activated sludge effluent, and the practitioner needs to determine the cost of upgrading the treatment by chemical addition and filtration to meet the water quality standard that requires reductions of BOD to 10 mg/L and TSS to 1 mg/L or less.

To use the CAPDET computer program, the unit processes in the current plug flow system and the upgraded treatment are specified as shown in Table 4-4. The CAPDET program can accept any number of wastewater treatment trains that are suitably described by the user.

Table 4-4. Example 2: Current and Upgraded Treatment Trains for CAPDET

Current treatment sequence	Upgraded treatment sequence
Raw sewage	Raw sewage
Preliminary treatment	Preliminary treatment
Primary clarifier	Primary clarifier
Plug flow	Plug flow
Secondary clarifier	Secondary clarifier
Chlorination	Coagulation
Gravity thickener	Filtration
Anaerobic digestion	Chlorination
Vacuum filtration	Gravity thickener
Hauling and land fill	Anaerobic digestion
	Vacuum filtration
	Hauling and land fill

Table 4-5. Example 2: Price and Cost Inputs to CAPDET

Cost analysis input parameters	
Interest rate:	10.000 percent
Planning period:	30 years
Year of dollars used:	1980

Cost Indexes	Unit prices
Buildings	55.00 $/ft^2$
Excavation	7.00 $/yd^3$
Wall concrete	207.00 $/yd^3$
Slab concrete	91.00 $/yd^3$
Marshall and Swift Index	577.00
Crane rental	67.00 $/h
EPA Construction Cost Index	163.00
Canopy roof	15.75 $/ft^2$
Labor rate	13.40 $/h
Operator class II	9.00 $/h
Electricity	0.04 $/kWh
Chemical costs	
Lime	0.03 $/lb
Alum	0.04 $/lb
Iron salts	0.06 $/lb
Polymer	1.62 $/lb
Engineering News Record Cost Index	2,886.00
Handrail	25.20 $/ft
Pipe Cost Index	295.20
Pipe installation labor rate	14.70 $/h
8-in. pipe	9.08 $/ft
8-in. pipe bend	86.82 $/unit
8-in. pipe tee	128.49 $/unit
8-in. pipe valve	1,346.16 $/unit

Table 4-5 shows unit costs and prices in 1980 dollars that the practitioner provides to CAPDET, as well as the planning period and interest rate to be used in computing project costs. In calculating the capital costs, CAPDET recognizes that each equipment item has a service life associated with it that may be less than the planning period and that the facility has some salvage value at the end of the planning period. As a result, the capital cost incorporates three components, initial and reinvestment costs and salvage value. Typical useful life periods are as follows: wastewater conveyance structures, 50 years; other structures, 30 to 50 years; process equipment, 15 to 20 years; and auxiliary equipment, 10 to 15 years. In addition, O&M costs can be specified to vary over the planning period.

Table 4-6 summarizes the costs of the two systems analyzed by CAPDET, a new treatment plant using the current treatment sequence and a new plant with the two new treatment steps included. The table also shows the unadjusted cost increments obtained from CAPDET for upgrading the POTW and the adjusted costs which are increased by 15 percent to reflect the costs of retrofitting an existing system.

The capital costs of upgrading (as shown in Table 4-6) are $1.01 million; total project costs are $1.81 million. Additional O&M costs (which vary between the first and final year) range from $370,000 to $200,000 annually. Present worth is $5.46 million; annualized cost is $580,000 based on a 30-year planning period and 10 percent rate of interest.

Table 4-6. Example 2: POTW Upgrading Cost Summary (millions of 1980 dollars)

	New POTW with plug flow secondary treatment	New POTW with plug flow and chemical addition and filtration	Incremental costs for upgraded POTW	
			CAPDET unadjusted	Adjusted for retrofit[a]
Capital cost	3.60	4.48	0.88	1.01
Total construction cost	4.40	5.46	1.06	1.22
Total project cost	6.53	8.10	1.57	1.81
O&M cost				
First year	0.31	0.63	0.32	0.37
Final year	0.46	0.63	0.17	0.20
Present worth	9.98.	14.76	4.78	5.46

[a]Adjusted costs are 15 percent higher than unadjusted costs.

Example 3: POTW Using Technology Assessment Manual

In this example, planning level estimates of costs for upgrading an existing facility are developed from generalized cost curves that have been developed in the EPA's Innovative and Alternative Technology Assessment Manual [U.S. EPA, 1980a]. The manual has been designed specifically to aid Federal and State review authorities in the administration of innovative and alternative requirements of the Construction Grants Program and to provide basic methodological and technical information to individuals involved in facility plan development.

A municipality is assumed to have secondary wastewater treatment in place at the POTW using the activated sludge process. Wastewater flow is 10 Mgal/d, and the effluent has a monthly average value of 30 mg/L for both BOD and TSS. To meet an ultimate oxygen demand (UOD)* of 85 mg/L as part of waste-load allocation, it has been determined that the advanced waste treatment process described in the Manual as "nitrification, separate stage, with clarifier" is required. The construction and O&M costs are obtained from Fact Sheet 2.1.14 in the Manual using a 10-Mgal/d flow rate. Construction costs are $1.6 million and O&M costs are $70,000 in 1976 dollars.

Several other adjustments to the values read from the cost curves are necessary. The referenced Fact Sheet is based on an ENR construction cost index of 2,475 (for September 1976). Adjusting the construction costs for a first quarter 1980 ENR index of 2,886 yields a construction cost of $1.9 million. The O&M costs must also be adjusted to first quarter 1980. The EPA O&M index for the third quarter of 1976 is 2.06 and for the first quarter of 1980 is 2.83, yielding an adjustment factor of 1.37. Therefore, O&M costs are $100,000.

The Fact Sheet in the Manual directs the user to estimate other capital expenditures that have not been included in the construction cost curves. Table 4-7 replicates Table A-2, which is provided for that purpose in the Manual. Following the directions incorporated with Table A-2, the practitioner estimates nonconstruction capital expenditures. As shown in Table 4-7, total capital cost is $3.5 million.

The costs of the system are summarized in Table 4-8 together with effluent information. The annualized costs in the table are based on a capital recovery factor of 0.106, reflecting a 10 percent social discount rate and a 30-year plant life.

Example 4: What To Do When There Is "No Information"

The practitioner may find that no Development Document or other technical data have been published that are directly applicable to a particular type of industrial plant. Nevertheless, it is possible to identify treatment options and develop preliminary cost estimates, suitable for at least the early phases of water quality program analysis.

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*UOD + BOD_5 x 1.5 + NH_3 x 4.5.

Table 4-7. Example 3: Development of Capital Costs (Nitrification)
(All costs in millions of 1st quarter 1980 dollars)

Component installed construction costs				
Unit processes				
Nitrification			$1.9	
Miscellaneous structures (Administrative offices, laboratories, shops and garage facilities)			$0.0	
Subtotal 1				$1.9
Noncomponent costs				
	Average[a]	Range[a]		
Piping	10%	8-15%	$0.2	
Electrical	8%	5-12%	0.4	
Instrumentation	5%	3-10%	0.1	
Site preparation	5%	1-10%	0.1	
Subtotal 2				$0.8
Nonconstruction costs				
Engineering and constructign supervision @ 15 percent[b]			$0.4	
Contingencies @ 15 percent[b]			$0.4	
Subtotal 3				$0.8
Total capital costs				$3.5

[a] Range due to level of complexity, degree of instrumentation, subsoil condition, configuration of site, etc., percentage of subtotal 1.

[b] Percentage of subtotal 1 plus 2.

Table 4-8. Example 3: Summary of Costs for Nitrification Upgrade

Costs (millions of 1980:1 dollars)				Effluent (mg/L)		
Construction costs ($)	Total capital costs ($)	O&M costs ($)	Annualized cost ($)	BOD	NH_3	UOD[a]
1.9	3.5	0.10	0.46	10	1	19.5

[a] $UOD = BOD_5 \times 1.5 + NH_3 \times 4.5$.

A reasonable approach is to first identify the pollutants that are of major concern at the particular plant, their concentration, and the effluent flow. The next step is to identify waste treatment unit processes that may be applicable for the identified pollutants. This can be done by identifying one or more analogous industries--e.g., an industrial plant where the specific pollutants of interest are being effectively treated, or have been studied. In all likelihood, the method of treatment of a specific pollutant in one industry will be applicable to the particular plant of interest to the practitioner.

The next step is to acquire Development Documents and other reports on the analogous industries. Using the information on the analogous plants, the practitioner should search out the cost-versus-flow-size relationships for the one or more unit processes used to treat the pollutants of interest. This will allow the practitioner to synthesize a wastewater treatment train and estimate a total cost for the process units in the train. This approach is preferable to using a total system cost estimate, in which the costs for each unit process are not explicitly identified.

4.8 FINAL CAUTIONS

This section describes several important factors that suggest caution is necessary when measuring waste treatment costs, particularly industrial wastes.

The costs of treating wastes are only one element of the entire production process for a firm. This element is the management of the residuals that accompany production (see Ayres and Kneese [1969]). The costs of treating wastes can be affected by changes in the level of production, which alters the volume of wastes and perhaps the type of treatment required. Changes in the type of product produced, in the processes used to make it, or in the means of recovering the waste all can affect the cost and type of treatment required. For example, a technology change in pulp production for the paper industry from sulfite to kraft lowered the volume of suspended solids. When the practitioner considers the cost of a regulatory action, it is important to keep this total system view in mind.

4.9 SUMMARY

This section summarizes the major points from the chapter.

- Costs are measured on the basis of opportunity cost--the value of the next best forgone alternative.

- The two main approaches to estimating costs are the econometric and engineering approach. The engineering approach is most often used because data needed in the econometric approach are seldom available.

- Two major cost categories are capital costs and operation and maintenance (O&M) costs. Capital costs are initial costs of construction or upgrading. Operation and maintenance costs are annual costs of running and maintaining a facility after its construction.

- Three useful sources of cost data are vendors, estimating manuals, and industry information.

- Discounting links the four major components of project costs: initial investment, O&M, reinvestment, and salvage value.

- Cost indexes allow cost estimates from different years to be compared on a common basis. Useful index are EPA's Sewage Treatment Plant Construction Index, the GNP price deflator series, and Chemical Engineering Plant Construction Cost Index.

- Important factors affecting costs of waste treatment are flow rate, pollutant loadings, plant location, and performance capability.

- A model plant data form can organize information required for costing.

- Three levels of waste treatment are unit process (single treatment), treatment process (sequence of unit processes), and treatment train (sequence of treatment processes).

- Planning level estimates of costs based on prior analyses of treatment cost and having an accuracy of ±30 percent are appropriate for many water quality program decisions.

- EPA Development Documents provide a valuable source of planning level costs for specific industries.

- CAPDET is a computerized model that prepares cost estimates of alternative treatment trains, estimates the costs of upgrading, and computes a financial impact statement for publicly owned treatment works. CAPDET provides accuracy between ±15 and ±30 percent.

- Technology assessment manuals provide basic technologies for publicly owned treatment works.

- Treatment cost estimates are sensitive to many factors in firms' overall production operation, including output levels, types of products, or manufacturing processes.

CHAPTER 5

COMPLETING THE BENEFIT-COST ASSESSMENT

5.1 INTRODUCTION

What is a sensitivity analysis? How is it used in a benefit-cost assessment? What methods are appropriate for displaying the results of a benefit-cost assessment? Is a checklist of elements possible in a benefit-cost assessment?

In answering these questions, this chapter discusses three sets of practical problems encountered in benefit-cost assessments: establishing plausible results, displaying those results, and organizing the assessment's elements. The complexity of these practical problems varies directly with the complexity of the particular assessment. For example, in a qualitative assessment, a sensitivity analysis need be conducted only in very general terms. However, in a complex assessment, such as one presented in, the example below, the plausibility of individual variables is specifically considered. In other words, the resources used in a sensitivity analysis can be tailored to the importance of the decision.

The following sections of this chapter highlight these practical aspects of a benefit-cost assessment. Specifically, Section 5.2 presents a sensitivity analysis for a water quality standards example involving monetized benefits and costs. Section 5.3 describes narratives, arrays, and graphs as alternative ways of displaying the results of an assessment. Section 5.4 presents a checklist for organizing an assessment. Finally, Section 5.5 summarizes the chapter's main points.

5.2 SENSITIVITY ANALYSIS: A GAUGE TO BELIEVABILITY

Introduction

One ingredient in a good benefit-cost assessment is a sensitivity analysis of its key variables and assumptions. The most common variables considered in a sensitivity analysis are the parameters that determine benefits and costs, the discount rate, and the time horizon of the assessment. For example, the effectiveness of a particular treatment process may be uncertain so that the anticipated water quality may not be fully achieved. As previously discussed, the discount rate can be among the most important of these features because it affects both benefits and costs.

A sensitivity analysis establishes a range for the net benefits in the assessment rather than simply portraying a single estimate. In principle, this is similar to the procedure in statistics that establishes interval estimates to bound the range of possibilities. In a benefit-cost assessment, greater uncertainties in the estimates of benefits and costs yield larger bounds to include most of the possible outcomes.

A sensitivity analysis will show when the assessment is affected by the assumptions made. In instances where similar benefit-cost assessments are expected in the future, a sensitivity analysis can serve as an agenda for research by highlighting assumptions that influence the estimated net benefits. Even when an assessment is sensitive to the assumptions employed, its results are not invalidated. Rather, this sensitivity calls for more care in interpreting the results and in determining whether the assumptions are reasonable.

A sensitivity analysis employs high and low estimates for both benefits and costs and estimates net benefits for a range of discount rates. Although there are no formal procedures in a sensitivity analysis, the following example highlights the decisions required to implement the various steps.

Table 5-1. Key Elements of Benefit and Costs

Cost savings[a]		Benefits forgone[b]	
Line item (and key assumption)	Likely estimate (and range), $ million	Line item (and key assumption)	Likely estimate (and range), $ million
Capital costs			
New advanced waste treatment plant (size of plant)	4.8 (3.0 to 6.0)	Additional fishing (5 percent growth rate)	1.75 (0.50 to 3.0)
Process changes at meat processing plant (extent of changes)	3.2 (1.2 to 5.0)	Additional swimming (probability of swimming is constant)	0.50 (0.2 to 1.25)
		Additional near-water activities (no new activities)	0.50 (0.2 to 1.50)
Operating costs			
Advanced treatment	1.0		
Meat processing	0.5		

[a]Cost savings are the investment and operating costs forgone by not meeting the fish and wildlife propagation use for river. Likely estimate is listed first with the range in parentheses.

[b]Benefits forgone stem from the recreational activities had the fish and wildlife propagation use been achieved. Likely estimate is listed first with the range in parentheses.

Example

Suppose a State is considering changing the use designation for Segment 30 of a river from fish and wildlife propagation (which is not being attained) to agricultural uses. The need for a sensitivity analysis is demonstrated by the data in Table 5-1, which shows the key elements in the benefit-cost assessment--cost savings and benefits forgone. Uncertainty both in the ultimate size of a new municipal waste treatment plant and in the estimation of the cost savings for the process change at a meat packing plant dictates the bounds for the cost estimates. In this case, the capital cost savings occur in the current year, so they are not affected by the selection of the discount rate.

The estimates of the benefits forgone by the change in designated uses show even more uncertainty. The value of the estimated loss in fishing activities depends on a 5 percent per year increase in fishing expected under the previous designated uses. By varying the assumed increase in fishing activities under the new designated uses, the forgone benefits range from $500,000 per year to $3,000,000 per year. The estimation of forgone swimming activities is based on the assumption that the level of swimming would not change. If adjustments are made for the uncertainty of the assumption, the estimated forgone swimming benefits range from $200,000 per year to $1,250,000 per year. The range of forgone benefits for near-water activities depends on the assumption that no new activities are developed for the river. When this assumption is relaxed, benefits for near-water activities range from $200,000 to $1,500,000.

Step 1: Translate the Benefits and Costs into Present Values

The first step in sensitivity analysis is to translate the benefits and costs into present values to make the net benefit calculation. This example simplifies the calculations by assuming a real rate of 4 percent and a project life of 50 years. Only quantified and monetized benefits are considered in this example, and all capital costs are spent in year zero. The problem, then, is to translate the annual costs and annual benefits that occur each year into their present value equivalents, which requires the use of present value tables. The information needed for using present value (PV) tables is P/A,* 4 percent, 50 years. For the most likely case:

Operating cost savings = P = $1.5 (21.482) = $32.2 million

Total cost savings = 32.2 million plus 8.0 million capital cost forgone, or $40.2 million

Benefits forgone = P = $2.75 (21.482) = $59.1 million

*P/A is a heading found in most present value tables for translating annual costs into their present value equivalents.

Net benefits calculated for the most likely estimate benefits and costs are:

Net benefits = PV benefits forgone - PV cost savings

$18.9 million = $59.1 million - $40.2 million

The assessment of net present value benefits shows the cost savings from the change would be outweighed by the benefits forgone if the most likely estimates are used. Table 5-2 summarizes the results of calculations for the ranges of benefits and costs in addition to the most likely case.

Step 2: Perform Sensitivity Analysis for Discount Rate and Key Assumptions

The sensitivity analysis shown in Table 5-3 describes the bounds for the net benefit estimates, using alternative discount rates and ranges of benefits and costs. Part A of Table 5-3 shows the most likely estimates of net benefits calculated with three different discount rates. Part B of Table 5-3 shows the outcomes that would result for the worst case expected to occur by estimating the cost savings at the lowest end of their range and the benefits foregone at the highest end for three different discount rates. Part C of Table 5-3 presents the estimates that correspond to the most optimistic case, with cost savings at the highest end of their range and benefits forgone at the lowest end of their range.

Step 3: Interpret Sensitivity Analysis

The sensitivity analysis shows that the net present value is sensitive to the discount rate in that the magnitude of the net cost savings estimates vary over a large range. However, changes in the discount rate alone over the range employed are not enough to change the direction of the net benefit assessment. In both the most likely and the worst cases the forgone benefits exceed the cost savings for changing the use designation. Only in the most optimistic case, where the cost savings are at the highest estimate and benefits forgone are at their lowest do the cost savings exceed the forgone benefits.

The recommendation that could be made from the sensitivity analysis is that the change is likely to produce forgone benefits greater than the costs, with only a small chance that the results would be otherwise. To the extent there are effects that cannot be expressed in dollars, this range can also be used to indirectly define what the dollar value of these effects would need to be to change the evaluation. In the determination of the appropriate use classification, the decisionmaker could then weigh this small chance.

5.3 DISPLAYING THE ASSESSMENT RESULTS

This section discusses three methods for displaying the results of a benefit-cost assessment: narratives, arrays or matrices, and graphical displays. Each method is described briefly, along with its advantages and disadvantages.

Table 5-2. Sensitivity Analysis Calculations: Discount Rate at 4 percent

Cost savings, $	Benefits forgone, $
Capital cost: 8.0 million in 1982 Range: 4.2 to 11.0	Recreation: 2.75 per year Range: 0.9 to 5.75 per year
Operating cost: 1.5 per year Range: None	
Present value of operating costs: 32.2 million	Present value: 59.1 million Range: 19.3 to 123.5 million
Present value of total (most likely case): 40.2	Total (most likely case): 59.1
Range of present values of total cost savings: 36.4 to 43.2 million	Range of total benefits forgone for all cases: 19.3 to 123.5 million

Table 5-3. Sensitivity Analysis

Discount rate (%)	Net present value of cost saving minus benefits forgone (million $)
A. Most Likely Levels of Benefits Forgone and Cost Savings	
2	-31.3
4	-18.9
6	-11.7
B. Cost Savings at Lowest Estimate--Benefits Forgone at Highest	
2	-129.4
4	-87.1
6	-62.8
C. Cost Savings at Highest Estimate--Benefits Forgone at Lowest	
2	29.9
4	23.9
6	20.5

Narratives

A narrative uses words to describe the results of an assessment. It can be used to describe either qualitative or quantitative information and is a simple, straightforward approach to displaying the results of an assessment. its main disadvantage arises when there are several types of beneficial and detrimental effects to be weighed in the water quality decision. The evaluation of these diverse benefits and costs may be aided by expressing some of them with numerical estimates of benefits and costs. Combining narrative information with the array method discussed below can ease the comparison of benefits and costs. Examples of narratives used in combination with matrices are shown throughout Chapter 6.

Arrays

An array, or matrix, is a tabular display that contains written and numerical descriptions of the outcomes of an assessment. Arrays are most effective when combined with the narrative display method discussed above. An array organizes information in a simple yet visually effective manner. By including qualitative information, the practitioner can easily describe the nature of the benefits and costs and the degrees of confidence in the estimates of either. If quantitative and monetized information is included, it can be supplemented with descriptions of any benefits and costs that are not monetized or cannot be quantified.

Arrays may be readily adapted to the wide variety of cases likely to be encountered in an assessment of water quality programs. They do not require assumptions about the relationships among the variables presented in the array, and they make it easier for the practitioner to describe relationships known only in various degrees of accuracy. Arrays are particularly well-suited for displaying intangible benefits and costs and are used in both Chapter 2 and Chapter 6 to highlight these issues. Most effective arrays are used to organize information and to display substantive descriptions of the information presented. Arrays that present too much information can be divided into several arrays, but care is required to avoid unnecessary confusion. Inadequate descriptions may be worse because they require that users invest their own time.

Graphs

Graphs are an effective way of presenting information in a benefit-cost assessment, but considerable caution and scrutiny are advised when using them. Graphs can effectively show relationships between two variables, but often the information required to draw them is simply not available. These problems are less important for pie charts and bar graphs but are prevalent for tradeoff curves, which show relationships between two well-defined objectives.

Figure 5-1 presents an example graph that can be used for two well-defined objectives for a reservoir: flood control and recreation. Flood control is measured on one axis in thousand acre-feet of water impounded annually,

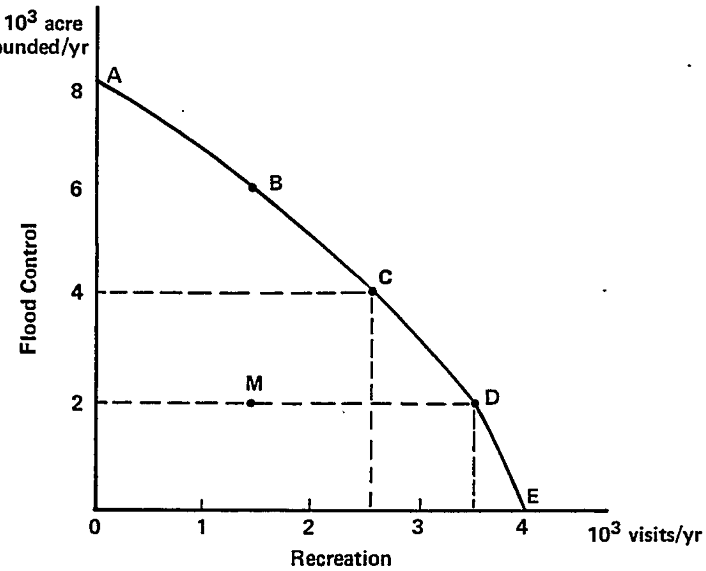

Figure 5-1. Tradeoff curve.

and recreation is measured on the other in visits per year to the site. In this case, the shape of the curve shows that as more of the reservoir is used for a single objective, larger and larger amounts of the other must be given up.

The tradeoff curve shows a frontier of alternative combinations of flood control and recreation that can be attained with a given reservoir in any year. A point inside the frontier, like M, represents an inferior, or less attractive, combination because more recreation can be attained while maintaining at least the same amount of flood control. However, the tradeoff curve provides no information about the relative attractiveness of points such as A through E. All are on the frontier, and society must choose which allocation of the two objectives is most desirable. The extreme points A and E clearly show that substantial amounts of either flood control or recreation must be given up for an exclusive use. However, to know whether they are efficient from society's viewpoint requires that the value of each good be known. The economic principles behind the demand curve (which indicates that people will buy more as price is lowered) imply that there may not be a simple one-to-one relation between extra units of a commodity and the extra value from each unit.

While a useful concept, tradeoff curves are inappropriate in many benefit-cost assessments. Many assessments for water quality policies will involve more than two objectives that would be extremely difficult to express in a simple tradeoff relationship. For example, it is unlikely that suitable quantitative units could be derived to meaningfully express such objectives as enhanced ecological diversity, which may involve complex relationships that can easily confuse the practitioner about tradeoff relationships.

Key Elements	Status of Data for Assessment			
	Not Applicable	Available	Requested	Unavailable
• Results of use attainability assessment				
• Other background on river segment, water quality				
1. Advanced treatment application				
2. Previous standards documents				
• List of benefits				
• List of costs				
• Data on benefits				
– Primary				
1. Recreation survey—State				
2. Recreation survey—U.S. and region				
– Secondary				
1. Published Federal, State, and local studies				
2. Census				
• Data on costs				
– Primary				
1. Engineering studies of treatment costs				
2. Economic cost estimates				
3. Financial cost estimates				
– Secondary				
1. Published Federal, State, and local studies				
2. Financial/investment sources				
• Techniques selected for measuring benefits				
1. Direct survey				
2. Participation survey				
3. Travel cost				
4. Hedonic				
• Techniques selected for measuring costs				
1. Engineering estimates				
2. Computer-assisted modeling techniques				
3. Economic cost estimates				
• List of key assumptions in measuring benefits and costs				
• Discount rate				
• Time horizon				
• Sensitivity analysis				
• Present value of net benefits				
• Assessment of distribution				
• Cost impact assessment				
• Final assessment document				

Figure 5-2. Checklist for a water quality standards benefit-cost assessment.

In summary, tradeoff curves are convenient display techniques but are inappropriate when the objectives are not well defined or easily expressed in quantitative or monetized units. The practitioner should use this technique with a great deal of caution and only when substantial data are available.

5.4 BENEFIT-COST ASSESSMENT CHECKLIST

This section describes a checklist that can be used in organizing a benefit-cost assessment. The example is for a water quality standards case, but the checklist is a general one.

The checklist in Figure 5-2 provides a means of tracking the various steps involved in the assessment process. This checklist can be tailored to fit the needs of each assessment by varying the types of benefits and costs included and by using the columns at the right-hand side of the list. These columns allow the checklist to accommodate the range from simple qualitative to complex quantitative assessments by designating the status of the data required for the assessment. A qualitative assessment can be conducted even with such status categories as “not applicable” and “unavailable.” The complex assessment is made easier when the categories are “available” or “requested.” The larger the “unavailable” category, the more strongly a State should consider using additional resources, either inside or outside State government, to obtain the needed information, especially if benefits or costs are likely to be sizable and if the decision is unclear after a qualitative assessment. For a complex case involving potentially large benefits and costs, the extra value of acquiring the necessary data can be substantial. Data on a specific water body and the use of the techniques described in this handbook can greatly simplify the complex quantitative assessment and assist in evaluating a proposed water quality action.

5.5 SUMMARY

- A sensitivity analysis for key variables and assumptions employed in an assessment is essential for a plausible assessment.

- Sensitivity establishes a range of outcomes possible for the assessment and will show when the assessment is sensitive to its assumptions.

- Three key components of an assessment that will be essential in the sensitivity analysis are the discount rate and estimates of benefits and costs.

- A narrative describes the results of an assessment in words. Its main advantage is its simple straightforward nature, while its disadvantage is in presenting results for more complex assessments.

- Arrays or matrices are tabular displays that contain written and numerical descriptions. Narratives are often combined with the arrays as an effective display technique and are suited for a wide range of assessments.

- Graphs can effectively illustrate relationships between objectives that are quantified or monetized. However, the information necessary for these display techniques is frequently unavailable.

- Tradeoff curves show a frontier of alternative combinations of quantities for two objectives. Caution and scrutiny are advised in using these curves in an assessment because the necessary information is often unavailable or it is impossible to apply to water bodies with a wide range of uses.

- A checklist is one way of organizing the procedures and information in a benefit-cost assessment.

CHAPTER 6

BENEFIT-COST--SAMPLE SCENARIOS

6.1 INTRODUCTION

In water quality programs, the benefit-cost assessment practitioner must evaluate a wide range of policy actions. These could include both minor changes in designated uses for an intermittent stream and major changes in designated uses or in advanced treatment or combined sewer overflow to provide recreation and intangible benefits that require substantial investments by cities and firms. Thus, the framework for evaluating these policy actions must be capable of comparing incremental benefits and costs for a diversity of cases yet provide for a consistency in the application and presentation of the assessment. Even though scenarios are presented only for potential water quality standards decisions, the range of issues is broad enough to be useful to other water quality programs.

To illustrate the type of assessments that might arise in water quality programs, this chapter develops three sample scenarios--simple, medium, and complex. Each scenario is designed to build on the preceding one, as new dimensions are added. Each scenario is introduced by a brief description of hypothetical sample cases. Each scenario refers the reader to the relevant handbook chapter(s) that provide more detailed discussion on specific issues.

Although the step-by-step framework illustrated in the following scenarios is both systematic and flexible enough to accommodate most of the benefit-cost assessment needs of various water quality programs, the values it assigns to benefits and costs should be regarded as approximations rather than absolutes. This note of caution has nothing to do with the framework itself, but with the specific information--e.g., poor quality data on linkages between water quality, fish propagation, and recreational fishing--used to estimate either costs or benefits.

The following sections of this chapter present the three scenarios for benefit-cost assessment. Specifically, Section 6.2 describes a simple case scenario that uses only qualitative information, Section 6.3 presents the medium case scenario, providing some quantitative benefits and costs, and Section 6.4 contains a complex case scenario involving multiple benefits and costs. Finally, Section 6.5 summarizes the key issues in the scenarios.

6.2 SIMPLE CASE SCENARIO

Introduction

The strength of benefit-cost assessment lies in its ability to organize material in a consistent manner yet remain flexible enough to accommodate a wide range of cases. This simple scenario illustrates a qualitative benefit-cost assessment and demonstrates both the consistency and flexibility in this evaluation procedure.

In many water quality applications, the potential benefits and costs do not justify anything more than a qualitative benefit-cost assessment. Although a qualitative assessment does not quantify the information it organizes, it does provide a framework for presenting the character of the individual problem and for describing the judgment employed to make the assessment. For example, water quality standards decisions where qualitative assessment may be appropriate include stream-specific standards, such as the following:

- Public water supply designations for streams that have never been so used or that--because of low cost alternatives--are not likely to be so used in the future. Possible changes include removing the water supply use and adding recreation or agricultural uses that the water supply use might have precluded.

- Primary contact recreation uses for a stream that currently has few access points, as well as water quality limitations. Possible changes include limiting types of recreation or changing uses to accommodate agricultural and industrial activities.

Simple Case Scenario Format

I. Define the Action

A State is reviewing the designated uses for a specific segment of a river currently designated for use as a public water supply, although it has never been used in this capacity, and for primary body contact recreation. The action to be assessed is the removal of the water supply use and the addition of an irrigation use. The segment is located in a portion of the State that produces a substantial amount of agricultural products. The segment is a primary source of water recreation in the area and supports fishing, swimming, and limited boating.

II. Translate the Effects into Beneficial Outcomes and Costs

Although the use change will cause slightly lower levels of dissolved oxygen and small increases in the levels of several other biological and chemical water quality parameters, recreation activities will be unaffected. The primary benefit will be the increase in high-quality water available for irrigation, resulting in cost savings for farmers who presently have irrigated farmland or who will be able to irrigate additional farmland.*

In terms of forgone benefits, the cost of the action is the loss of a potential water supply source. However, groundwater sources exist, and residents are presently using them at lower costs and are expected to continue their use in the future. Nothing (e.g., shortages or contamination) is expected to threaten these groundwater supplies.

III. Calculate the Value of the Beneficial Effects Based on Willingness to Pay

The value of the benefits of the change would equal the farmers' willingness to pay to obtain the water for irrigation rather than do without it. The benefits are expected to be positive on this basis, but not necessarily large because some alternative irrigation supplies exist.

IV. Calculate the Value of the Detrimental Effects Based on Opportunity Costs

The opportunity cost of this action is loss of the potential source of drinking water. The alternative supplies of drinking water make this opportunity cost near zero. If future demand and supply of drinking water should change substantially, the State could reconsider the designated uses because the long-term physical effects on the water will be limited in nature.

V. Compare the Total Benefits and Costs

The benefits of the action, are the amounts the farmers would be willing to pay from this new irrigation source to irrigate their farmland without the action. The costs of the action, however, are zero, because they consist entirely of the lost opportunity for an alternative supply of drinking water, which can be obtained from existing groundwater resources. Thus, the total benefits of the action are greater than the costs. Therefore, the action will provide positive net benefits for the State and country. Recreation activity will be maintained, and cost savings for farmers will be greater than the loss of a potential source of drinking water.

VI. Assess the Plausibility of the Results

The results are not likely to change under almost all possible circumstances. Only if dramatic changes occur in the drinking water situation--i.e., if groundwater supplies become contaminated or suddenly in short supply--would the outcome be different.

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*This particular segment has ample flow but farmers have not been permitted to use if for irrigation. Withdrawal for irrigation will not noticeably affect recreation activities or fish populations.

6.3 MEDIUM CASE SCENARIO

Introduction

As a group, medium cases can be distinguished from simple and complex cases. While simple cases usually require only a qualitative assessment of benefits and costs, medium cases normally involve some quantitative measures of benefits and costs. Further, while medium cases usually involve only one type of benefit--such as recreation--and the application of measurement approaches and results from other studies, complex cases often require development of case-specific measurement approaches.

One practical way to distinguish between simple and medium cases is to conduct the qualitative assessment and then to judge whether it provides enough information for a clearcut decision. If the outcome is not clear, the more quantitative medium case assessment may be needed. Water quality standards decisions that might require medium assessments include the following:

- Fish and wildlife propagation use for a stream that is not being attained because of industrial dischargers. The treatment options are limited to high-cost land-treatment solutions, and the river is not an important recreation source. Change could be to provide for a less restrictive fish and wildlife use or for agricultural/industrial use.

- Fish and wildlife propagation use for a major river tributary with industrial dischargers. A change in designated use to accommodate existing industrial cooling would maintain relatively low levels of dissolved oxygen in a large segment of the river, primarily affecting fishing. The assessment would compare the loss in potential fishing benefits with cost savings to industrial firms.

- Fish and wildlife propagation use for a stream whose hydrological equilibrium has been affected by irrigation. A change in designated use to accommodate agricultural irrigation would cause the loss of a potential warm water fishery in the stream. The assessment would compare loss in potential fishing benefits with cost savings to agricultural irrigation users.

- Attaining a limited warmwater fishery (sunfish, carp, catfish) use for a channelized stream would require an advanced treatment plant for municipal wastes. One change would be to provide roughfish passage. The assessment would compare the loss in potential fishing benefits with the cost of advanced treatment.

Medium Case Scenario Format

I. Define the Action

A State is reviewing the designated uses for a specific segment of a river currently designated for agricultural and industrial use and secondary recreation, primarily boating. The action to be evaluated is a use change to provide a warmwater fishery in addition to other uses. The river segment is capable of sustaining a warmwater fishery if discharges from a municipal treatment plant are reduced to improve the level of dissolved oxygen.

II. Translate the Effects into Beneficial Outcomes and Costs

The effects of the change will be an improvement in dissolved oxygen levels to sustain the warmwater fishery under all flow conditions. This change will provide a new source for smallmouth bass recreational fishing while maintaining the existing uses. The primary cost of the change will be additional treatment of municipal wastes, but advanced treatment is not anticipated.

III. Calculate the Value of the Beneficial Effects Based on Willingness to Pay

A travel cost model can be used to estimate the recreational fishing benefits. These benefits are estimated to be $70,000 per year and are assumed to remain at that level for the next 20 years.* This amount represents fishermen's willingness to pay for the water quality improvement, but does not measure nonuser values or intangible benefits associated with the water quality improvement.

IV. Calculate the Value of the Detrimental Effects Based on Opportunity Cost

The municipal discharger will be required to upgrade the quality of its treatment plant. From engineering estimates, this upgrading is expected to require an initial investment of $500,000 but no increases in operating expenses. There will be a small economic impact on households who pay for the treatment services. (See Chapter 4 for details on measuring costs.)

V. Compare the Total Benefits and Costs

To compare them, benefits and costs must be converted into present values. Costs incurred in the present year are already in present value terms ($500,000), but the benefits must be converted into a present value equivalent from a stream of annual dollars over 20 years. Using a social rate of time preference as presented in Chapter 2, these benefits are discounted

*See the complex scenario for the use of a travel cost model to estimate recreational fishing benefits. The results are summarized for the medium case to minimize duplication among the scenarios. See Chapter 3 for general discussion of the travel cost approach.

at 2 percent for a total 20-year value of $1,148,000. Thus, total benefits resulting from the change are $1,148,000, and total costs are $500,000, resulting in a positive net benefit of $648,000. Adding the new use will therefore provide benefits in excess of the required investment costs.

VI. Assess the Plausibility of the Results

The key element influencing the sensitivity of this scenario is the selection of the discount rate. To determine the plausibility of the results, net benefits should be calculated with different discount rates and compared. Chapter 2 recommended a high estimate of 5 percent for the, social rate of time preference, and the Office of Management and Budget (OMB) requires the use of 10 percent for major regulations. Net benefits calculated with these rates are listed below.

Discount rate (percent)	Net benefits ($)
2	648,000
5	372,340
10	95,980

As indicated, the use change would produce positive net benefits under any of the three discount rates, implying that benefit estimates are not sensitive to the discount rate selected. Sensitivity analyses also may be performed for the estimates of benefits and costs--for example, with benefits and costs estimated at ±30 percent of the average value. More details on using sensitivity analysis are provided in Chapter 5.

In assessing the plausibility of the results one might also consider the distribution effects discussed in Chapter 2. In this sample case these effects are an inconsequential part of the assessment because no one group is adversely affected. However, distribution effects vary from case to case and should be addressed.*

6.4 COMPLEX CASE SCENARIO

Introduction

The complex case scenario is distinguished from the simple and medium case scenarios by several characteristics, including its consideration of multiple types of tangible benefits, intangible benefits, and investment in waste treatment beyond the technology-based requirements. In addition, benefits and costs in complex cases are likely to be an order of magnitude, or more, above those in medium cases. In fact, if benefits and costs are not signifi-

*The complex scenario that follows provides a detailed assessment of distribution effects.

cantly greater than those of the typical medium case scenario, use of the complex case scenario is not recommended because the effort it requires would not be justified.

Measurement and valuation of benefits and costs may require several methods discussed in Chapters 3 and 4. The types of benefits and costs, data availability, and available staff resources will influence the level of detail in the assessment. For controversial decisions, a State may decide to obtain assistance from outside the agency to conduct the assessment.

Complex cases may include the following:

- Adding fish and wildlife propagation and primary contact recreation use designations for a stream that will require advanced treatment for municipal discharges. Benefits will include multiple types of recreation activities, intangible benefits such as enhanced ecological diversity, and nonuser benefits. Costs will include investments by firms in waste treatment beyond investment required for technology-based requirements.

- Providing public water supply from a stream that will require advanced treatment for municipal wastes. Water supply benefits could be for more than one downstream municipality.

Complex Case Scenario Format

I. Define the Action

A State is reviewing the designated uses for a 10-mile segment of River 1, located between Cities A and B. The river is currently designated for secondary contact recreation, but the State is considering adding swimming and fish and wildlife propagation. These uses cannot be attained by imposing the technologies required under the Clean Water Act (Section 301(b)(2)), but they could be attained with more stringent controls on municipal and industrial point dischargers.

River 1 drains an area of 7,386 square miles, and most of its length is characterized by steep banks and rugged terrain. The major point sources of discharges on the river segment of interest are iron and steel facilities and a municipal sewage discharge just outside City B and upstream from City A.

The river is navigable the entire year, and a considerable amount of coal is barged through several locks and dams operated by the U.S. Army Corps of Engineers. River 1 is currently used for boating recreation and for activities near water at several parks located along its banks. The most notable water quality problems limiting swimming and fish and wildlife propagation have been associated with the dissolved oxygen and ammonia levels, with frequent violations of current standards at low flow.

II. Translate the Effects into incremental Beneficial Outcomes, Costs, and Economic Impacts

A. Benefits

- Recreational fishing
- Swimming
- Activities "near water"
- Navigation
- Ecological diversity
- Nonuser/nonuse benefits.

B. Costs

- Capital and operating costs for steel plants
- Capital and operating cost for City B

C. Distributional Impacts

- Reduced profitability of steel plants
- Effects on operations (will shutdowns occur?)
- Increased sewer charges for municipal taxpayers
- Employment
- Price
- Impact on firms within industry

III. Calculate the Value of Beneficial Outcomes Based on Willingness to Pay

A. Recreational Boating Benefits

Step 1

Determine what data are available for recreation on or near River 1. Likely sources include the State recreation plan, the EPA 208 management plan, the 1977 Department of Interior outdoor recreation survey, and the U.S. Army Corps of Engineers.

Step 2

Use the Corps of Engineers recreation survey data on River 1, which contains information on users and where they are from. This information will allow estimation of recreation benefits with the simplest version of the travel cost model. (See Chapter 3 for more details on travel cost models.)

A number of implicit assumptions are used in this scenario. For example, the State is assumed to have the information necessary to estimate the current and potential demand for fishing and swimming for River 1. The simplest measure of travel cost is used even though it excludes the cost of travel time, time spent onsite, and the influence of substitute sites on the demand for River 1 recreation. Also assume that the travel cost to the site is capable of capturing all the factors that influence the decision to fish or swim along the river. This implies that no changes in access, docks, and other site features are occurring. (See the case study of the travel cost model in Chapter 3.)

Equation (6.1) illustrates the travel cost demand equation for these assumptions. The equation omits several origin-specific variables (such as income, age, education, etc.) that determine recreational demands for a site because they would only change the position of the demand curve for each origin zone. The subscript i refers to these omitted variables:

$$\frac{V}{POP_i} = f_i(TC_i, A) \quad , \tag{6.1}$$

where

A = activities that would be permitted by the water quality use classifications (A = B for boatable, F for fishable, S for swimmable),

V_i = number of visits to the site from origin zone i, and

POP_i = population of origin zone i.

Step 3

Calculate recreation benefits for existing water quality level. These calculations are needed to obtain the baseline and must be netted out from the benefits of the additional use designations. Use the data in Table 6-1 to estimate travel cost model. Remember: these are user benefits only.

Table 6-1. Demand for Recreation for River 1--Water Quality at Level Suitable for Boating

Limits of zone of origin (miles)	1980 population (1,000)	Total No. party visits	Visits per 1,000 population	Consumer surplus per individual ($)
1 to 20	1,000	1,650,000	1,650	2.40
21 to 40	1,500	600,000	400	1.80
41 to 60	2,000	200,000	100	1.40
61 to 80	2,500	50,000	20	1.00
81 to 100	3,500	25,000	7	0.60
100+	5,000	2,500	0.5	0.20

Calculation of Benefits

$$\text{Benefits} = \sum_{i=1}^{n} POP_i \int_{TC_i}^{TC_i^*} f_i(p_i, B)dp_i \qquad (6.2)$$

Benefits = (number of individuals) x (benefits per individual)

where

TC_i^* = the travel cost at which there would be a zero visit rate, and

TC_i = travel cost for ith origin zone.

Figure 6-1 illustrates the consumer surplus estimates that result from this calculation. Two assumptions are implicit for the estimation. First, as with XYZ in Figure 6-1, calculate the representative individual's consumer surplus in an origin zone, and then assume that all individuals in the origin zone have the same consumer surplus. This procedure is possible because use (i.e., the visit measure) is considered to arise from the population as a whole. (The calculation would be different for travel cost models estimated from survey data. See Chapter 3 for specifics.)

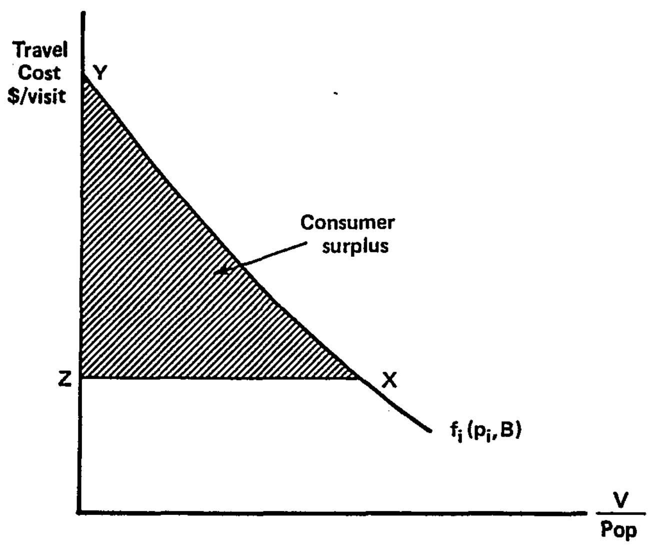

Figure 6-1. Travel cost demand function and consumer surplus with boatable water.

For example, in Table 6-1, the fifth column reports an example of the estimated individual consumer surplus by origin zone. Multiplying each consumer surplus times the population and adding across origin zones gives the aggregate consumer surplus for the site with boatable water:

$$\text{Benefits for Boatable Water, 1980-81} = \sum_{\text{zone } i=1}^{6} \text{population} \times (\text{consumer surplus per individual})$$

$$= \$(\underbrace{1{,}000{,}000 \times 2.40}_{\text{Zone 1}} + \underbrace{1{,}500{,}000 \times 1.80}_{\text{Zone 2}} + \underbrace{2{,}000{,}000 \times 1.40}_{\text{Zone 3}}$$

$$+ \underbrace{2{,}500{,}000 \times 1.00}_{\text{Zone 4}} + \underbrace{3{,}500{,}000 \times 0.60}_{\text{Zone 5}} + \underbrace{5{,}000{,}000 \times 0.20}_{\text{Zone 6}})$$

$$= \$(2{,}400{,}000 + 2{,}700{,}000 + 2{,}800{,}000 + 2{,}500{,}000$$

$$+ 2{,}100{,}000 + 1{,}000{,}000)$$

Benefits for Boatable Water = $13.5 million for the site with current water quality levels.

B. Recreational Fishing Benefits

Step 1

Use the results on fishing benefits in the Monongahela River study (see travel cost case study, Chapter 3, for details). The results from the Monongahela study can be used to calculate benefits analogous to those reported in Table 6-2. Note: practitioners might consider three questions in determining the plausibility of results: What similarities exist between River 1 and the Monongahela River? What are the problems in adapting the results? How significant are they?

Table 6-2. Demand for Recreation for River 1--Water Quality at Level Where Gamefish (Bass) Can Live in River

Limits of zone of origin (miles)	1980 population (1,000)	Total No. party visits	Visits per 1,000 population	Consumer surplus per individual ($)
1 to 20	1,000	3,400,000	3,400	0.10
21 to 40	1,500	1,500,000	1,000	0.10
41 to 60	2,000	800,000	400	0.10
61 to 80	2,500	500,000	200	0.10
81 to 100	3,500	350,000	100	0.10
100+	5,000	50,000	10	0.10

[a]These calculations assume a parallel shift in demand. It need not be parallel in particular applications (see travel cost case study, Chapter 3).

Step 2

For this framework, the travel cost model provides the relationship between the demand for the recreation site and the water quality use designation. Thus, an improvement in water quality from boatable (B) to fishable (F) can be expected to shift the demand for the site's services. This conclusion follows from the site's ability to support both types of recreational activities under the higher designated use. Figure 6-2 illustrates the type of shift involved.

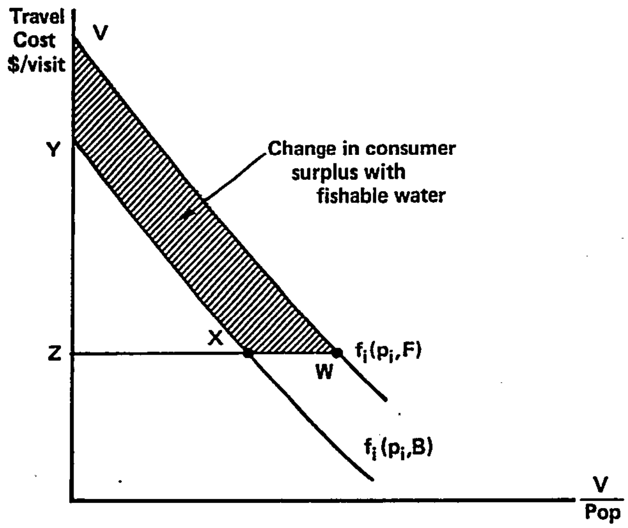

Figure 6-2. Travel cost demand function and change in consumer surplus with fishable water.

To calculate the incremental benefits associated with this change in use designation, we need to estimate YXWV. In terms of the travel cost demand model, YXWV would be given as:

Benefits (incremental to fishable) =

$$\sum_{i=1}^{n} POP_i \int_{TC_i}^{TC_i^{**}} f_i(p_i, F)dp_i - \sum_{i=1}^{n} POP_i \int_{TC_i}^{TC_i^{*}} f_i(p_i, B)dp_i \quad . \quad (6.3)$$

The second term in Equation (6.3) simply repeats the benefit estimate for the site with the existing designation which allows boating. Thus, the increment to benefits because of the change in water quality is being calculated. This example assumes that individuals from the same origin zones are using the site, and no users from new origin zones so Equation (6.3) can be rewritten as the sum of the increments to the individual benefits realized in each origin zone, as in Equation (6.4):

$$\text{Benefits for increment to fishable water} = \sum_{i=1}^{n} POP_i \left[\int_{TC_i}^{TC_i^{**}} f_i(p_i, F)dp_i - \int_{TC_i}^{TC_i^{*}} f_i(p_i, B)dp_i \right] \quad (6.4)$$

number of individuals x increment to each individual's benefits from use designation

For the representative individual, this increment is YXWV in Figure 6-2.

Table 6-2 reports some illustrative increments in the fifth column, and the calculation process is then similar to that described above:

$$\text{Benefits for Increment to Fishable Water, 1980-1981} = \sum_{i=1}^{6} \text{visits x travel costs}$$

$$= \$(\underbrace{1,000,000 \times 0.10}_{\text{Zone 1}} + \underbrace{1,500,000 \times 0.10}_{\text{Zone 2}} + \underbrace{2,000,000 \times 0.10}_{\text{Zone 3}} + \underbrace{2,500,000 \times 0.10}_{\text{Zone 4}} + \underbrace{3,500,000 \times 0.10}_{\text{Zone 5}} + \underbrace{5,000,000 \times 0.10}_{\text{Zone 6}}$$

= $(100,000 + 150,000 + 200,000 + 250,000 +

350,000 + 500,000)

Benefits for increment to fishable water = $1.6 million per year.

C. Swimming Benefits

Step 1

Use the results on swimming benefits in the Monongahela River study (see travel cost case study, Chapter 3, for details) to calculate information such as that in Table 6-2.

Step 2

To calculate the benefits from swimming use, the frame of reference must be defined. Specifically, which incremental benefits are of more interest--those associated with moving from a fishable to a swimmable use designation, or those associated with moving from boatable to swimmable? The method used to estimate these incremental benefits will depend on the reference point. For example, in Figure 6-3, which shows all three demand functions, movement from fishable to swimmable leads to incremental benefits (per individual) of VWUT. A change from boatable to swimmable includes this increment along with the increment associated with the improvement to fishable (YXWV).

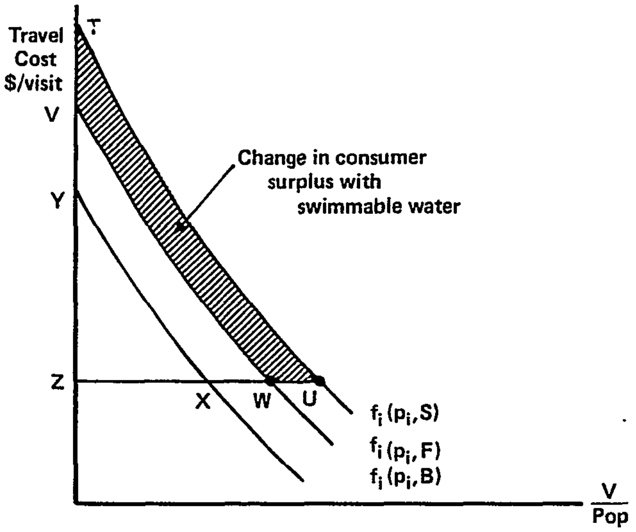

Figure 6-3. Travel cost demand function and change in consumer surplus with swimmable water.

The calculations would follow the same outline used in the preceding two examples. Important in this case is the point of reference used to calculate the incremental benefits. If procedures from previous section are followed:

Benefits for the increment from fishable to swimmable water = $750,000.

D. <u>Recreational Benefits of Activities Near Water</u>

Improvements in water quality will make additional acres usable for activities near River 1, including, for example, hunting, birdwatching, hiking, photography, and sightseeing. This example shows what can be done to estimate the benefits when demand information is not available. In particular, a participation model can be used to predict the increase in recreation activities near water and a recreation day value estimate can be used from other sources. (See participation survey case study, Chapter 3, for details.)

An important issue that arises with this approach is the consistency of benefits derived from the travel cost model with those from the participation model. Specifically, the travel cost model describes the demand for recreational site services which can be used in a variety of recreational activities, including those “near water." Since the participation model for predicting demand for recreation near water may be measuring benefits reflected in the travel cost model, some double counting can occur.

The following five steps can be used to estimate the value of the increase in near-water activities.

<u>Step 1</u>

Determine the availability of data on activities near water for River 1.

Step 2

Estimate the increase in near-water activities resulting from the fish and wildlife propagation use designation. Analysis of River 1 determined that 8,931 acres along the river are currently suitable for these activities. Achieving the use designation was predicted to make another 2,700 acres suitable for near-water activities and to improve the recreational facility rating by 1 unit (on a scale of 1 to 5).

Step 3

Estimate the change in the probability of participation (ΔP) in the near-water activities among the population as a result of the improvements. Using a model (see Chapter 3, participation survey case study for details) that correlates participation in near-water activities with available water recreation area and a rating of the recreational facilities, the increased probability of participation can be calculated as:

$$\Delta P = 0.38485 \left(\begin{array}{l}\text{change in acreage of recreation} \\ \text{water available per capita}\end{array}\right) + 0.03142 \left(\begin{array}{l}\text{change in recrea-} \\ \text{tional facility rating}\end{array}\right)$$

$$\Delta P = 0.38485 \left(\frac{2{,}700 \quad \text{new acres}}{2{,}000{,}000 \ \text{population in Cities A and B}}\right) + 0.03142 \left(\begin{array}{l}\text{1 unit improvement in} \\ \text{recreational facility} \\ \text{rating}\end{array}\right)$$

$$\Delta P = 0.0319.$$

Step 4

Estimate the change in participation days attributable to River 1 between Cities A and B. Specifically, using the national average of 2.0 near-water activity days per participant per year, additional near-water activity days can be calculated as:

$$\text{Change in near-water activity days} = \left(\begin{array}{l}\text{change in} \\ \text{probability} \\ \text{of near-water} \\ \text{participation}\end{array}\right) \left(\begin{array}{l}\text{Regional} \\ \text{population} \\ \text{Cities A} \\ \text{and B}\end{array}\right) \left(\begin{array}{c}\text{Near-water} \\ \text{days per} \\ \text{participant}\end{array}\right)$$

$$= (0.0319) \times (2{,}000{,}000) \times (2.0)$$

Change in near-water activity days = 127,600/year.

Step 5

Estimate the value of additional near-water activity days. Researchers have estimated values per near-water activity day to range from $12.00 to $18.50 (Volume II will provide more details on these values). Multiplying these values by the number of additional near-water activity days gives the following range of values for the additional activities:

(12.00/near-water activity day)(127,600 days) = $1.5 million

(18.50/near-water activity day)(127,600 days) = $2.4 million

Note: Remember the limitations of this approach:

1. The valuation step is not based on willingness to pay.

2. Limitations are caused by transferring the model from one study to another.

E. Benefits of Improved Ecological Diversity

Attaining the fish and wildlife propagation use designation also means enhanced ecological diversity of River 1 between Cities A and B. These benefits are not quantifiable at the present time but would include more diverse flora and fauna, enhanced diversity of fish species, and other related elements. Note: These benefits will be listed in the policy array as "positive nonquantifiable" (see Chapter 2 on intangible benefits), allowing the decision-makers to better focus on these questions. In some cases, in fact, it may be possible to list specific species that the new use will add or preserve.

F. Benefits of Improved Navigation

Although achieving the designated use may also benefit navigation in River 1, indications are that the magnitude of these benefits is negligible. Thus, no attempt will be made to quantify them (see Chapter 3 on measuring benefits to firms).

G. Nonuser/Nonuse Benefits

In addition to recreation in or near the water by current users, intrinsic benefits--option values, existence values, and aesthetics--may account for important benefits of improved water quality. Option value refers to the value current and potential users place on having the option to use the water resource at some future time. This value is assigned to the resource because there is some uncertainty regarding its future availability or regarding future demand. Existence benefits are measured by the value people place on actions that ensure a resource is (or will be) there, regardless of their actual or potential use. This is sometimes termed vicarious enjoyment or attributed to a bequest motive. Aesthetics refer to beauty that may be appreciated by users and/or those who reside or travel nearby.

Many unresolved issues exist concerning the inclusion and valuation of intrinisic benefits. For example, there is not yet any agreement on whether aesthetics should be included in intrinsic benefits or measured separately or indeed, whether they be measured at all. Thus, intrinsic benefits are included in this assessment as “positive not quantified” (see the contingent valuation case study in Chapter 3, which highlights an approach for quantifying and monetizing these benefits.)

H. Estimate Benefits That Will Accrue in Future Years

Assume that River 1 recreation benefits will remain constant for the 25-year lifetime used for the analysis. This is probably a conservative assumption because, with visit rates staying the same, any population growth in the area would lead to more recreation (unless congestion becomes a problem). This growth is offset, however, by other important factors such as the influence of substitute sites that are excluded from the estimation models. Thus, each benefit estimate can be considered to be a constant stream over the project lifetime.

IV. Value the Detrimental Effects Based on Opportunity Costs and Calculate Economic Impacts

A. Calculate Increased Capital and Operating Costs for Model Steel Plant

Step 1

Determine availability of data sources (see Chapter 4 for details on likely sources of cost data).

Step 2

Use the model plant technique discussed in Chapter 4 along with the wasteload allocation to estimate the capital costs of achieving the fish and wildlife propagation use designation. A related study of pollution controls for steel plants suggests that the technologies shown in Table 6-3 will be needed to meet the regulation. Two steel plants correspond closely with the model plants; two are about 3/4 the size assumed for the plant; and 1 plant is 1-1/4 times larger than the model plant. Table 6-4 shows capital cost estimates for these plants.

Table 6-3. Capital Equipment and Cost for Model Plant to Meet Regulation

Capital equipment	Cost (million $)
Wastewater discharge treatment pond	1.2
Water integrated flow system	1.6
Pretreatment and handling system	1.2
5 segments 30" piping	2.0
Total	6.0

Step 3: Calculate Operating Costs

Assume for the model plant analysis that operating costs are roughly 0.05 of capital costs per year for the life of the plant, regardless of the size of the plant. Using this estimate and the capital costs from Table 6-4, calculate:

Table 6-4. Estimated Capital Costs

	Number of plants	Percent of model plant	Total estimated capital cost (million $)
	2	0.75	9
	2	1.00	12
	1	1.25	7.5
Total	5		28.5

Operating costs/year = 0.05 x $28.5 million = $1.4 million/year.

The problem of converting costs into comparable measures is addressed in Chapter 4.

B. Calculation of Capital and Operating Costs for City B

To meet the requirements of the designated use of fish and wildlife propagation, City B will have to add an advanced waste treatment plant for its sewage wastes. Capital and operating costs can be calculated using the model plant method for advanced waste treatment (see Chapter 4).

Step 1

Determine availability of data on costs of advanced treatment plants (see Chapter 4 for details on availability of data on advanced treatment plants).

Step 2

Determine additional capacity needed for the advanced waste treatment plant. Assume that the facility is to provide for maximum daily flow equal to two times expected average daily flow. (This information would come from a City B sewer study, for example.) The additional advanced waste treatment capacity required is 60 Mgal/d.

Step 3:

Table 6-5 shows the capital cost estimate resulting from the model plant approach.

Table 6-5. Cost of Treatment Plant, City B

Plant capacity	Capital cost
60 Mgal/d	$5 million

Step 4

Use the model plant to estimate operating costs. Based on other studies 10 percent of capital costs can be used to represent operating costs for City B:

Operating cost = Capital cost x operating cost factor

$500,000/yr = 5 million x 0.10.

C. Perform Plant Closure Analysis to Assess Impact of Regulation on Plant Operations

The plant closure test provides a straightforward assessment of the impact of the regulation following the rules of thumb referred to in Chapter 2 for plant closures. There is considerable uncertainty involved in actual plant closure decisions, so this appraisal will give a benchmark rather than a complete determination of plant closures.

Step 1

Determine data availability (see Chapter 2 and Chapter 4 on financial data sources that are needed for this test).

Step 2

Determine opportunity cost of capital and average liquidation value to the two steel companies that own the five steel plants along River 1. Use these estimates in the following formula to determine the critical rate of return for closures:

Average liquidation value (m) x opportunity cost of capital (r)
= critical rate of return for closure

American Steel: m x r = critical rate of return

0.50 x 5 percent = 2.5 percent.

Riverton Steel: m x r = critical rate of return

0.60 x 6 percent = 3.6 percent.

Step 3

Compare critical rate of return with plant's rate of return on replacement cost with the regulation to determine potential closure candidates:

American Steel: Rate of return vs. critical rate of return

5.0 percent vs. 2.5 percent.

Riverton Steel: Rate of return vs. critical rate of return

4.8 percent vs. 3.6 percent.

Based on this simplified test using rules of thumb, there are no closure impacts. If closure were indicated, more detailed calculations and data would be needed to assess the issue more thoroughly. Volume II will address these more detailed comparisons.

D. Perform Profit Reduction Test

Another test to assess the magnitude of the impact of the regulation on companies is the profit reduction test. A simplified version of this test is illustrated below.

Step 1

Determine available data (see Chapter 2).

Step 2

Estimate reduction of profits as a percent of current dollar returns for the two steel companies:

American Steel: 5 percent reduction in current dollar returns.

Riverton Steel: 8 percent reduction in current dollar returns.

These reductions are both relatively small impacts, so no additional calculations are needed.

E. Determine Impact on Households in City B

Another issue in the impact assessment is who bears the cost of advanced treatment. Issues that will need resolution include the following:

- Does City B receive EPA assistance for the advanced treatment plant? If so, the citizens of City B and all U.S. taxpayers bear the cost impacts. If not, only residents of City B bear them.

- Will future costs be incurred by the residents of City B when these costs are passed along?

For purposes of illustration, no advanced treatment assistance from EPA is assumed.

Step 1

Determine available data (see Chapter 2 on municipal waste treatment cost impacts for more on available data).

Step 2

Determine impact of increased cost on residents of City B. Sewage costs will increase an average of $15 per year per household for residents of City B.

V. Compare Total Benefits and Costs

A. Check for Less Than Fully Employed Resources

Volume II will present guidelines on determining whether money costs overstate true social costs due to the presence of significant unemployed resources. Assume the review shows that unemployment equals 5 percent in both City A and City B and that a major percentage of materials comes from outside the area. There are no problems with overstating costs in this case.

B. Discounting Benefits and Costs

This is a crucial step in the process of assembling the benefit-cost assessment. There are several key steps to be performed (see Chapter 2 for detailed treatment of these steps).

Step 1

Select discount rate for converting future benefits and costs into present values. OMB guidelines for regulatory impact analyses recommend a real discount rate of 10 percent. This seems high for a real rate that reflects either the opportunity cost of capital or society's preferred rate. Thus, a range of rates should be used, with 10 percent on the upper end, and the sensitivity of results should be compared to the discount rate. A social rate of time preference procedure suggested in Chapter 2 is illustrated in Step 2 below.

Step 2

Discount annual monetized benefits into present values.

Annual Monetized Benefits

	million $
Fishing	1.55
Swimming	0.75
Near water	1.5 to 2.4
Total	3.8 to 4.7

Since the benefit amounts are constant across time periods, to convert monetized annual benefits into present value equivalents, use the following formula. It calculates the present value (P) of a stream of annual benefits (A) for n years (assumed project life is 25 years) and interest rate (i):

$$P = A \left(\frac{1 - \frac{1}{(1 + i)^n}}{i} \right) .$$

Table 6-6 shows the present values of benefits calculated with discount rates ranging from 2 to 10 percent. Monetized benefits range from roughly 35 to 92 million 1981 dollars.

Table 6-6. Present Value of Benefits

Discount rate (percent)	Present value of benefits (million $)
2	74.2 to 91.8
4	59.4 to 73.4
6	48.6 to 60.1
10	34.5 to 42.7

Step 3

To simplify matters, assume that all the capital costs are incurred in 1981, so that they are already present values. Based on the Lind procedure, these displaced private investments by the steel companies are multiplied by the shadow price of capital--1.9. The capital costs for City B treatment plant are assumed to displace consumption (so they do not need adjusting by the shadow price of capital).

The next task is to translate the stream of operating costs into a present value equivalent. The operating costs are assumed to be displaced expenses for the firm and therefore do not require adjustment by the shadow price of capital. These expenses represent displaced consumption and are discounted at the social rate of time preference. This can be done with the same formula as above:

$$P = A \left(\frac{1 - \frac{1}{(1 + i)^n}}{i} \right) ,$$

where A is now a constant stream of annual operating costs. Table 6-7 shows the present value of operating costs calculated with the same range of discount rates used in the benefits calculation.

Table 6-7. Present Value of Operating Costs

Discount rate (percent)	Present value of operating costs (million $)
2	37.1
4	29.7
6	24.3
10	17.2

Table 6-8 shows the present value of total project costs, which range from 76 to 96 million 1981 dollars.

Table 6-8. Total Project Costs

Discount rate (percent)	Capital[a]	Operating	Total (million $)
2	59.2	37.1	96.3
4	59.2	29.7	88.9
6	59.2	24.3	83.5
10	59.2	17.2	76.4

[a]Private capital costs of the steel companies are adjusted by shadow price of capital.

Note: Even if EPA assistance is received for plant construction, the society still incurs roughly the same costs because these EPA funds would be diverted from their next best alternative use. There would perhaps be some difference because Federal and local dollars might have different forgone opportunities, but the difference is probably minor for purposes of this assessment.

Table 6-9. Benefits and Costs of Attaining Fish and Wildlife Propagation Use Designation

Cost/benefits	Quantity	Monetary value (million $)
Benefits		
Recreation (fishing, swimming, near water)	Not quantified	35 to 92
Enhanced ecological diversity	Not quantifiable	Not monetizable
User/nonuse--intrinsic benefits to users and nonusers	Not quantified for this study	Not monetized for this study
Costs		
Capital and operating (Firms; City B)	Not relevant	76 to 96
Environmental	None	0

VI. Assess the Plausibility of Total Benefits and Costs

To assess the plausibility of benefits and costs, construct an array and compare them. For example, Table 6-9 is an array showing both the benefits and the costs of attaining the fish and wildlife use designation. The ranges of monetized benefits and monetized costs overlap, nonmonetized benefits are positive, and there are no nonmonetized costs. The upper end of the monetized benefits is slightly less than the upper end of the range of monetized costs. The lower end of the monetized benefits is considerably less than the lower end of the cost range. Thus, the use designation decision would have to consider whether the intrinsic benefits and nonquantified, enhanced ecological diversity are greater than the difference between lower benefits and cost bounds. When the suggested 2 percent social rate of time preference is used, the monetized benefits are approximately equal to costs.

Table 6-10 shows expected benefits from the use designation change and their distribution among area residents and visitors. In some instances, describing the distribution of benefits among more narrowly defined groups may be desirable. For example, assessments involving a river segment that forms the boundary between two States may require more precise distribution information because the political issues are more complex when more than one State is involved.

Table 6-10. Distribution of Benefits and Costs

Benefit/cost	Distribution
Recreation	Users of River 1--primarily recreators from City A and City B
Enhanced ecological diversity	To some extent same as above, but probably accrues to society as a whole including future generations.
Nonuse/nonuser benefits	Residents of river basin. Visiting recreators who have bequest motive for future generations.
Navigation	Shippers, boat owners, purchasers of materials shipped along river. Small magnitude in this study.
Increased operating and capital cost for steel plants	American and Riverton stockholders to the extent the costs are not passed on to customers. Given the elasticity of demand for steel and market shares of these firms, some costs will be passed on to users of steel products. U.S. taxpayers may also bear some costs because of special depreciation treatment for pollution control expenditures.
Capital and operating costs of advanced treatment plant	$15 per user of water and sewer service in City B. This may be lower if construction grant is obtained; then U.S. taxpayers will share in the burden.

To gain additional perspective on the distribution of benefits and costs, the breakdown of recreational benefits by different income groups is shown below:

Income ($)	Benefits (percent)
0 to 10,000	15
10,000 to 20,000	25
20,000 to 30,000	35
30,000 to 40,000	20
40,000+	5

In this example, 75 percent of the benefits accrue to households with incomes of less than $30,000/year. Decisionmakers may view this use change as more desirable because of its larger share of benefits going to low and middle income groups.

The expected costs of the programs also are arrayed in Table 6-10. The basic economic principle underlying the distribution of the industrial operating and capital cost is the responsiveness of demand for the industry's or firm's products--the larger the responsiveness of quantity demanded to price changes, the smaller will be the ability of the firm or industry to pass along cost increases to its customers. The stockholders, workers, and other resource suppliers to the firm will have to bear the cost increases that are not passed along through lower dividends or reduced wages. For the steel firms in this example, the degree of sales responsiveness to price changes will be influenced by their share of the market, the demands for products which use the type of steel produced, competition from foreign sources of steel, and competition from substitutes (aluminum).

The municipal waste treatment costs likely will be borne by the residents of City B. Residents will include current residents and future residents who move, or are annexed, into the city's water or sewer service system. If the city receives a Federal construction assistance grant, then the largest share of the capital costs is distributed among a much larger group--the Federal taxpayers.

This example shows how distribution issues are integrated with the other steps in the assessment process.. They are described and listed but do not affect the measurement of either benefits or costs. Finally, the exact nature of the distribution descriptions will depend on the complexity of the issues in the assessment itself.

6.5 SUMMARY

- The strength of benefit-cost assessment is its ability to consistently organize information for a wide range of applications.
- Qualitative assessments, using primarily descriptive information, are sufficient in many water quality applications because of the sizes of potential benefits and costs.
- Defining the water quality action to be evaluated in the benefit-cost assessment determines the baseline and suggests the level of complexity in the assessment.
- Translating effects of a water quality action into beneficial outcomes and costs requires an understanding of the linkages between each element.
- Valuing beneficial effects should be based on individual's willingness to pay for them.
- Valuing detrimental effects should be based on opportunity cost to society of the effects.

- Comparing total benefits and total costs may involve qualitative, quantitative, or monetized information.

- Assessing the plausibilty of benefits and costs may involve testing the sensitivity of assumptions made in estimating benefits and costs, or in selecting a discount rate.

- Describing the distribution of benefits and costs may provide valuable data for the decisionmaker.

CHAPTER 7

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