

**Assessing the Benefits of
Drinking Water
Regulations : A Primer
for Stakeholders**

OGWDW (Mail Code 4607M)

EPA

www.

April 2002

ACKNOWLEDGMENTS

This report was developed as a joint product of EPA's Office of Ground Water and Drinking Water and National Center for Environmental Economics. Representatives from many different offices within EPA reviewed and provided insightful comments on earlier drafts of this report. In addition, the discussions of the Benefits Working Group of the National Drinking Water Advisory Council helped shape its content.

This document is intended to provide information on the process currently followed by EPA when assessing the benefits of drinking water regulations. It is not intended as guidance.

Table of Contents

ACKNOWLEDGMENTS	i
OVERVIEW	Overview-1
INTRODUCTION	CHAPTER ONE
1.1 Types of Benefits	1-2
1.1.1 Water Supply Life-Cycle	1-2
1.1.2 Major Benefit Categories	1-4
1.2 Use of This Report	1-7
REQUIREMENTS FOR ECONOMIC ANALYSES	CHAPTER TWO
2.1 The Safe Drinking Water Act	2-1
2.1.1 MCL Development Process	2-2
2.1.2 Benefits Assessment	2-5
2.1.3 Comparison of Benefits to Costs	2-6
2.2 General OMB and EPA Guidance	2-6
2.2.1 OMB Guidance Under Executive Order 12866 ...	2-6
2.2.2 EPA Guidelines For Economic Analyses	2-8
2.3 Requirements Related to Impacts on Government and Business Units	2-9
2.3.1 The Unfunded Mandates Reform Act (UMRA) ..	2-10
2.3.2 The Small Business Regulatory Enforcement Fairness Act (SBREFA)/Regulatory Flexibility Act (RFA)	2-11
2.4 Requirements Related to Impacts on Subpopulations ...	2-13
2.4.1 Environmental Justice	2-13
2.4.2 Children's Health	2-14
2.5 An Integrated Approach	2-16

METHODS FOR BENEFITS ANALYSES CHAPTER THREE

3.1 The Economist's Perspective 3-2
 3.1.1 Willingness to Pay 3-2
 3.1.2 Equity Considerations 3-5
 3.1.3 Nonquantified and Nonmonetized Benefits 3-6

3.2 Primary Valuation Methods 3-7
 3.2.1 Contingent Valuation and Other
 Stated Preference Methods 3-9
 3.2.2 Wage-Risk Studies 3-12
 3.2.3 Cost-of-Illness Studies 3-13
 3.2.4 Averting Behavior Studies 3-14
 3.2.5 Avoided Cost Studies 3-18

3.3 Methods for Valuing Mortality,
Morbidity, and Other Effects 3-19
 3.3.1 Valuing Mortality Risk Reductions 3-19
 3.3.2 Valuing Morbidity Risk Reductions 3-25
 3.3.3 Valuing Other Benefits 3-27

CONDUCTING BENEFIT TRANSFERS CHAPTER FOUR

4.1 Implementation Steps 4-2
 4.1.1 Step 1: Describe the Policy Case 4-3
 4.1.2 Step 2: Identify Existing Relevant Studies 4-5
 4.1.3 Step 3: Review Existing Studies for
 Quality and Applicability 4-6
 4.1.4 Step 4: Transfer the Benefit Estimates 4-12
 4.1.5 Step 5: Address Uncertainty 4-15

4.2 Benefit Transfer Worksheet 4-15

IMPLEMENTING BENEFITS ANALYSES CHAPTER FIVE

5.1 Sequencing the Analysis 5-1
 5.1.1 Conduct Scoping and Screening Analysis 5-2
 5.1.2 Collect and Analyze Additional Data as Needed . . 5-2
 5.1.3 Communicate the Results 5-3

5.2 Steps in the Benefits Analysis 5-5
 5.2.1 Identify Potential Benefits 5-6
 5.2.2 Quantify Physical Effects 5-7
 5.2.3 Estimate the Value of the Effects 5-8

5.3 Cross-Cutting Issues	5-11
5.3.1 Discounting and Inflation	5-11
5.3.2 Other Issues	5-15
APPENDIX A: REPORT OF THE BENEFITS WORKING GROUP ..	A-1
REFERENCES	References-1
INDEX	Index-1

OVERVIEW

The U.S. Environmental Protection Agency's (EPA's) Office of Ground Water and Drinking Water developed *Assessing the Benefits of Drinking Water Regulations: A Primer for Stakeholders* to provide information to stakeholders and other interested parties on analyzing the effects of regulations establishing Maximum Contaminant Levels (MCLs) for drinking water. This *Overview* summarizes the information contained in this document for those interested in a brief synopsis of key issues.

EPA created this document in response to new provisions contained in the 1996 Amendments to the Safe Drinking Water Act (SDWA), working closely with a group of stakeholders -- the Benefits Working Group of the National Drinking Water Advisory Council. The Amendments create specific requirements for assessing benefits and for using the resulting information in EPA decision-making. This document focuses on the benefits valuation issues commonly addressed by EPA's economists and policy analysts. We also briefly discuss the assessment of costs and risks, and provide references for more detailed information on these topics.

In addition to SDWA's statutory provisions, regulatory benefit-cost analyses conducted by the Federal government are subject to several other sets of requirements. Chief among these are guidelines developed by the U.S. Office of Management and Budget for all Federal agencies and guidance developed by EPA for its own programs. These documents require analysts to adhere to "best practices" as defined by the economics profession, and emphasize the need to clearly communicate (1) the rationale for decisions made in the course of the analysis; (2) the implications of the findings; and (3) the uncertainties in the resulting estimates. Regulatory analyses also comply with several statutory and administrative requirements for addressing impacts on selected groups, including small businesses and government units, low income and minority populations (i.e., environmental justice), and children. This document is based on, and consistent with, these sources of requirements for regulatory analyses.

The remainder of this *Overview* discusses five subjects: the SDWA requirements for benefits assessment; the general categories of benefits most often addressed; the measures of value preferred by economists; the general methods used to estimate these values; and the specific methods used to value benefits related to reducing the risks of mortality, morbidity and other effects. The following chapters provide more detailed information on these topics as well as references to the underlying literature.

SDWA Requirements For Benefits Analysis

EPA has used benefit-cost analysis for many years as one of several sources of information on the impacts of alternative policy choices. While there are many ways to categorize the positive and negative impacts of a regulation, traditionally EPA has

defined the "cost" side of the analysis as including estimates of the expenditures needed to comply with new regulations (e.g., of installing pollution control equipment) and of the market effects of these expenditures (e.g., on the prices charged for the products of affected industries). The "benefits" side of the analysis generally focuses on the effects of reducing contamination levels, including effects on human health, the natural environment, and man-made materials.

EPA's ability to use the results of these analyses in decision-making under SDWA was limited prior to the 1996 Amendments. The Agency's choice of regulatory levels was constrained by statutory language requiring EPA to set MCLs as close to the MCLG as is "feasible" [SDWA, Section 1412(b)(4)(B)], and defined feasible as the use of the best technology and treatment techniques examined for efficacy under field conditions, taking cost into consideration [SDWA, Section 1412(b)(4)(D)]. Under the amendments, EPA may, at its discretion, establish a less stringent MCL if the costs of achieving the lowest feasible level are not justified by its benefits.

The amendments list a number of issues that should be addressed in benefits analyses, including:

- the quantifiable and non-quantifiable health risk reduction benefits of control of the contaminant proposed for regulation at the specified MCL;
- the quantifiable and non-quantifiable health risk reduction benefits of any control of co-occurring contaminants that can be attributed solely to the proposed MCL, exclusive of compliance with other proposed or promulgated regulations;
- the quantifiable and non-quantifiable costs of compliance with the proposed MCL, including monitoring, treatment, and other costs, exclusive of costs of compliance with other proposed or promulgated regulations;
- the incremental costs and benefits associated with each alternative MCL under consideration;
- the effects of the contaminant on the general population, and on groups within the population that are likely to be at greater risk of adverse health effects from drinking water contaminants, such as infants, children, pregnant women, the elderly, and individuals with a history of serious illness;

- the increased health risks, if any, that may result from compliance with the proposed MCL, including risks associated with co-occurring contaminants; and,
- other relevant factors, including the quality of the available information supporting the analysis, the uncertainties in the analysis, and factors relating to the degree and nature of the identified risks.

SDWA also requires that these analyses be based on the best available scientific research.

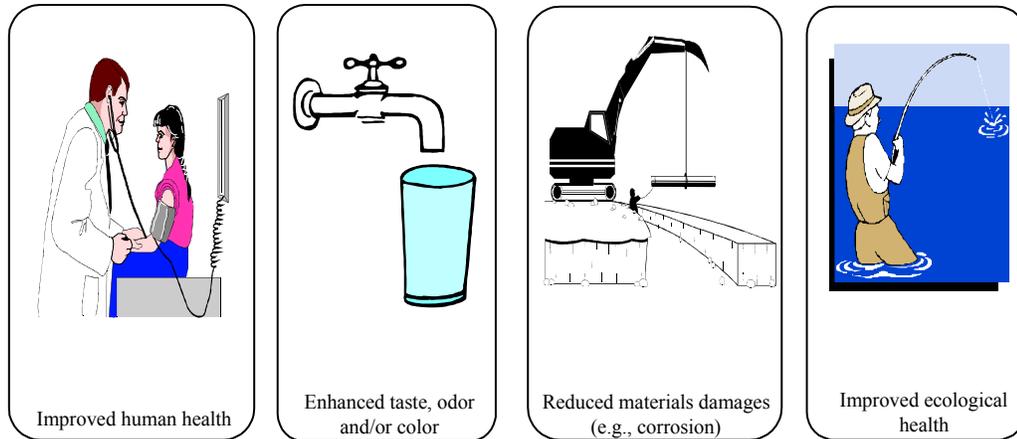
Types of Benefits

For regulations that establish MCLs, a variety of benefits may be associated with reducing the effects of contamination on users of public water supplies (including households, commercial establishments, and industry) as well as on the water system

itself. Chief among these effects are reductions in human health risks. The regulations may decrease the risks of incurring particular illnesses or adverse health effects as well as the risks of dying from these illnesses.

Depending on the characteristics of the contaminants, drinking water regulations may have other types of benefits, including aesthetic effects (improved taste, odor, and/or color) and effects on man-made materials (e.g., reduced corrosion). In cases where significant increases in source water protection result from the regulation, ecological benefits may also accrue. Ecological benefits may include improved fishing and recreational opportunities, protection of biodiversity, or enhanced nonuse values (e.g., the pleasure of knowing that clean water exists). Examples of these benefits categories are illustrated in Exhibit 1.

Exhibit 1
Benefits of Drinking Water Regulations



To determine the types of benefits to be assessed for a specific regulation, analysts generally begin by developing an inclusive list of the possible effects of controlling the contaminants on all types of water users. Analysts then often conduct screening analysis of selected effects, focusing on those that are most likely to be significant. Next, analysts expand and/or refine the analysis as needed to address key sources of uncertainty. This type of sequencing is designed to focus Agency resources on addressing those issues most likely to affect the ultimate policy decision.

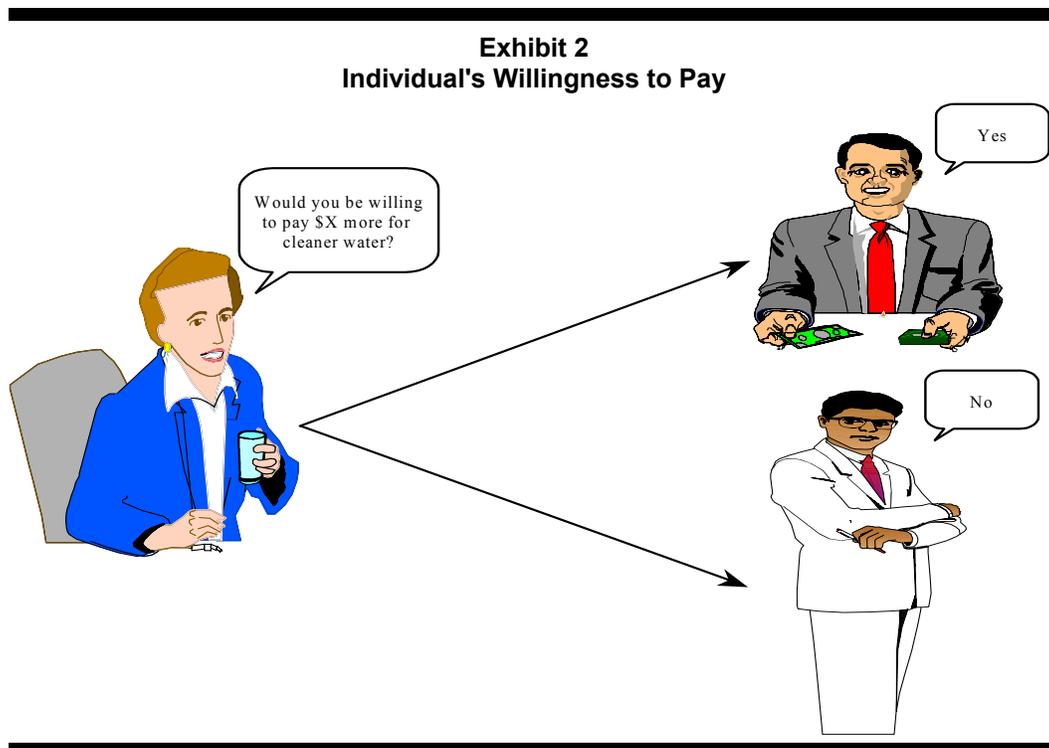
Definition of “Value”

The practice of benefits assessment is based on the discipline of welfare economics. When determining the value of benefits such as those resulting from drinking water regulations, economists begin with the assumption that individuals derive utility (or a sense of satisfaction or well-being) from the goods and services they consume. Individuals can maintain the same level of utility while trading off different bundles of goods and services (e.g., one may be equally happy going to the movies or a baseball game), and their willingness to make these trade-offs can be measured in dollar terms.

In theory, the dollar value of a regulatory requirement is most appropriately measured by determining the change in income (or compensation) that has the same effect on utility (or the level of individual satisfaction) as the requirement. Because utility is difficult to measure directly, economists usually rely on estimates of *willingness to pay* to value the effects of these types of requirements. Willingness

to pay is the maximum amount of money an individual would voluntarily exchange to obtain an improvement; e.g., in drinking water quality.

Willingness to pay is a different concept than cost or price. Cost refers to the resources needed to produce a good or service; it does not measure the value of the good or service to members of society. Price is determined by the interactions of suppliers and consumers in the marketplace. Individual willingness to pay may exceed the current price, in which case the individual benefits from the fact that the market price is less than he or she is willing to pay. If price instead exceeds willingness to pay, then the individual would not purchase the good. An example of this concept is provided in Exhibit 2.



The amount by which willingness to pay exceeds price is referred to as consumer surplus by economists, and aggregate changes in this difference (i.e., across all consumers) can be used to measure the dollar value of the social welfare effects of government policies. For example, consumers generally benefit from price decreases because willingness to pay will then exceed price by a larger amount.

Measuring the value of benefits in dollar terms has two key advantages. First, expressing both costs and benefits in monetary terms allows policymakers to more easily compare these measures of a regulation's impact. Second, valuation provides

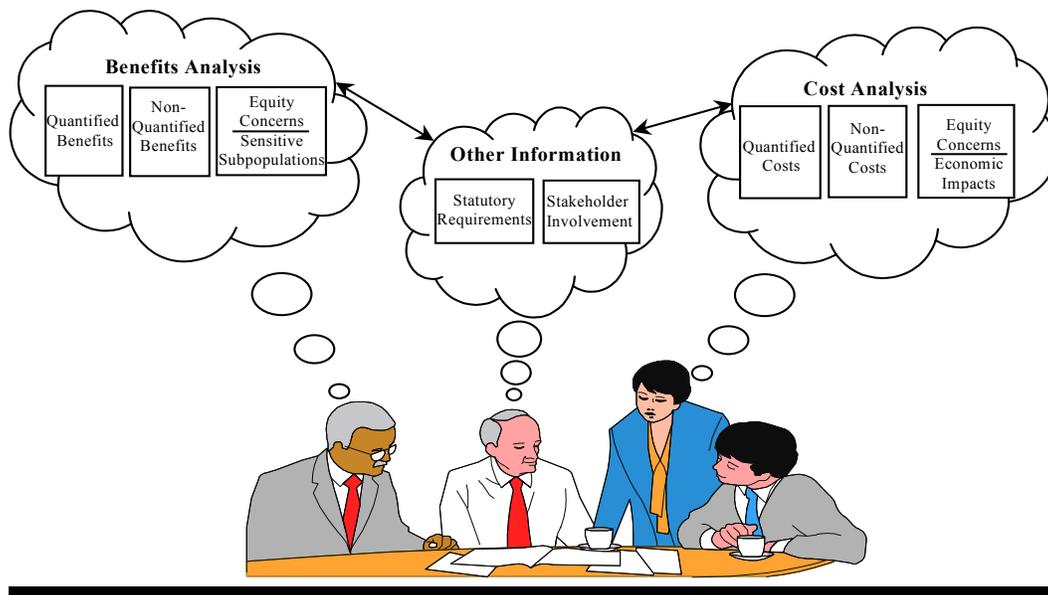
explicit information on the values held by individual members of society for the benefits of alternative policy choices.

However, critics of benefit-cost analysis are concerned that this approach does not take into account the distributional effects of a policy. For example, they argue that lower income individuals may not be treated equitably if decisions are based solely on willingness to pay (which is constrained by income). Economists traditionally focus on how individuals value changes in their own well-being -- aggregating the individual values to determine total benefits, and argue that ethical judgements about distributional effects should be addressed separately.

Because of these concerns, economic benefit-cost analyses of EPA regulations are supplemented by analyses of effects on equity. For example, analysis of environmental justice (effects on low income and minority groups) and risks to children are required for all major EPA regulations. In addition, SDWA requires that EPA consider effects on sensitive subpopulations *"such as infants, children, pregnant women, the elderly, and individuals with a history of serious illness, or other subpopulations likely to be at greater risk..."*

Also, many benefits can be difficult to quantify or may be quantifiable but difficult to value in monetary terms. EPA explicitly considers these non-quantified or non-monetized benefits in setting regulatory standards. The many factors EPA considers are illustrated in Exhibit 3 below.

Exhibit 3 Information for Decision-Making



Valuation Methods

The preferred approach for valuing the benefits of environmental regulations is generally to determine individuals' willingness to pay (WTP) by observing the market demand for related improvements. However, there is often no marketplace for directly buying and selling reductions in environmental contamination. When market data are lacking, economists may use a variety of methods to estimate WTP, which are often divided into two categories: *stated preference methods* and *revealed preference methods*.

Stated preference methods typically employ survey techniques and ask respondents to "state" what they would pay for a good or service. These methods can be used to directly value the program of concern (e.g., "how much would you be willing to pay for a program that would reduce the concentrations of arsenic in drinking water from 10 $\mu\text{g}/\text{L}$ to 5 $\mu\text{g}/\text{L}$?") or to assess specific effects of the program (e.g., "how much would you be willing to pay for a program that would reduce the risks of incurring kidney disease from 10/100,000 to 5/100,000?").

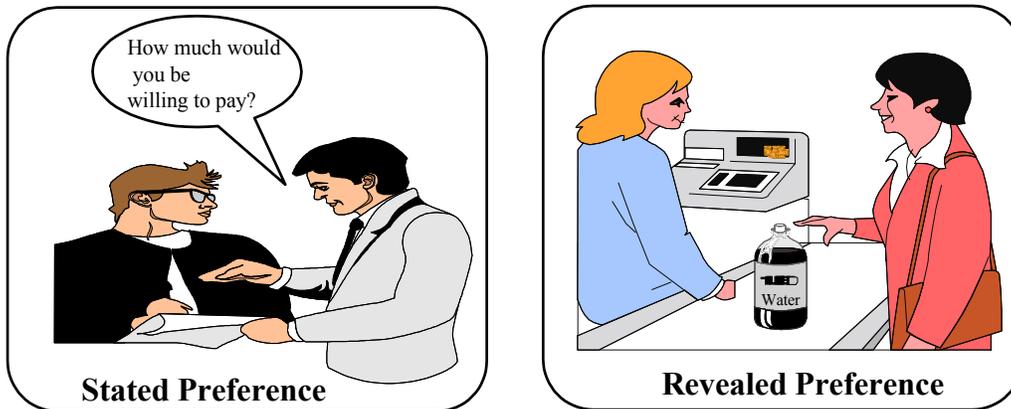
Revealed preference methods are based on observed behaviors that can "reveal" values based on prices and preferences for related market goods or services. For example, if an individual chooses to pay \$50 a month to drink bottled water rather than \$30 a month to drink tap water because he or she believes that the bottled water

is cleaner and safer, presumably this individual values the additional cleanliness and safety of the bottled drinking water at no less than \$20 per month ($\$50 - \$30 = \20).

Examples of revealed preference methods may include studies of wage-risk trade-offs, costs of illness, and averted costs. These methods use actual market data for related goods instead of relying on individual's predictions of their own behavior. However, there is often an imperfect match between the commodities valued in these studies and individual's willingness to pay for the effects associated with a rulemaking. For example, bottled water purchases may not be affected by establishment of an MCL for an individual contaminant or group of contaminants, if such purchases reflect concern about a range of contaminants or about convenience, taste, odor, or color. The medical expenditures included in a cost of illness study may reflect the availability of insurance, rather than individual's true willingness to pay, and exclude the value of avoiding pain and suffering.

The types of studies often used to value the benefits of environmental regulations are illustrated in Exhibit 4 below.

Exhibit 4
Stated and Revealed Preferences



When assessing EPA regulations, analysts often transfer benefits estimates from existing studies rather than conduct new primary research. Benefit transfer involves reviewing the relevant valuation literature, selecting studies that address effects similar to those addressed by the regulations, and applying the estimates from the studies to the regulatory analysis. Key issues in conducting these transfers include ensuring that the studies used are of reasonable quality (e.g., adhere to best practices

for the particular type of research) and are applicable to the policy of concern (e.g., consider similar effects and similar populations). In some cases, it may be possible to adjust the primary research results to address differences between the study scenario and the regulatory scenario.

Valuation of Health Risks and Other Effects

Regulation of contaminants in drinking water may reduce the risks of incurring a variety of health effects, including acute or chronic illnesses that may sometimes result in death. Below, we summarize current practices for valuing mortality and morbidity risks, as well as other effects.

Mortality Risks

Mortality risk reductions are generally valued using estimates of the "value of statistical life" (VSL). VSL does not refer to the value of an identifiable life, but instead to the value of small reductions in mortality risks throughout a population. A "statistical" life can be thought of as the sum of small individual risk reductions across an entire exposed population. For example, if 100,000 people would each experience a reduction of 1/100,000 in their risk of premature death as the result of a regulation, the regulation can be said to "save" one statistical life (i.e., $100,000 * 1/100,000$). If each member of the population of 100,000 were willing to pay \$50 for this risk reduction, the corresponding value of a statistical life would be \$5 million (i.e., $\$50 * 100,000$). VSL estimates are appropriate only for valuing small changes in risk; they are not values for saving an individual's life.

To value mortality risks, EPA analysts often use VSL estimates applied in the recent report to Congress, *The Benefits and Costs of the Clean Air Act, 1990 to 2010*, since these estimates have been subject to substantial peer review. They are derived from 26 studies, 21 of which consider the increase in wages that workers demand for riskier jobs and five of which are based on contingent valuation surveys. The resulting values (in 2000 dollars) range from \$0.8 million to \$17.8 million per statistical life saved, with a mean of \$6.3 million. Given the uncertainty in these estimates, a range of values are generally presented in the benefits analysis, including upper and lower bound estimates as well as the central estimate. EPA is now researching a number of topics related to improving the use of these types of estimates.

When applying this range of estimates to the effects of a particular rule, benefit analysts consider differences between the scenarios addressed in the original studies and the risk reductions addressed by the regulations. For example, the types of fatal risks assessed in the 26 studies (primarily work place accidents) differ from the types of fatal risks affected by environmental regulations (which are often cancer-related).

The subjects of the studies may differ in age, income, or baseline health status from the populations most likely to be affected by the regulations. The studies also do not address factors such as altruism; i.e., individual's willingness to pay for improvements in the health of others. The empirical literature does not provide adjustment factors for many of these (potentially counter-balancing) sources of bias, hence many of these concerns are often discussed qualitatively.

Morbidity Risks

Regulations establishing MCLs also often reduce the risks of incurring nonfatal cancers or other nonfatal health effects. Studies of total willingness to pay (WTP) to avoid an illness, which generally use contingent valuation or other stated preference methods, are available for only a limited number of health effects. Benefit transfer techniques are often used to apply these estimates of WTP to other types of effects. In some cases, analysts may instead rely on estimates using the cost of illness (COI) method. COI studies often include medical expenses (e.g., doctor visits, prescription medicine, hospital stays) and may include lost work time (e.g., foregone earnings), but generally do not address lost leisure time or pain and suffering. They focus on expenditures (which may be influenced by the availability of insurance), rather than on willingness to pay to reduce future risks. Economists believe that COI studies generally understate willingness to pay for morbidity risk reductions.

Analyses of the morbidity risk reductions attributable to drinking water regulations may include estimates of COI and/or total WTP, along with a discussion of the advantages and drawbacks of the valuation methods and an evaluation of the quality and relevance of the individual studies from which the estimates were obtained. The COI studies will provide reasonably certain estimates of averted costs that generally can be interpreted as a lower bound on WTP; the WTP estimates may be less certain (due to the methods used or specific effects studied) but more consistent with the theoretically correct definition of value.

Other Effects

In addition to effects on morbidity or mortality, some drinking water regulations may affect the aesthetic qualities of public water supplies (taste, odor, color) or the damages they cause to man-made materials (corrosion, build-up, impurities). The approach to assessing these types of effects often relies on avoided cost methods. These methods generally involve comparing the costs (e.g., for replacing corroded pipes) that are likely to be incurred in the absence of the rule to the costs likely if alternative MCLs are established. In some cases, studies of willingness to pay (e.g., using contingent valuation) may also be available. For regulations that lead to increases in source water protection, ecological benefits may also accrue -- such as improved recreational opportunities, protection of biodiversity, or nonuse values such as the pleasure of knowing clean resources exist. The methods appropriate for

valuation of these effects will depend on the types of effects considered, but may include analyses of avoided costs or use of contingent valuation surveys.

In applying these valuation methods, analysts often apply informed judgement to determine the appropriate approach for a particular rulemaking. As noted in OMB guidance on conducting economic analysis: *"You will find that you cannot write a good regulatory analysis according to a formula. The preparation of high-quality analysis requires competent professional judgement. Different regulations may call for very different emphasis in the analyses, depending on the importance and complexity of the regulatory issues and the sensitivity of the benefit and cost estimates to key assumptions."* The rationale for these judgements, the limitations and uncertainties in the analysis, and the implications for decision-making are communicated in the materials presenting the results of the analysis.

INTRODUCTION

CHAPTER 1

In 1996, Congress amended the Safe Drinking Water Act (SDWA) and substantially changed the approach for protecting the nation's drinking water supplies. These Amendments strengthened the U.S. Environmental Protection Agency's (EPA's) programs for reducing drinking water contamination by requiring the dissemination of more information to consumers, supporting better approaches for developing sound regulations, and enabling water systems to more easily implement needed improvements. This document was developed by EPA's Office of Ground Water and Drinking Water (OGWDW) for stakeholders and other interested parties to address one of the key areas affected by the 1996 Amendments: the use of benefit-cost analysis in establishing regulations for contaminants in drinking water.

EPA has used benefit-cost analysis for many years as one of several sources of information on the impacts of alternative policy choices. Traditionally, the cost side of the analysis includes estimating the expenditures needed to comply with new regulations (e.g., to install pollution control equipment) and determining the market effects of these expenditures (e.g., on the prices charged for the products of affected industries). The benefits side of the analysis generally focuses on the effects of reducing exposure to contaminants, including effects on human health and the environment.

EPA's ability to use the results of these analyses in decision-making under SDWA was limited prior to the 1996 Amendments. The Agency's choice of regulatory levels was constrained by statutory language requiring EPA to set Maximum Contaminant Levels (MCLs) as close to the MCLG as is "feasible" [SDWA, Section 1412(b)(4)(B)], and defined feasible as the use of the best technology and treatment techniques examined for efficacy under field conditions, taking cost into consideration [SDWA, Section 1412(b)(4)(D)]. Under the Amendments, EPA, at the discretion of the Administrator, may now establish less stringent MCLs if the costs of achieving the lowest feasible level are not justified by its benefits.

Because of the importance of these issues, EPA asked members of key stakeholder groups to assist in designing improved approaches to benefit-cost analysis. In 1998, EPA convened a Benefits Working Group to provide recommendations to the National Drinking Water Advisory Council on how EPA can best address the benefits of drinking water regulations. The Working Group's deliberations were carefully considered in the development of this document, and its report is included as Appendix A.

This document is divided into five chapters. The remainder of this first chapter introduces the benefits that may result from establishing MCLs for drinking water contaminants and describes the contents of the subsequent chapters in more detail. The second chapter describes the requirements for conducting benefit-cost analysis under SDWA as well as other applicable statutes and administrative orders. The third chapter describes the theory and methods for benefits analysis, focusing on the types of benefits most frequently associated with establishing drinking water MCLs. In the fourth chapter, we describe the benefit transfer technique, which is often used to estimate the value of benefits from environmental regulations. The fifth chapter provides information on how these analyses are implemented. An appendix summarizes the deliberations of the National Drinking Water Advisory Council's (NDWAC's) Benefits Working Group.

1.1 Types of Benefits

For environmental regulations, EPA generally defines benefits as the impacts of reducing the emissions of pollutants into the environment. In the case of regulations that establish MCLs (or, when necessary, treatment requirements) for public drinking water systems, these benefits result largely from reducing the adverse effects of contamination on users of this water, including households, commercial establishments, and industry.¹ The most significant effects of these regulations are improvements in human health, but other types of benefits (such as improved taste or reduced pipe corrosion) may also accrue.

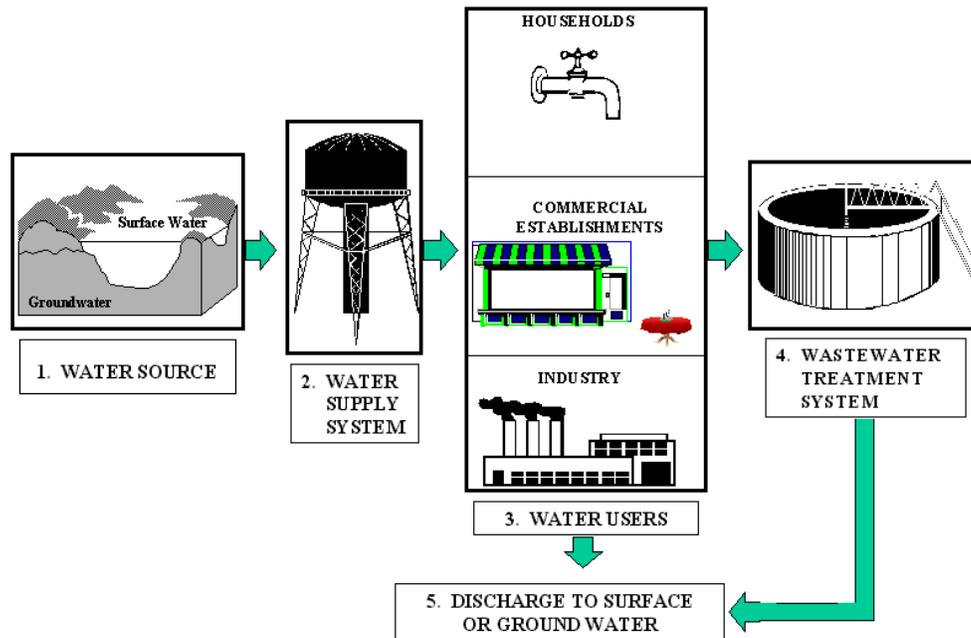
1.1.1 Water Supply Life-Cycle

In Exhibit 1-1, we provide a simple illustration of the life-cycle for publicly-supplied drinking water. This life-cycle begins with the surface or ground water sources that feed the water system. According to the U.S. Geological Survey, daily use of public water supplies totaled 40 billion gallons in the U.S. in 1995.² Surface waters are the source of about 62 percent of this supply; ground water sources account for the remaining 38 percent.

¹ "Public water systems" refer to systems serving the public (e.g., a community), which may be publicly or privately owned. Under the *National Primary Drinking Water Regulations* (40 CFR 141.2), these systems include those with at least 15 service connections or that regularly serve an average of at least twenty-five individuals at least 60 days per year.

² U.S. Geological Survey, *Estimated Use of Water in the United States in 1995*, 1997.

**Exhibit 1-1
Public Water Supply Life-Cycle Overview**



The water supply system collects water from these sources, treats it as necessary, and then distributes it to residential, commercial, industrial, or other users. EPA data indicate that about 47 percent of community water supplies were delivered to residential customers in 1995.³ The remaining 53 percent includes commercial use (23 percent), industrial use (11 percent), government use (4 percent), agricultural use (1 percent), and wholesale (14 percent, primarily sales to other water systems for residential use). Once the water is used, it generally enters a sewer system and is conveyed to a wastewater treatment plant, where it is treated and discharged. Wastewater may also be directly discharged to surface water (e.g., by an industrial user) or released to ground water (e.g., when used for lawn-watering or treated by a home septic system).

Regulations establishing an MCL (or treatment requirements in lieu of an MCL) are likely to have the largest impact on the quality of water as it is delivered to the user

³ U.S. Environmental Protection Agency, *Community Water Systems Survey, Volume I: Overview*, January 1997.

(i.e., from Step Two to Step Three in Exhibit 1-1). The contaminants in discharges to surface and ground water (i.e., after Steps Three and Four) depend in part on the quality of the influent water supply and in part on how the water is used (e.g., for household hygiene or industrial cooling), and are generally regulated separately under the Clean Water Act and other authorities.

While MCLs focus on the quality of water delivered to end users, ground and surface water sources (Step One in Exhibit 1-1) can be affected by local decisions on how best to achieve an MCL. To comply with new regulations, systems may install treatment or blend contaminated and uncontaminated water to reduce concentration levels. Alternatively, systems may change the source of their water by connecting to a neighboring system, by developing a new well field, or by switching from ground water to surface water or vice-versa. Water systems may choose to implement source water protection measures rather than to undertake or improve water treatment.⁴ They may take steps to for example, ban development in a buffer zone surrounding a water source. In the following chapters, we concentrate on the benefits associated with delivering cleaner water to users because, at a national level, these are likely to be the most significant benefits associated with new MCLs in most cases.

1.1.2 Major Benefit Categories

In this document, we organize "types of benefits" or "types of effects" into four major categories, based on the methods used to assess benefits (described in Chapter 3) within each category. This distinction is illustrated in Exhibit 1-2 and discussed below.

Exhibit 1-2 Benefits Terminology

Benefits categories represent the general types of benefits a regulation may produce. These include human health effects, ecological effects, aesthetic effects, and/or effects on materials.

Types of benefits are the specific types of effects within each category that are addressed by a regulation. For example, stomach cancer and kidney disease are two types of effects in the human health category that may be reduced by regulation of certain drinking water contaminants.

Methods for assessing benefits include both the approaches used to quantify physical effects (e.g., risk assessment) and the approaches used to determine the dollar value of the physical effects (e.g., survey research or market data).

⁴ EPA also develops other types of regulations that protect water sources (e.g., by requiring industry to clean-up contaminated sites); this document focuses on regulations establishing MCLs.

Regulations establishing MCLs often have impacts that fall primarily into three categories: human health effects, aesthetic effects (e.g., taste, odor, color), and effects on materials (e.g., corrosion). The fourth category, ecological effects, may also be important in cases where the regulations increase source water protection or decrease the contamination associated with wastewater discharges or other wastes generated by water users or the system itself.

Households are often the users most significantly affected by regulations establishing MCLs both because of their level of water use and because of SDWA's focus on reducing risks to human health. Industrial or commercial establishments, who may use public supplies for drinking water or food preparation, as an input to a production process, or for cooling or cleaning, may also benefit from the establishment of MCLs. Government and agricultural use make up a relatively small proportion of the total use of publicly supplied water and often may be less substantially affected by related regulations than other types of use.

Determining the benefits categories affected by a particular regulation generally involves tracing the uses of the water supplies and the effects of changes in contamination levels on these uses. In some cases, the type of use affected may be passive; e.g., individuals may value simply knowing that clean water exists.

The relationship between use of public water supplies and potential benefits is illustrated by the examples in Exhibit 1-3 below. While the exhibit provides some examples of potential benefits for each type of user, it is not intended to be comprehensive; other types of benefits may accrue from regulation of individual contaminants. In general, analysts explore the types of benefits associated with a particular regulation on a case-by-case basis.

Exhibit 1-3

Public Water Users and Potential Benefits

User	Examples of Uses	Examples of Potential Types of Benefits From Improved Water Quality
Households	▶ Drinking water and food preparation	▶ Decreased health effects associated with ingestion; improved taste and odor
	▶ Showering and bathing	▶ Decreased health effects through dermal exposure and inhalation
Commercial establishments	▶ Drinking water and food preparation	▶ Decreased health effects associated with ingestion; improved taste and odor
	▶ Laundry and cleaning	▶ Reduced discoloration
Industry	▶ Drinking water and food preparation	▶ Decreased health effects associated with ingestion; improved taste and odor
	▶ Production input	▶ Improved product quality
	▶ Cooling and cleaning	▶ Reduced damage (e.g., corrosion, scaling) to equipment

Whether a specific use is affected by the regulations for an individual contaminant (or group of contaminants) will depend on both the characteristics of the contaminant and the changes in contamination levels attributable to the regulations. For example, in the case of a corrosive contaminant, damages to equipment or piping may be only partially reduced if the MCL is not set below the level at which noticeable damages occur. For a contaminant associated with lung disease, disease incidence may not be affected if the quantities inhaled (e.g., during showering) are not sufficient to cause the disease. The potential benefits therefore may vary substantially depending on the regulatory levels considered as well as the nature of the contaminants.

While for simplicity we have excluded the water system itself from Exhibit 1-3, benefits to the system may also accrue from regulations establishing MCLs, such as reduced damages to treatment equipment and distribution piping or changes in risks to the general public due to transportation of treatment residuals. Transportation or other risks are often best addressed as part of the risk assessment conducted for the benefits analysis (because such analysis requires the skills of health scientists), and direct savings to the system may be best addressed as part of the cost analysis (because such analysis requires the skills of water supply engineers and are an off-set to other compliance costs).

For example, if the use of new treatment techniques reduces pipe corrosion or blockage associated with the contaminant, cost analysts may choose to subtract the savings (from the reduced frequency of pipe repair or replacement) from the costs of installing and maintaining the equipment, rather than assessing the averted costs as part of the benefits analysis. To avoid double-counting, cost and benefit analysts agree in advance about whether each type of effect should be included in the cost or the benefit analysis.

As suggested by Exhibit 1-3 above, most of the benefits associated with regulations establishing MCLs fall into three categories: health effects, aesthetic effects (also referred to as amenities), and effects on materials (or materials damage). Exhibit 1-4 lists some examples of the types of effects that fall into each of these benefit categories. Methods for assessing these types of benefits are discussed in detail in Chapter 3 of this document.

Exhibit 1-4	
Benefit Categories and Types of Benefits	
Benefit Category	Examples of Types of Benefits
Human Health Effects	<ul style="list-style-type: none"> ▶ Reduced mortality ▶ Decreased incidence of nonfatal cancers ▶ Decreased incidence of other nonfatal chronic and acute illnesses ▶ Reduced incidence of developmental, neurological, or reproductive effects
Aesthetic Effects	<ul style="list-style-type: none"> ▶ Improved taste ▶ Improved odor ▶ Reduced discoloration
Effects on Materials	<ul style="list-style-type: none"> ▶ Reduced corrosion or scaling ▶ Reduced build-up in piping ▶ Improved product quality

For regulations that lead to significant increases in source water protection, additional types of benefits may accrue. If source water protection is used in lieu of treatment to achieve an MCL, it will provide the same benefits (resulting from reducing contamination in water delivered to users of public supplies) as discussed above. In addition, source water protection may lead to ecological benefits stemming from the use of the water for recreational or commercial activities such as fishing, or from protection of biodiversity. "Nonuse" values, such as the pleasure of simply knowing that clean resources exist for current and future generations, may also be affected.

1.2 Use of this Report

The remainder of this document provides additional information on identifying and assessing these various types of benefits.

- Chapter Two, **Requirements for Benefits Analyses**, discusses the statutes, administrative orders, and other requirements that govern the conduct of benefits analysis at EPA. These requirements include those contained in SDWA as well as requirements developed by the Executive Office of the President and EPA to guide analyses of all major regulations. EPA analyses should also address several requirements for assessing impacts on business and government, as well as impacts on certain groups within the population, such as minorities, low income groups, and children.
- Chapter Three, **Methods for Benefits Analyses**, describes the theory and methods used in these analyses. It introduces several basic concepts and valuation methods, and then describes best practices for assessing effects on human health, aesthetics, and manufactured materials. Analysis of the ecological effects potentially associated with source water protection is also briefly described.
- Chapter Four, **Conducting Benefit Transfers**, provides information on how the benefit transfer technique is used to value the benefits of drinking water standards. Benefit transfer refers to the use of valuation information from one or more existing studies to assess similar, but not identical, effects.
- Chapter Five, **Implementing Benefits Analyses**, addresses the steps in the analysis and provides information on addressing data limitations and other issues. It also discusses several cross-cutting issues that arise when conducting these analyses, such as defining conditions with and without the regulations.
- Appendix A, **Report of the Benefits Working Group**, then provides the recommendations of the stakeholder group convened to advise EPA on these topics.

This appendix is followed by a list of references and an index to the major topics addressed in this document.

REQUIREMENTS FOR ECONOMIC ANALYSES

CHAPTER 2

The process for developing Federal regulations has been subject to requirements for preparing supporting benefit-cost analyses for more than 20 years under an increasing variety of laws and executive orders.⁵ In some cases these requirements focus on national analysis of regulatory impacts; in other cases they address effects on particular groups of concern, such as small businesses and government units, or minorities, low income groups, and children. For drinking water regulations, the Safe Drinking Water Act (SDWA) also contains several provisions that apply specifically to the analysis of benefits and costs.

This chapter summarizes the provisions of statutes, executive orders, and guidance documents that apply to the economic analysis of potential Federal regulations, with particular emphasis on the application of these requirements to the assessment of regulations establishing Maximum Contaminant Levels (MCLs) or treatment requirements for public drinking water systems. Many of these statutes, executive orders and guidance documents also contain requirements for the regulatory development process (e.g., for stakeholder involvement) and for the analysis of costs. While we allude to these other requirements, particularly where they constitute the primary purpose of an individual statute or executive order, we focus on information related to assessing benefits and comparing benefits to associated costs.

The purpose of this chapter is to introduce the requirements for the regulatory analyses described in these documents. The documents referenced in this chapter provide more detailed information on each set of requirements, as well as on the process for implementing and updating them.

2.1 The Safe Drinking Water Act

SDWA, as amended in 1996, provides the framework for developing National Primary Drinking Water Regulations, which establish MCLs or treatment techniques for controlling specific contaminants in drinking water.⁶ SDWA also includes requirements for benefits assessment and for comparing benefits to costs as described below.

⁵ A concise summary of the development of the U.S. regulatory analysis program is contained in the U.S. Office of Management and Budget's *Report to Congress On the Costs and Benefits of Federal Regulations*, September 30, 1997. (The subsequent updates of this report do not provide this historical perspective.)

⁶ The 1996 SDWA amendments and related information are available on EPA's Website at: <http://www.epa.gov/ogwdw/sdwa/sdwa.html>.

2.1.1 MCL Development Process

SDWA was originally enacted in 1974 and substantially amended in both 1986 and 1996. The 1986 Amendments specified 83 drinking water contaminants for regulation, and required EPA to regulate 25 of these contaminants every three years. EPA developed regulations for many of these contaminants before the 1996 Amendments, which changed the contaminant identification process to include risk-based prioritization of regulatory decisions with sound scientific peer review.⁷

In response to these new requirements, EPA must publish a list once every five years of unregulated contaminants it will consider for regulation [SDWA, Section 1412(b)(1)(B)]. Based on review of available information, the Agency must determine whether to regulate at least five contaminants from this list every five years. In accordance with these provisions, the Agency published its first *Contaminant Candidate List* of 60 chemical and microbial contaminants in March 1998, and will decide whether to proceed with developing regulations for at least five of these contaminants by August 2001.⁸

The 1996 Amendments maintain the Act's historic focus on the protection of public health. Specifically, SDWA Section 1412(b)(1)(A) directs the Administrator to focus on those contaminants that may have adverse human health effects, that are known or substantially likely to occur in public water systems at levels and with a frequency of concern to public health, and that present meaningful opportunities for health risk reductions if regulated. In all of these decisions, the Agency is further directed to draw data from the best available peer-reviewed science [SDWA, Section 1412(b)(3)(A)].

For each contaminant that EPA chooses to regulate, SDWA requires the Agency to publish a Maximum Contaminant Level Goal (MCLG) and issue a National Primary Drinking Water Regulation that would reduce health risks. In this regulation, EPA must either establish a Maximum Contaminant Level (MCL) and list technologies that can achieve compliance with the MCL (specifying compliance technologies for small systems), or (if it is not economically or technically feasible to monitor the contaminant in drinking water) specify a treatment technology. EPA sets the MCLG at the concentration at which there are no known or anticipated adverse health effects associated with exposure to the contaminant, taking into account an adequate margin

⁷ In addition, the 1996 Amendments established specific requirements for the regulation of four contaminants: arsenic, radon, disinfection byproducts /cryptosporidium, and sulfate. The 1996 Amendments also require EPA to review and, if necessary, revise National Primary Drinking Water Regulations for currently regulated contaminants after six years.

⁸ The Contaminant Candidate List and supporting information is available on EPA's Website at: <http://www.epa.gov/ogwdw/ccl/cclfs.html>.

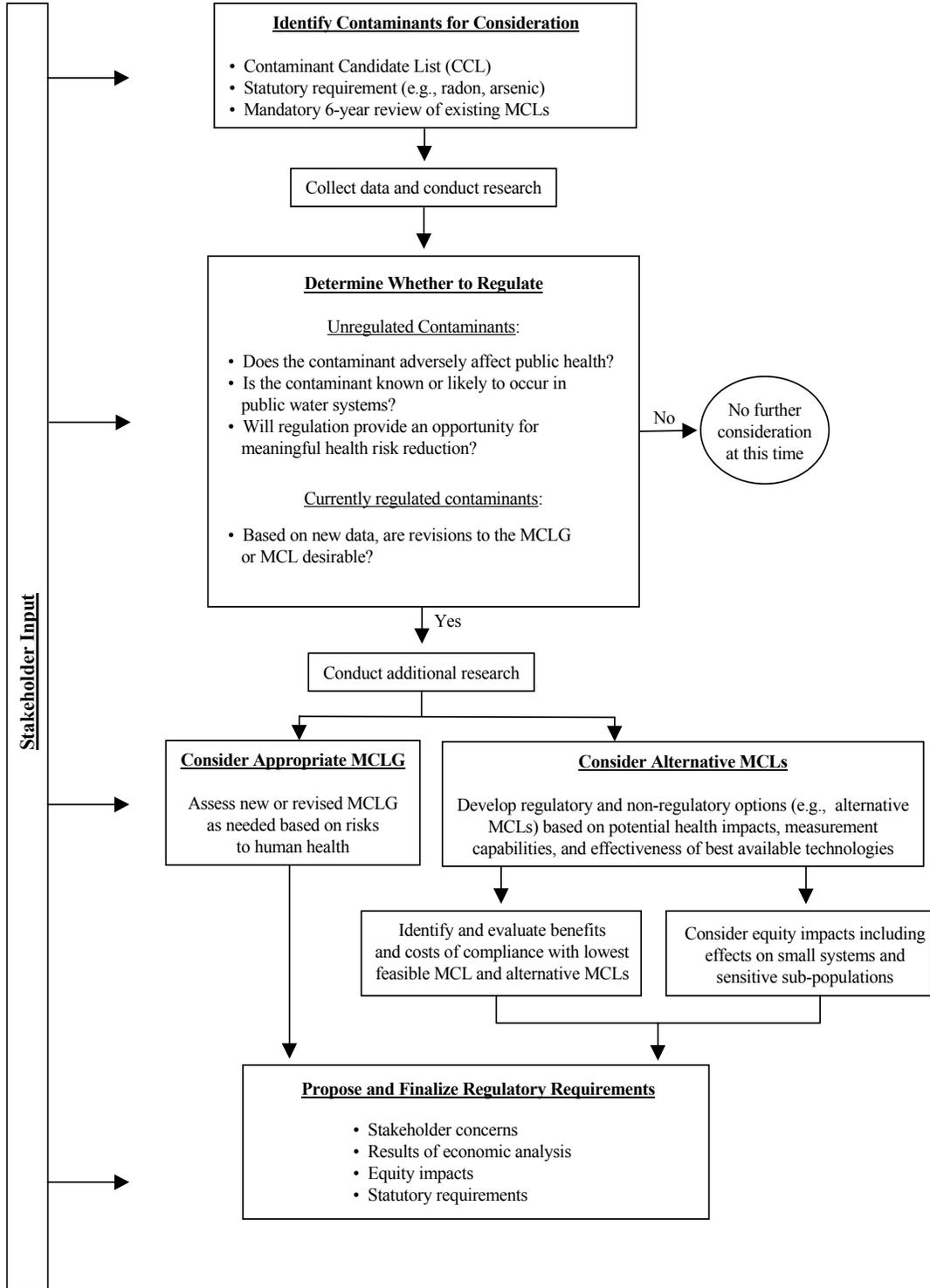
of safety and considering the effects on sensitive subpopulations. MCLGs for carcinogens are generally set at zero in the absence of data to support an alternative value. MCLGs for noncarcinogens are based on the Reference Dose (RfD, the level at which no adverse effects are likely to occur even for sensitive populations), combined with data on body weight, water consumption, and the percent of total exposure attributable to drinking water.

The 1986 SDWA amendments identified a process for setting MCLs as close to the MCLG as is "feasible" [SDWA, Section 1412(b)(4)(B)], and defined feasible as the use of the best technology and treatment techniques examined for efficacy under field conditions, taking cost into consideration [SDWA, Section 1412(b)(4)(D)]. This process was retained in the 1996 Amendments. However, under the 1996 Amendments, EPA can, at its discretion, establish a less stringent MCL that *"maximizes health risk reduction benefits at a cost that is justified by the benefits"* [SDWA, Section 1412(b)(6)(A)], with certain exceptions. In particular, SDWA Section 1412 (b)(6)(B) prohibits the Administrator from establishing a less stringent MCL if the benefits justify the costs for large water systems and those small systems not likely to gain variances, once the costs and benefits for those small systems likely to obtain variances are excluded from the analysis.

Exhibit 2-1 provides an overview of the regulatory development process under SDWA. EPA begins by selecting contaminants for regulatory consideration, then determines whether to proceed with developing new or revised regulations. These regulations may address both the MCLG and the MCL (or treatment requirements), depending on the status of the regulation and available research. The Agency considers the regulatory options and makes regulatory decisions based on stakeholder concerns, the results of the economic analysis, equity impacts, and statutory and other requirements.

Exhibit 2-1

OVERVIEW OF REGULATORY DEVELOPMENT PROCESS



2.1.2 Benefits Assessment

The 1996 SDWA Amendments impose significant new requirements on EPA for assessing benefits and for comparing benefits to costs. Specifically, when proposing any MCL, the Agency must publish an analysis of the benefits and costs of compliance with the MCL, including the following [SDWA, Section 1412(b)(3)(C)(i)]:

- the quantifiable and non-quantifiable health risk reduction benefits of control of the contaminant proposed for regulation at the specified MCL;
- the quantifiable and non-quantifiable health risk reduction benefits of any control of co-occurring contaminants that can be attributed solely to the proposed MCL, exclusive of compliance with other proposed or promulgated regulations;
- the quantifiable and non-quantifiable costs of compliance with the proposed MCL, including monitoring, treatment, and other costs, exclusive of costs of compliance with other proposed or promulgated regulations;
- the incremental costs and benefits associated with each alternative MCL under consideration;
- the effects of the contaminant on the general population, and on groups within the population that are likely to be at greater risk of adverse health effects from drinking water contaminants, such as infants, children, pregnant women, the elderly, and individuals with a history of serious illness;
- the increased health risks, if any, that may result from compliance with the proposed MCL, including risks associated with co-occurring contaminants; and,
- other relevant factors, including the quality of the available information supporting the analysis, the uncertainties in the analysis, and factors relating to the degree and nature of the identified risks.

If EPA proposes a treatment technique in lieu of establishing an MCL, the Agency must analyze the benefits and costs for the proposed treatment technique and alternatives considered, considering the same factors as listed above [SDWA, Section 1412(b)(3)(C)(ii)].

2.1.3 Comparison of Benefits to Costs

For each proposed MCL, SDWA further requires that the EPA Administrator publish a determination as to whether the benefits of the proposed regulation justify the costs [SDWA, Section 1412(b)(4)(C)], based on the analyses described above. If the benefits of setting the MCL at the feasible level would not justify the costs, "*the Administrator may, after notice and opportunity for public comment, promulgate an alternative MCL that will maximize health risk reduction benefits at a cost that would be justified by the benefits*" [SDWA, Section 1412(b)(6)(A)], with the exception (noted earlier) related to variances for small systems. These decisions are subject to judicial review [SDWA, Section 1448].

2.2 General OMB and EPA Guidance

In addition to the requirements imposed by SDWA, EPA benefit analyses must comply with more general provisions governing the assessment and promulgation of major Federal regulations. Executive Order 12866 establishes many of these requirements for major Federal regulations, defining major regulations as those that have an annual effect on the economy of \$100 million or more, have other significant adverse economic impacts, are inconsistent with the actions of other agencies, alter the budgetary impact of Federal programs, or raise unusual legal or policy issues. The Office of Management and Budget (OMB) in the Executive Office of the President reviews major Federal regulations prior to promulgation under this Executive Order to ensure that they are consistent with the goals of the President and based on sound analysis and judgement.

OMB has developed guidance for preparing the benefit-cost analyses required under Executive Order 12866. This guidance focuses on ensuring that the analysis complies with "best practices" as defined by the economics profession. In addition, EPA has developed similar guidance tailored to its own regulations to ensure that the required analyses are performed consistently and accurately. This section first discusses the OMB guidance, "Guidelines to Standardize Measures of Costs and Benefits of Federal Regulations and Format of Accounting Statements" and then the EPA guidance, *Guidelines for Preparing Economic Analyses*.

2.2.1 OMB Guidance Under Executive Order 12866

Executive Order 12866, *Regulatory Planning and Review*, requires Federal agencies to conduct economic analyses of significant regulatory actions as a means to improve regulatory decision-making.⁹ To assist agencies in carrying out these analyses, OMB issued guidelines to standardize benefit-cost analysis in their 2000 report to

⁹ Executive Order 12866, *Regulatory Planning and Review*, September 30, 1993.

Congress.¹⁰ As outlined in these guidelines, an economic analysis of a regulation should be designed to provide information for decision-makers on the potential benefits to society of alternative regulatory and nonregulatory approaches to risk management in comparison to potential costs, recognizing that not all benefits and costs can be described in monetary or even in quantitative terms. The guidelines focus on ensuring that decisions are based on the best available scientific, technical, and economic information.

The OMB guidelines are divided into four major sections:

- **General Considerations** discusses addressing the need for regulatory action, policy alternatives to consider, choice of a baseline, inclusion of non-monetized benefits and costs, and discounting of benefits and costs over time.
- **Benefit Estimates** describes the key concepts related to estimating benefits, valuing market and nonmarket goods, and valuing health and safety benefits.
- **Cost Estimates** provides an overview of the key concepts related to estimating costs, and the difference between real costs and transfer payments.
- **Other Key Considerations** describes methods for dealing with risk and uncertainty, use of sensitivity analysis to address alternative assumptions, distributional effects and equity considerations, and compliance assumptions.

In addition, the guidelines discuss a standard format for summarizing analytic results.

The guidelines are intended to provide a flexible framework for regulatory analyses, presenting information on practices that are consistent with the principles of economic theory. They also help standardize the measurement of benefits and costs of Federal regulatory actions. OMB emphasizes the need to clearly communicate the approach and findings of the analysis by presenting transparent analysis.

While the focus of OMB's regulatory review under Executive Order 12866 will vary depending on the characteristics of individual rules and the current priorities of the

¹⁰ U.S. Office of Management and Budget, "Guidelines to Standardize Measures of Costs and Benefits and the Format of Accounting Statements," in *Appendix 4: Report to Congress on the Costs and Benefits of Federal Regulations*, March 22, 2000.

President, this guidance suggests that the criteria for acceptable analysis include consistency with the general principles of economics and clear justification of the analytic approach used for the particular rulemaking. The information on benefits analysis provided later in this document complies with these general principles.

2.2.2 EPA Guidelines for Economic Analyses

EPA first issued formal guidelines for the preparation of regulatory impact analyses in 1983 in response to President Reagan's Executive Order 12291 (the predecessor to President Clinton's Executive Order 12866). EPA then amended these guidelines and added new appendices in 1991. Over the past four years, the Agency undertook a major effort to update and revise these guidelines, finalizing its *Guidelines for Preparing Economic Analyses* in 2000.¹¹

EPA's guidelines generally follow the same framework as OMB's guidance. The EPA *Guidelines* are in part based on research commissioned by EPA's Economic Consistency Work Group and subsequent decisions made by its Regulatory Policy Council. This research focused on six areas that are central to the preparation of sound regulatory analyses: defining the baseline, selecting discount rates, valuing mortality risk reductions, addressing equity and distributional issues, evaluating uncertainty, and assessing non-quantified and non-monetized effects. The EPA *Guidelines* incorporate new advances in applied economic research, and address the analytic requirements of a number of recent statutes and executive orders.

The EPA *Guidelines* are substantially more detailed than the OMB guidelines mentioned above, but place a similar emphasis on applying best practices derived from the field of economics, using informed professional judgement to appropriately design and implement the analysis, and ensuring that the analytic methods and results are clearly communicated. The EPA *Guidelines* address the following topics:

- Statutory and executive order requirements for conducting economic analyses;
- Stating the need for the proposal, including guidance on procedures and analyses for clearly identifying the environmental problem to be addressed and for justifying Federal intervention;
- Developing regulatory and nonregulatory approaches for consideration;

¹¹ U.S. Environmental Protection Agency, *Guidelines for Preparing Economic Analyses*, EPA 240-R-00-003, September 2000.

- Understanding the theoretical foundations of economic analyses, as well as general guidance on specifying the baseline, predicting responses to the regulations, and assessing uncertainty;
- Approaches to social discounting;
- Assessing the benefits of environmental policies;
- Analyzing the social costs of environmental policies;
- Assessing the economic impacts and equity effects of environmental policies; and,
- Using economic analyses in evaluating policy options.

The EPA *Guidelines* include a thorough discussion of the benefits categories, general analytic approach, and methods applicable to the assessment of benefits of environmental regulations. A review of these topics, illustrated with examples of their application to drinking water regulations, is included in Chapters 3 and 4 of this document. Several other topics addressed by the EPA guidelines affect both the cost and benefit analysis (e.g., the definition of the baseline) and are briefly summarized in Chapter 5 of this document.

2.3 Requirements Related to Impacts on Government and Business Units

The increasing scope and number of environmental and other regulations have raised concerns in recent years over the economic impacts of Federal actions on state and local governments and the business community. EPA is subject to two primary sets of requirements for assessing these types of impacts.¹² The Unfunded Mandates Reform Act requires EPA to assess the impacts of Federal regulations on non-Federal government units and to minimize associated costs (when not offset by adequate Federal funding). The Small Business Regulatory Enforcement Fairness Act amends the Regulatory Flexibility Act; in combination these Acts establish analytical and procedural requirements for addressing the impacts of Federal regulations on small government and business entities. As discussed below, the guidelines for addressing these statutory requirements focus largely on the analysis

¹² In addition to these statutes, EPA is subject to Executive Order 13132, *Federalism*, which requires intergovernmental consultation. Executive Order 13084, *Consultation and Coordination with Indian Tribal Governments*, also requires consultation on potential regulatory requirements. However, these Orders do not specifically address the conduct of economic analysis.

of costs, but information on associated benefits is often useful for related decision-making.

2.3.1 The Unfunded Mandates Reform Act (UMRA)

The Unfunded Mandates Reform Act (UMRA), which Congress enacted in 1995, requires that Federal agencies assess the budgetary impacts of proposed regulations on state, local and tribal governments as well as on the private sector. The general requirements for analysis under UMRA are very similar to the requirements described in the above-mentioned OMB and EPA guidance for regulatory analysis, but focus on the effects of Federal requirements on other government entities and the private sector. Information on complying with the requirements of UMRA can be found in OMB's *Guidance for Implementing Title II of S.1.*¹³ EPA is also developing draft guidance on these topics.

Title II of UMRA directs agencies to prepare an economic analysis prior to promulgating any regulation that may mandate direct expenditures of \$100 million in any one year by state, local, and tribal governments combined, or by the private sector. The statute further requires that the economic analysis include:

- a qualitative and quantitative assessment of the anticipated benefits and costs of the mandate, including its effects on health, safety, and the natural environment [Section 202(a)(2)];
- an assessment of the extent to which Federal resources and financial assistance (e.g., through the Drinking Water State Revolving Fund) are available to offset the costs imposed on state, local, and tribal governments [Section 202(a)(2)(A)];
- estimates, where feasible, of disproportionate budgetary effects on any particular region, any particular state, local, or tribal government, any particular type of community (e.g., urban or rural), or particular segments of the private sector [Section 202(a)(3)(B)]; and,
- estimates, where feasible, of the proposed regulation's effects on the national economy (e.g., its effects on productivity,

¹³ U.S. Office of Management and Budget, *Guidance for Implementing Title II of S.1.*, Memorandum from Sally Katzen, March 31, 1995. Information on the historical relationship between UMRA and SDWA is also provided in: U.S. Congressional Budget Office, *The Safe Drinking Water Act: A Case Study of an Unfunded Federal Mandate*, September 1995.

economic growth, employment, and job creation) [Section 202(a)(4)].

To foster greater communication and coordination between all levels of government during regulatory development, UMRA also includes requirements for Federal consultation with representatives of state, local, and tribal governments so as to provide "meaningful and timely" input to the development of a regulatory proposal [UMRA, Section 204].

For each proposed rule, UMRA requires that agencies "*consider a reasonable number of regulatory alternatives and ... select the least costly, most cost-effective, or least burdensome alternative,*" unless this provision is inconsistent with applicable law. Otherwise, the Agency must publish (with the final rule) an explanation of why the least costly, most cost-effective, or least burdensome alternative was not chosen. In total, the requirements of UMRA suggest that analysts may wish to disaggregate both benefit and cost estimates so that the cost impacts of any significant unfunded mandates can be compared to their benefits for the particular types of affected entities. In addition, the requirements of UMRA must be taken into account when selecting the regulatory options to be considered in the benefit-cost analysis.

2.3.2 The Small Business Regulatory Enforcement Fairness Act (SBREFA)/Regulatory Flexibility Act (RFA)

The Small Business Regulatory Enforcement Fairness Act (SBREFA) was passed in 1996, amending the Regulatory Flexibility Act (RFA) of 1980. The purpose of these combined statutes is to ensure that agencies consider the economic impacts of their regulations on small entities, both public and private, and provide flexibility to minimize these impacts. Many of the specific requirements in these statutes apply primarily to the analysis of the direct economic impacts (i.e., costs) associated with regulatory compliance and related decision-making; however, analysts may also wish to provide information on benefits to help inform these decisions. These statutes also contain specific requirements for consulting with representatives of small entities and for publishing a small entity compliance guide. EPA guidance for implementing SBREFA and RFA is available in: *Revised Interim Guidance for EPA Rulewriters: Regulatory Flexibility Act as Amended by the Small Business Regulatory Enforcement Fairness Act* and related documents.¹⁴

¹⁴ U.S. Environmental Protection Agency, *Revised Interim Guidance for EPA Rulewriters: Regulatory Flexibility Act as Amended by the Small Business Regulatory Enforcement Fairness Act*, March 1999; and U.S. Environmental Protection Agency, *1999 Update to Elements of a Reg Flex Analysis*, 1999. The U.S. Small Business Administration (SBA) has also developed guidance (*Implementation Guide for the RFA*, February 1998). However, the SBA differs from EPA in its legal and policy interpretations of some

The RFA provides definitions of small entities, including "small businesses," "small governments," and "small organizations." However, for drinking water regulations, EPA's policy has been to instead define water systems serving less than 10,000 customers as small entities.¹⁵ Such systems account for nearly 95 percent of all community water systems nationwide, although they serve relatively small populations and hence provide a much smaller proportion of total water supplies. EPA's definition of small water systems does not correspond precisely to the definition of small entity under RFA; however, EPA has in the past consulted with and received approval from the Small Business Administration for the use of this alternative definition.¹⁶

Under SBREFA and RFA, EPA must evaluate the reporting, record-keeping, and other compliance requirements imposed on small entities by the proposed regulation. EPA must also consider regulatory alternatives and other measures that can minimize the economic impact of the proposed regulation on small entities while accomplishing the stated objectives of the applicable statute(s). Because the Acts' requirements are potentially resource intensive, analysts first conduct a screening analysis to determine if a full "Regulatory Flexibility Analysis" is required. A detailed analysis is not required if the agency can certify that the rule "*will not, if promulgated, have a significant economic impact on a substantial number of small entities.*" It is EPA's policy, however, to consider a rule's impact on any small entities and minimize any adverse impact to the extent feasible, regardless of whether a full Regulatory Flexibility Analysis is required.

The specific requirements for these analyses focus on the adverse economic impacts of the regulations, and generally do not specifically address benefits. However, disaggregate information on the benefits to small entities may be useful in decision-making, particularly if the benefits analysis addresses cost savings (e.g., from reduced pipe corrosion) that may offset compliance costs. Decision-makers may also be interested in information on the extent to which small systems account for a disproportionately large or small share of the total benefits of the regulations. Actions taken to minimize economic impacts on small entities could include the granting of waivers or the adoption of alternative standards, which will affect overall costs and benefits under the regulations. As noted earlier (in Section 2.1 of this

provisions of SBREFA and RFA.

¹⁵ U.S. Environmental Protection Agency, *National Water Quality Inventory: 1994 Report to Congress*, 1994.

¹⁶ See, for example, U.S. Environmental Protection Agency. "National Primary Drinking Water Regulations: Consumer Confidence; Proposed Rule," *Federal Register*, Vol. 63, No. 30, p. 7605, February 13, 1998.

chapter), the SDWA requirements for considering whether benefits justify costs explicitly take into consideration the availability of variances for small systems.

2.4 Requirements Related to Impacts on Subpopulations

In addition to the SDWA requirements for addressing risks to sensitive subgroups when developing MCLs (see Section 2.1 above), recent executive orders require the consideration of effects on minority and low income groups and children.¹⁷ As mentioned in Section 2.2, both the OMB and EPA guidance also require addressing any potentially disproportionate adverse impacts on a number of groups. Below, we describe the two executive orders and related guidance that explicitly address the risks imposed on specific subpopulations: Executive Order 12898 on environmental justice, and Executive Order 13045 on children's health.

2.4.1 Environmental Justice

Under Executive Order 12898, *Federal Actions to Address Environmental Justice in Minority Populations and Low Income Populations*, each Federal agency is required to identify and address "disproportionately high and adverse human health or environmental effects of its programs, policies, and activities on minority populations and low-income populations." Specifically, the Order requires each agency to develop an environmental justice strategy. This strategy must include provisions for improving related research and data collection efforts, for ensuring greater public participation, and for identifying differential patterns of natural resource consumption among minority and low-income populations.

Accordingly, EPA's 1995 *Environmental Justice Strategy: Executive Order 12898* develops objectives for partnerships, data collection, and outreach in five mission areas central to the promotion of environmental justice:

- public participation, accountability, partnerships, outreach, and communication with stakeholders;
- research on health and environmental issues (e.g., ongoing cooperative studies of drinking water consumption patterns and resulting contaminant exposures by EPA and USDA);
- data collection, analysis, and stakeholder access to public information;
- environmental protection for American Indian, Alaska native and indigenous peoples; and

¹⁷ In addition, as noted earlier Executive Order 13084 requires consultation with tribal groups.

- enforcement, compliance assurance, and regulatory review.¹⁸

EPA's *Environmental Justice Handbook*, issued in September 1993, defines environmental justice as the fair treatment of people of all races, incomes, and cultures with respect to the development, implementation, and enforcement of environmental laws, regulations and policies. To help ensure that fair treatment, the Agency has developed an *Environmental Justice Implementation Plan* designed to foster progress toward achieving the objectives specified in the *Environmental Justice Strategy*. Additional guidance for addressing environmental justice concerns in the context of the National Environmental Policy Act (NEPA) is provided by EPA and the Council on Environmental Quality.¹⁹

In addition, EPA's Office of Ground Water and Drinking Water and Office of Science and Technology are undertaking several efforts to address these issues. EPA published the *Safe Drinking Water Act Guide for Environmental Justice Stakeholders* and convened a meeting of these stakeholders in March 1998.²⁰ EPA's health scientists are also researching several issues concerning the sensitivity of various groups to drinking water contaminants. The implications of these issues for benefits analyses are two-fold. First, the analysis of health risks should consider the extent to which minority groups or low income populations may be more sensitive to the effects of contaminants than the general population, either due to baseline health conditions or patterns of exposure to drinking water contaminants. Second, any disproportionate adverse affects of contaminants on these populations should be addressed and highlighted in benefits analyses.

2.4.2 Children's Health

Recognizing the growing body of evidence that children may be more susceptible or vulnerable to adverse health effects resulting from environmental contaminants, the EPA Administrator in the fall of 1995 issued a *Policy on Evaluating Health Risks to Children*. This policy directed the Agency, when setting standards to protect public health, to explicitly and consistently consider risks to children and infants. The

¹⁸ U.S. Environmental Protection Agency, *Environmental Justice Strategy: Executive Order 12898*, April 1995. More information on environmental justice issues, including information on the other documents cited in this section, can be found on EPA's Environmental Justice Website: <http://www.epa.gov/oeca/oej>.

¹⁹ U.S. Environmental Protection Agency, *Interim Final Guidance for Incorporating Environmental Justice Concerns in EPA's NEPA Compliance Analyses*, Office of Federal Activities, April 1998, and Council on Environmental Quality, *Guidance for Addressing Environmental Justice Under the National Environmental Policy Act*, March 1998.

²⁰ Information on these efforts is available on EPA's Website at http://www.epa.gov/ogwdw/ndwac/sum_ej-a.html.

Policy was subsequently reinforced by the announcement of EPA's *National Agenda to Protect Children's Health from Environmental Threats*. The Agenda stipulated that, as a matter of policy, all standards EPA sets will be protective enough to address the potentially heightened risks faced by children.

In April 1997, President Clinton issued Executive Order 13045, *Protection of Children From Environmental Health Risks and Safety Risks*, directing all Federal agencies to give high priority to the identification and assessment of disproportionate environmental health risks and safety risks to children, to coordinate research on children's health, and to ensure that their standards address disproportionate risks to children.²¹ The Order further directs agencies, when proposing and promulgating regulations concerning environmental health risks or safety risks that may disproportionately affect children, to submit to OMB an evaluation of the proposed regulation's environmental health or safety effects on children, and an explanation of why the proposed regulation is preferable to other reasonably feasible alternatives considered by the agency.

In May 1997, the Administrator created the Office of Children's Health Protection (OCHP) to coordinate the implementation of Executive Order 13045 and the Agency's *National Agenda*. To assist Agency staff in the regulatory development and assessment process, OCHP and the Office of Regulatory Management and Information issued draft Interim Final Guidance on implementation of the executive order in *EPA's Rule Writer's Guide to Executive Order 13045: Guidance for Considering Risks to Children During the Establishment of Public Health-Related and Risk-Related Standards*.²² This guidance is designed to ensure that the "analytical blueprint" for the regulatory development process includes the components required by the Executive Order; it also addresses issues related to distinguishing between risk assessment and risk characterization.

This general concern about children's health effects is also reflected in SDWA. As discussed earlier in Section 2.1, SDWA requires EPA to evaluate health risk reduction benefits for those groups within the population that are likely to be at greater risk of adverse health effects from drinking water contaminants, including infants and children. Benefits analysts therefore pay particular attention to children's health risks when assessing the effects of drinking water regulations, highlighting potentially significant impacts.

²¹ These documents and other information related to children's health effects are available on EPA's Website at: <http://www.epa.gov/children>.

²² U.S. Environmental Protection Agency. *EPA's Rule Writer's Guide to Executive Order 13045: Guidance for Considering Risks to Children During the Establishment of Public Health-Related and Risk-Related Standards*, Review Draft, April 21, 1998.

2.5 An Integrated Approach

As the above discussion makes clear, the development of drinking water regulations is subject to the provisions of several statutes, executive orders, and guidance documents. One of the primary challenges for regulatory analysts and decision-makers in assessing the benefits of regulatory options is to integrate these many requirements into a coherent analytic strategy. This strategy generally includes a national benefit-cost assessment, and, as appropriate, evaluation of the effects on distinct subgroups of the affected population (e.g., small businesses, government entities, children, minorities, or low-income households).

Some of the statutes and executive orders discussed earlier are applicable to all actions taken by the Agency, whereas others are applicable only to "major" regulations. Exhibit 2-2 summarizes the applicability of each set of requirements. In parentheses, we indicate the section of this chapter that provides more information on each set of requirements and that references sources of additional information on applying these criteria.

Exhibit 2-2
Applicability of Statutory and Executive Order Requirements
for Benefit-Cost Analysis

Safe Drinking Water Act (see Section 2.1 above): All National Primary Drinking Water Regulations.

Executive Order 12866, "Regulatory Planning and Review" (see Section 2.2.1 above): All "significant regulatory actions" that may "(1) Have an annual effect on the economy of \$100 million or more or adversely affect in a material way the economy, a sector of the economy, productivity, competition, jobs, the environment, public health or safety, or State, local, or tribal governments or communities; (2) Create a serious inconsistency or otherwise interfere with an action taken or planned by another agency; (3) Materially alter the budgetary impact of entitlements, grants, user fees, or loan programs or the rights and obligations of recipients thereof; or (4) Raise novel legal or policy issues arising out of legal mandates, the President's priorities, or the principles set forth in this Executive Order."

Unfunded Mandates Reform Act (see Section 2.3.1 above): All rules that "may result in the expenditure by State, local, and tribal governments, in the aggregate, or by the private sector, of \$100,000,000 or more (adjusted annually for inflation) in any 1 year."

EPA Guidelines for Preparing Economic Analyses (see Section 2.2.2 above): Not specified; generally applies to all economic analyses prepared by EPA.

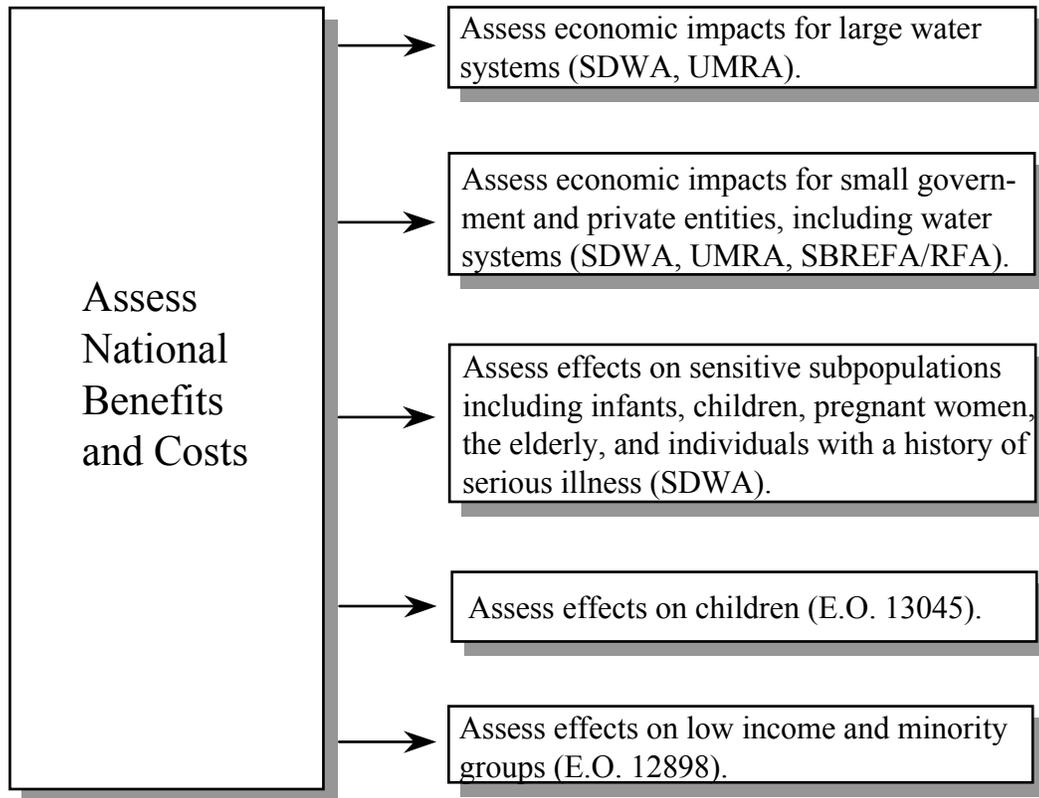
Small Business Regulatory Enforcement Fairness Act and the Regulatory Flexibility Act (see Section 2.3.2 above): All rules that will have "a significant economic impact on a substantial number of small entities."

Executive Order 12898, "Federal Actions to Address Environmental Justice in Minority Populations and Low Income Populations" (see Section 2.4.1 above): No specific criteria; generally applies to all EPA programs.

Executive Order 13045, "Protection of Children from Environmental Health Risks and Safety Risks" (see Section 2.4.2 above): All "economically significant" rules as defined under Executive Order 12866 that "concern an environmental health risk or safety risk that an agency has reason to believe may disproportionately affect children."

Exhibit 2-3 summarizes the necessary disaggregated analyses and indicates the source of the requirement (e.g., SDWA), as discussed in previous sections of this chapter.

Exhibit 2-3
Summary of Required Analyses



To meet the requirements specified in Exhibit 2-3, benefits analysts work with others, such as cost analysts, health scientists, and stakeholders, in developing the overall economic analysis. Proper assessment of disproportionate health risks to sensitive populations, for example, involves consultation with health researchers and risk assessors to integrate the latest information on health risks to children and other groups. Similarly, effective and meaningful comparison of benefits and costs for small entities involves working closely with cost analysts and representatives of small water systems to address related impacts.

METHODS FOR BENEFITS ANALYSES CHAPTER 3

Regulations establishing Maximum Contaminant Levels (MCLs) or treatment requirements under the Safe Drinking Water Act (SDWA) may have several types of benefits. On a national level, the most significant benefits generally will be improvements in human health. As described in Chapter 1, other benefits may include aesthetic effects (such as improved taste or odor) and effects on materials (such as reduced pipe corrosion). Regulations that lead to greater source water protection may also have ecological benefits, such as increased protection of biodiversity.

As discussed in Chapter 2, analysis of these types of effects is necessary to meet the SDWA requirements for assessing the extent to which the benefits of achieving the lowest feasible MCL may be commensurate with the costs. Benefit-cost analysis is also necessary for all major rulemakings under government-wide and EPA requirements. These analyses also address the impact of regulations on certain groups of concern (including state and local governmental units, private entities, minorities, low income groups, and children), as required by SDWA and several statutes and executive orders.

The practice of benefits assessment is based on the discipline of welfare economics. In this chapter, we briefly introduce the theoretical foundation and economic methods for benefits analysis, then describe "best practices" for assessing particular types of benefits.²³ Although it is generally useful to express the value of benefits in dollar terms using the methods discussed below, analysts may often find that it is not possible to quantify or value all of the benefits of drinking water regulations. In such cases, nonquantified and nonmonetized benefits are carefully described in the analysis so that they can be taken into consideration by decision-makers.

This chapter is divided into three parts. First, we introduce the economic concepts that provide the foundation for benefits analyses. Next, we describe research methods commonly used to determine the dollar value of these benefits. Finally, we describe approaches for assessing specific types of benefits in more detail. Chapter 4 discusses the transfer of benefit estimates from existing studies to the analysis of drinking water regulations, while Chapter 5 provides information and examples related to implementing these methods.

²³ For a more detailed technical discussion of the economic theory and methods for benefits assessment described in this chapter, see: U.S. Environmental Protection Agency, *Guidelines for Preparing Economic Analyses*: EPA 240-R-00-003, September 2000; and, Freeman, A. Myrick III, *The Measurement of Environmental and Resource Values: Theory and Methods*, Resources for the Future, Washington, D.C., 1993.

3.1 The Economist's Perspective

The simplest way to value benefits from a drinking water regulation would be to use market data or survey responses to determine directly the value of decreasing contaminant concentrations. For example, if a "decrease in arsenic contaminant concentrations from 50 µg/L to 10 µg/L" was a product available for purchase, we could use market data on the demand for this product to value benefits. Alternatively, we could survey consumers and ask how much they would be willing to pay to reduce contaminant concentrations by specific amounts.

Unfortunately, we often cannot determine the value of benefits in such a straightforward manner. Because reductions in contaminant concentrations are not goods that are directly bought and sold, there is little empirical information on the prices people would be willing to pay for these reductions. In addition, people who are not familiar with the effects of individual drinking water contaminants may have difficulty responding to a survey asking them what they would be willing to pay for reduced concentrations; conducting a survey that fully informs them about each contaminant can be quite expensive and time consuming.

Faced with these difficulties, benefit analysts usually begin by listing the possible effects reduced by the regulations, then focus on valuing each specific effect (such as the changes in the risks of contracting a particular disease). Values are derived for each effect, then aggregated (taking care to avoid double-counting) to determine the total benefits of the regulations. For example, rather than directly estimating the value of a specific reduction in the concentrations of a chemical (such as arsenic or benzene), analysts generally estimate the value of the risks averted (such as the risks of incurring certain nervous system disorders or kidney cancer) and other benefits (such as improved taste or odor), then aggregate the values of these effects to determine the total benefits of the rule.

To determine the monetary value of these benefits, economists focus on what people would be willing to pay for specific health improvements and other effects of the regulations. The basis for this focus on willingness to pay, and its advantages and limitations, are described below.

3.1.1 Willingness to Pay

In considering policies that affect social welfare, economists begin with the assumption that individuals derive utility (or a sense of satisfaction or well-being) from the goods and services they consume. Conversely, people may derive disutility from negative experiences, such as illness or harm to the environment. Individuals can maintain the same level of utility while trading off different bundles of goods and services (e.g., one may be equally happy going to the movies or a baseball game), and their willingness to make these trade-offs can be measured in dollar terms.

In theory, the dollar value of the benefits associated with a regulatory requirement is most appropriately measured by determining the change in income that has the same effect on utility (or the level of individual satisfaction) as the requirement. Because utility is impossible to measure directly, economists rely instead on estimates of willingness to pay or willingness to accept compensation to value the effects of regulations and other actions that lead to improvements in environmental quality. Willingness to pay is the maximum amount of money an individual would voluntarily exchange to obtain an improvement (e.g., in drinking water quality), given his or her budget constraints. Willingness to accept is the least amount of money an individual would accept to forego the improvement.

These two measures are not necessarily equal. One reason for the difference is that the two measures have different starting points. For environmental improvements, willingness to pay uses the level of utility *without* the improvement as a reference point, while willingness to accept uses as its reference point the level of utility *with* the improvement. Under conventional assumptions, economists expect that the difference between these measures will be small in many cases; e.g., as long as the amount involved is not a significant proportion of income.²⁴ In practice, benefits analysts usually rely on measures of willingness to pay because of concerns about the accuracy and reliability of the methods available for estimating willingness to accept compensation.²⁵ Willingness to pay is generally easier to measure and quantify.

While willingness to pay is constrained by income, it is a different concept than affordability. "Affordability" is a nontechnical term that is often used to refer to peoples' judgements about what is "reasonable" to pay for a particular good or service. In contrast, willingness to pay is the maximum amount an individual would *actually* pay for a good or service, given his or her income constraints and other desired expenditures.²⁶

²⁴ In the case of environmental goods, additional considerations may lead to larger differences between willingness to pay and willingness to accept, as discussed in EPA's *Guidelines for Preparing Economic Analyses* and Hanemann, W.M., "Willingness to Pay and Willingness to Accept: How Much Can They Differ?," *American Economic Review*, Volume 81, Number 3, 1991, pp. 635- 647.

²⁵ Accuracy refers to whether the findings are correct; for example, to how well the study results mirror the value in the underlying population. Reliability refers to whether the findings can be replicated; for example, to whether applying a survey to a second sample would result in the same or similar estimates as those from the first sample.

²⁶ While it is reasonable to assume that individuals' donations to environmental causes or organizations reflect willingness to pay for protection and preservation of the environment, these contributions cannot be interpreted as a direct proxy for willingness to pay. Donations generally reflect only partial values; for example, some people will not make

Willingness to pay is also a different concept than cost or price. "Cost" refers to the resources needed to produce a good or service; it does not measure the value of the good or service to members of society. "Price" is determined by the interactions of suppliers and consumers in the marketplace. For some individuals, the market price may exceed willingness to pay, in which case they will not purchase the good. For other individuals, willingness to pay may exceed the current price, in which case these individuals will benefit from the fact that the market price is less than he or she is willing to pay.

Economists refer to the aggregate amount that individuals are willing to spend on a good or service over and above that required by the market price as "consumer surplus." Changes in this surplus can be used to measure the benefits of various policy options. For example, if a government program reduces the price of a good or service, consumers are likely to purchase more of the product. For some consumers, the price drop will cause the difference between price and willingness to pay to rise. These impacts will increase consumer surplus, and the dollar amount of the increase can be used to measure the social welfare benefits of the policy.²⁷

Measuring the value of benefits in dollar terms, based on estimates of willingness to pay, provides useful information for decision-makers. First, it is easier to compare costs and benefits and make related decisions when both are expressed in monetary terms. Second, valuation (accompanied by discussion of uncertainties in the estimates used) provides explicit, objective information on the amount of money members of society would be willing to exchange for the benefits of alternative drinking water standards or other policy choices.

the donation if they believe that payments by others will lead to an adequate level of environmental protection.

²⁷ The concept of consumer surplus, and its relationship to the analysis of benefits, is described in more detail in: EPA's *Guidelines for Preparing Economic Analyses*; Freeman (1993); and Just, R.E., D.L. Hueth, and A. Schmitz, *Applied Welfare Economics and Public Policy*, Englewood Cliffs, NJ: Prentice Hall, 1982.

3.1.2 Equity Considerations

Some critics of the use of willingness to pay to value benefits are concerned about the effect of income on these values. If policy decisions were made solely on the basis of willingness to pay, critics argue, the results would not treat lower income individuals equitably. Economists deliberately attempt to separate these types of ethical judgements from the economic analysis of efficiency. They traditionally focus on how individuals value changes in their own well-being, aggregating the individual values to determine total benefits to society. If the group of individuals who benefit from a policy could compensate the group of individuals who are adversely affected, economists argue that net social welfare is maximized and the policy is considered economically efficient.

To address the limitations of this approach, economic analyses of EPA regulations are supplemented by analyses of effects on equity. As discussed in Chapter 2, analyses of environmental justice (risks and other effects on low income and minority groups) and risks to children are required for major EPA regulations. In addition, SDWA requires that EPA consider effects on sensitive subpopulations "such as infants, children, pregnant women, the elderly, and individuals with a history of serious illness, or other subpopulations likely to be at greater risk..." [SDWA, Section 1412(b)(3)(C)(i)]. SDWA also raises concerns about "affordability," particularly for small systems [SDWA, Section 1412(b)(4)(E)].²⁸ Requirements under other statutes mandate consideration of the costs the regulations impose on government units and private entities, as also discussed in Chapter 2.

The language of SDWA (e.g., on sensitive subpopulations and small systems) suggests that these types of equity effects should be considered when determining whether the costs of an MCL are justified by its benefits. In other words, SDWA appears to define "benefits" broadly to include both equity and traditional economic concerns about net social welfare. Because detailed information on conducting equity assessments is provided in the references cited in Chapter 2, we focus on the economic assessment of benefits in the remainder of this document.

The economic analyses described in this document can be designed to support the equity analyses. For example, in developing new studies, analysts may wish to ensure that these groups are adequately represented in the data collection strategy. When presenting the results of the analysis, analysts may decide to provide disaggregated estimates of the benefits for each subpopulation or group of concern, as well as national totals.

²⁸ Information on EPA's definition of "affordability" for SDWA requirements is available in: U.S. Environmental Protection Agency, *Announcement of Small System Compliance Technology Lists for Existing National Primary Drinking Water Regulations and Findings Concerning Variance Technologies*, 63 FR 42032, August 6, 1998.

3.1.3 Nonquantified and Nonmonetized Benefits

The economic framework for benefits analysis described in this document focuses on developing monetary measures for valuing benefits. Many benefits, however, can be difficult to quantify, or may be quantifiable but difficult to value in monetary terms. These types of benefits are generally described in the analysis and noted in any summary of the findings. SDWA specifically calls for consideration of such benefits, noting that "quantifiable and nonquantifiable" effects should be taken into account when establishing an MCL [SDWA, Section 1412(b)(3)(C)(i)].

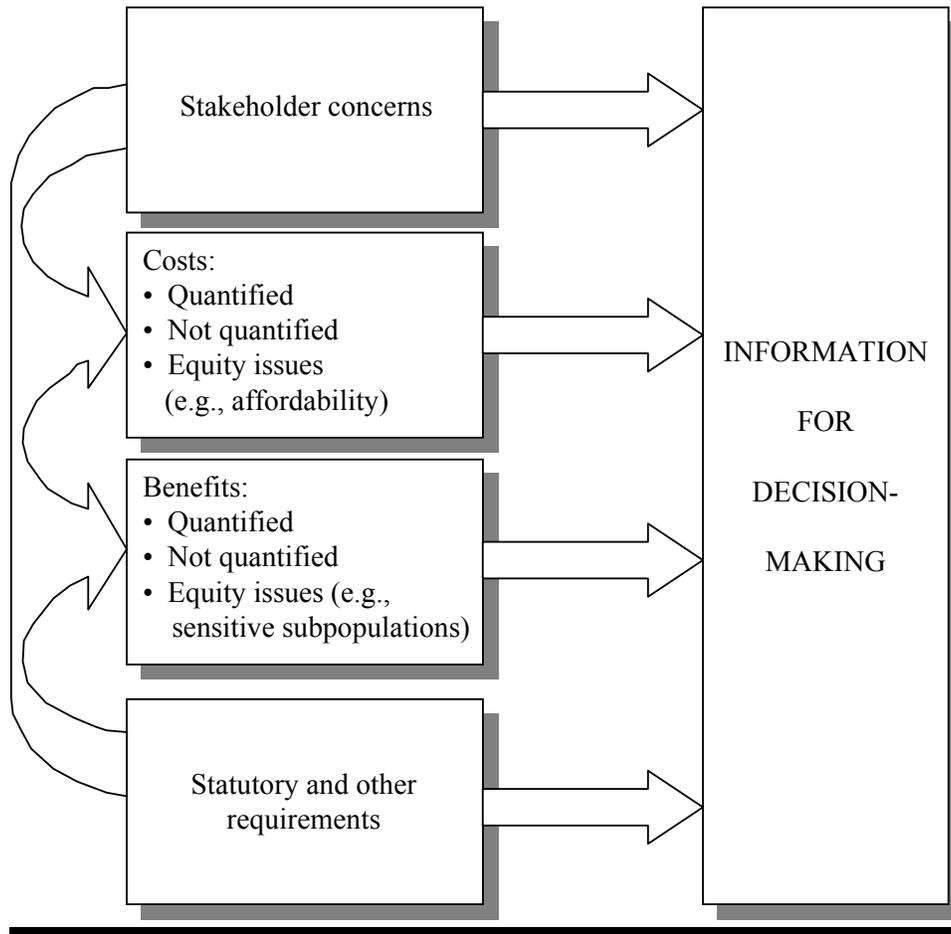
For example, EPA may know that a drinking water contaminant causes adverse health effects, but lack data on how changes in exposure levels correspond to changes in the incidence or severity of the effects. Despite this uncertainty, EPA may consider these effects when establishing regulatory levels to ensure that human health is adequately protected. These nonquantified or nonmonetized benefits are often presented in the same tables or charts as the quantified results to ensure that they are taken into account by decision-makers, along with information on the uncertainties in the estimates.

When conducting a benefit-cost analysis, analysts may find that the quantified costs exceed the monetized benefits or vice-versa. The question then becomes determining whether it is reasonable to assume that the nonquantified or nonmonetized benefits (or costs) bridge the gap between the quantified costs and benefits. In some cases, the gap may be small enough that decision-makers will conclude that benefits may be equal to, or exceed, costs if nonquantified effects are considered. Analysts may also consider whether the nonquantified impacts could disproportionately impact the results across regulatory options. For example, if consideration of a particular health effect (e.g., a type of cancer not quantified in the analysis) is likely to increase the benefits estimates by a similar percentage across all regulatory options, its consideration may not change the relative rankings of the options. However, if the impacts are uneven (e.g., some regulatory options do not reduce exposure below the threshold level at which a health effect occurs), consideration of the nonquantified benefits may affect the relationship between costs and benefits for only some of the regulatory options.

The factors to be considered by decision-makers are summarized in Exhibit 3-1. As indicated by the exhibit, the analysis of costs and benefits includes quantified and nonquantified effects and addresses concerns about the distribution (or equity) of these impacts. Statutory requirements and stakeholder concerns help shape the

contents of the analyses as well as the use of the analyses in regulatory decision-making.

**Exhibit 3-1
Information for Decision-Making**



3.2 Primary Valuation Methods

As discussed above, the preferred approach for valuing the benefits of environmental regulations generally is to determine individuals' willingness to pay (WTP) for the proposed improvements. When market data are not available, economists use a variety of other methods to estimate willingness to pay.²⁹ One of several approaches

²⁹ For information about market methods, see EPA's *Guidelines for Preparing Economic Analyses*.

for categorizing these methods is to divide them into two categories: *stated preference methods* and *revealed preference methods*.³⁰

Stated preference methods typically employ survey techniques and ask respondents to "state" what they would pay for a good or service. These methods can be used to directly value the program of concern (e.g., "how much would you be willing to pay for a program that would reduce the concentrations of arsenic in drinking water from 10 µg/L to 5 µg/L?"), in which case they are designed to fully inform respondents about the effects of the reduction. Such studies are also used to assess specific effects (e.g., "how much would you be willing to pay for a program that would reduce the risks of incurring kidney disease from 10/100,000 to 5/100,000 annually?"). Stated preference methods are attractive in theory because they allow researchers to directly elicit values for particular effects. However, conducting a study that yields accurate and reliable results can be expensive, and relatively few have been completed that directly address the effects of concern for drinking water contaminants.

Revealed preference methods are based on observed behaviors that can "reveal" the values of nonmarket goods based on prices and preferences for related market goods or services. For example, if an individual would be charged \$30 a month for tap water to drink, but instead pays \$50 per month for bottled water that he or she believes to be cleaner and safer, then presumably this individual values the additional cleanliness and safety of the bottled drinking water at no less than \$20 per month (\$50 - \$30 = \$20). These methods use actual market data for related goods instead of relying on individuals' predictions of their own behavior. However, there is often an imperfect match between the commodities valued in these studies and individuals' willingness to pay for the effects associated with a particular rule.

Below, we introduce each of the primary research methods most likely to be used in valuing the effects of drinking water regulations; the footnotes provide references for more information on each method. We describe contingent valuation and conjoint analysis, wage-risk studies, cost-of-illness research, averting behavior studies, and avoided cost methods.

³⁰ More information on methods for valuing the benefits of drinking water regulations as well as examples of these studies is available in: Research Triangle Institute, *Valuing Water Quality: Theory, Methods, and Research Needs*, prepared for the U.S. Environmental Protection Agency, April 1998.

3.2.1 Contingent Valuation and Other Stated Preference Methods

Contingent valuation (CV) is a stated preference method that uses consumer surveys to directly elicit statements of willingness to pay for a commodity.³¹ The values derived from the surveys are "contingent" on the realization of the scenarios described in the study. For example, a survey might ask individuals what they would be willing to pay for a specified reduction in the risk of developing kidney disease from long-term exposure to contaminants in drinking water. The researcher can define the scenario to address all the factors that may influence total willingness to pay, such as pain and suffering in the case of illness.

Contingent valuation surveys can be used to derive estimates for the full range of effects of environmental regulations, including changes in mortality and morbidity risks, improved aesthetic effects, reduced damages to materials, and changes in ecological risks. Contingent valuation is also the primary method used to assess the "nonuse" values of natural resources, such as the value of simply knowing that clean water exists.³² Some examples of contingent valuation studies are provided in Exhibit 3-2.

³¹ For more information on contingent valuation, see: Bjornstad, D.J. and J.R. Kahn, *The Contingent Valuation of Environmental Resources: Methodological Issues and Research Needs*, Edward Elgar: Brookfield, VT, 1996; Carson, R.T., "Contingent Valuation: A User's Guide," *Environmental Science and Technology*, Vol. 34, 2000, pp. 1413-1418; Hanemann, W. Michael, "Valuing the Environment through Contingent Valuation," *Journal of Economic Perspectives*, Fall 1994, Vol. 8, No. 4, pp. 19-43; Kopp, R., W.W. Pommerehne, and N.T. Schwarz, (eds.), *Determining the Value of Non-Marketed Goods*, Boston, MA: Kluwer Academic Publishers, 1997; and Mitchell, R. and R.T. Carson, *Using Surveys to Value Public Goods: The Contingent Valuation Method*, Resources for the Future, Washington, DC, 1989.

³² For more information on nonuse values, see: Kopp, R.J., "Why Existence Value Should be Used in Cost-Benefit Analysis," *Journal of Policy Analysis and Management*, Vol. 11, No. 1, pp. 123-130, 1992; and Cummings, Ronald G. and Glenn W. Harrison, "The Measurement and Decomposition of Nonuse Values: A Critical Review," *Environmental and Resource Economics*, Vol. 4, pp. 225-247, 1995.

Exhibit 3-2

Examples of Contingent Valuation Studies³³

Fatal Risks: Jones-Lee, et al. used contingent valuation to estimate individuals' willingness to pay to avoid the risk of death from auto accidents. The study also explored willingness to pay to reduce fatal risks for other people (e.g., passengers) and other types of fatalities (e.g., from heart disease and cancer). The researchers conducted face-to-face interviews with 1,103 persons in Great Britain and asked them to consider the value of avoiding fatalities expressed as "X" in 100,000 risks. Converted from British pounds (using the 1982 exchange rate) and inflated to 1997 dollars (using the GDP deflator), the average value of a statistical life resulting from this study is \$4.6 million.

Minor Health Problems: Berger, et al. used contingent valuation to study willingness to pay to avoid an additional day of minor health problems such as headaches and itching eyes. Participants were asked to rank seven minor health problems, state values for symptom-free days, and summarize the values on a tally sheet. The researchers interviewed 119 respondents and determined, for example, that the average willingness to pay to avoid a day of headache is \$109, and a day of itching eyes is \$48 (1984 - 85 dollars).

Ground Water Protection: Powell studied individuals' willingness to pay for ground water protection using a contingent valuation survey conducted in 12 towns in the northeast. The survey was performed by mail and 1,041 people responded. The questionnaire presented information on contamination and asked respondents to indicate their willingness to pay for a water supply protection district funded through increased utility bills. Mean willingness to pay was \$62 per household per year (1990 dollars).

Despite the widespread applicability and use of contingent valuation, the method has been heavily criticized in recent years. This criticism focuses largely on the measurement of nonuse values; the application of contingent valuation surveys to other types of effects tends to be less controversial. Contingent valuation studies need to be carefully implemented if they are to provide accurate and reliable estimates of willingness to pay, because individuals generally are not required to actually make the payments and may not fully understand the scenario presented in the survey.

Much of the debate has centered on the use of contingent valuation to assess damages to natural resources from oil spills and other contamination events as part of related litigation. The National Oceanic and Atmospheric Administration (NOAA) convened an expert panel in 1992 to develop guidelines for using

³³ Jones-Lee, Michael W., M. Hammerton and P.R. Phillips, "The Value of Safety: Results of a National Sample Survey," *Economic Journal*, Vol. 95, March 1985, pp. 49-72; Berger, M.C., et al., "Valuing Changes in Health Risks: A Comparison of Alternative Measures," *Southern Economic Journal*, Vol. 53, 1987, pp. 967-984; Powell, John R., David J. Allee, and Charles McClintock, "Groundwater Protection Benefits and Local Community Planning: Impact of Contingent Valuation Information," *American Journal of Agricultural Economics*, Vol. 76, December 1994, pp. 1068-1075.

contingent valuation to estimate nonuse values in such situations.³⁴ The panel made several recommendations for improving the reliability of these studies, such as encouraging in-person interviews (rather than mail or telephone surveys) and extensive pretesting of questionnaires and accompanying materials. Following the panel's recommendations can substantially increase the costs of contingent valuation research (e.g., to over \$1 million per study) and very few existing studies fully comply with these guidelines. Several of the recommendations are controversial and may not be relevant to studies conducted for purposes other than assessment of nonuse values for litigation. As a result, EPA is currently developing its own guidelines to specifically address the use of contingent valuation for policy analysis.

Economists recently have been experimenting with other stated preference methods, particularly those referred to as conjoint analyses.³⁵ These methods are relatively complex and include presenting respondents with several scenarios involving various amenities and prices. Estimates of willingness to pay may be elicited based on the way in which respondents rank, rate, or construct equivalent sets of alternatives. For example, Adamowicz et al. asked respondents to make choices among several hypothetical fishing scenarios that differed along 13 attributes such as site terrain, average fish size, and water quality, and combined the results with data on actual site choices to value recreational opportunities.³⁶

The "risk-risk trade-off" method is closely related to conjoint analysis, and has been used in research conducted by Viscusi and others to value changes in health risks. For example, Viscusi, et al. developed a computerized questionnaire that asked respondents to choose between places to live which varied with respect to the cost

³⁴ National Oceanic and Atmospheric Administration (NOAA), "Appendix I - Report of the NOAA Panel on Contingent Valuation," *Federal Register*, Vol. 58, No. 10, pp. 4602-4614, January 15, 1993. The official EPA response to these guidelines can be found in: U.S. Environmental Protection Agency, "Comments on Proposed Regulations on Natural Resource Damage Assessment," 1994.

³⁵ For more information on conjoint methods, see: Adamowicz, Wiktor, Jordan Louviere, and Joffre Swait, *Introduction to Attribute Based Stated Choice Methods*, prepared for the National Oceanic and Atmospheric Administration, January 1998; and Smith, V.K. "Pricing What is Priceless: A Status Report on NonMarket Valuation of Environmental Resources," *The International Yearbook of Environmental and Resource Economics, 1997/1998: A Survey of Current Issues*, (H. Folmer and T. Tietenberg, eds.), 1997.

³⁶ Adamowicz, Wiktor, et al., "Combining Revealed Preference and Stated Preference Methods for Valuing Environmental Amenities," *Journal of Environmental Economics and Management*, Vol. 26, No. 3, pp. 271- 292, 1994.

of living, the risks of chronic bronchitis, and/or the risks of automobile fatalities.³⁷ The results indicated that the median value of avoiding a case of chronic bronchitis is 32 percent of the value of avoiding an automobile fatality. When asked to trade-off changes in the cost of living for changes in risk, respondents indicated that the mean value of avoiding a case of chronic bronchitis was \$457,000 (1988 dollars).

3.2.2 Wage-Risk Studies

A wage-risk (or hedonic wage) study is a revealed preference method that values changes in risk by examining the additional compensation workers demand for taking jobs with higher risks. Typically, these studies focus on small changes in the risks of accidental workplace fatalities. Researchers use statistical methods to separate changes in compensation associated with changes in risks from changes in compensation associated with other job and personal characteristics.³⁸ An example of a wage-risk study is provided below.

Exhibit 3-3 Example of a Wage-risk Study³⁹

Fatal Risks: Moore and Viscusi used data from the Bureau of Labor Statistics (BLS) and the National Institute of Occupational Safety and Health (NIOSH), combined with information on worker attributes from the Panel Study of Income Dynamics, to estimate the value of a statistical life. The mean value of the risks studied was 5×10^{-5} for the BLS data and 8×10^{-5} for the NIOSH data. The researchers found that the value of statistical life estimates resulting from the NIOSH data (\$6 million to \$7 million) are significantly larger than values from the BLS data (\$2 million), and argue that the NIOSH values are likely to be more accurate (1986 dollars).

The wage-risk approach has several advantages. For example, the data and methods for estimating risk reduction and associated wage differentials have been well-established through a number of studies. In addition, the approach directly measures changes in the risk of premature mortality. A number of factors, however, may complicate the use of wage-risk studies to value the benefits of drinking water regulations. For example, workplace risks usually involve some degree of voluntary acceptance, while environmental risks usually affect individuals involuntarily. In addition, most wage-risk studies use data on middle-aged laborers (often male), who may not be representative of the members of the population most significantly

³⁷ Viscusi, W.K., Magat, W.A., and Huber, J., "Pricing Environmental Health Risks: Survey Assessments of Risk-Risk and Risk-Dollar Tradeoffs," *Journal of Environmental Economics and Management*, 1991, Vol. 201, pp. 32-57.

³⁸ More information on wage-risk studies is provided in: Viscusi, W.P., "The Value of Risks to Life and Health," *Journal of Economic Literature*, Vol. 31, 1993, pp. 1912-1946.

³⁹ Moore, Michael J. and W. Kip Viscusi, "Doubling the Estimated Value of Life: Results Using New Occupational Fatality Data," *Journal of Policy Analysis and Management*, Vol. 7, No. 3, 1988, pp. 476-490.

affected by the risks associated with drinking water contaminants. Despite these limitations, these revealed preference studies may provide the most defensible estimates of the value of mortality risk reductions and are the source of many of the estimates used by EPA when valuing these risks, as discussed in more detail later in this chapter.

3.2.3 Cost-of-Illness Studies

Cost-of-illness (COI) studies are frequently used to value morbidity (i.e., nonfatal health effects). These studies examine the actual direct (e.g., medical expenses such as doctor visits, medication, and hospital stays) and indirect (e.g., lost wages) costs incurred by affected individuals.⁴⁰ While cost-of-illness is sometimes categorized as a revealed preference method, it does not directly measure willingness to pay. In general, the logic for using these studies to value benefits is as follows: if illness imposes the costs of medical expenditures and foregone earnings, then a regulation leading to a reduction in illness yields benefits equal at minimum to the costs saved.⁴¹

The cost-of-illness method has several advantages, including: (1) it is well-developed, widely applied, and easily explained; (2) many of the types of costs it includes are easily measured; and (3) existing studies provide estimates for a large number of illnesses. These studies can be designed to address all expenditures associated with an illness, regardless of whether they are paid by the patient or a third party (i.e., insurance). Lost productivity can be estimated by lost wages for those in the paid labor force; however, lost productivity for unpaid labor in the home and lost leisure time can be more difficult to measure. Examples of cost-of-illness estimates are provided in Exhibit 3-4.⁴²

⁴⁰ Sources of more information on cost-of-illness methods include: U.S. Environmental Protection Agency, *Cost of Illness Handbook*, February 2001; Hartunian, N.S., C.N. Smart, and M.S. Thompson, *The Incidence of Economic Costs of Major Health Impairments*, Lexington Books: Lexington, MA, 1981; Hu, T. and F.H. Sandifer, *Synthesis of Cost-of-Illness Methodology: Part I*, report to the National Center for Health Services Research, U.S. Department of Health and Human Services, 1981.

⁴¹ Tolley, G., D.Kenkel, and R. Fabian (Eds.), *Valuing Health for Policy: An Economic Approach*, University of Chicago Press, 1994.

⁴² Although cost of illness values have been developed for both fatal and nonfatal health effects, the value of statistical life is generally the preferred valuation measure for fatalities, as discussed later in this chapter. Cost-of-illness estimates are generally applied to those nonfatal health effects for which estimates of willingness to pay are unavailable.

Exhibit 3-4
Examples of Cost of Illness Studies⁴³

Stomach Cancer: Based on research conducted by Baker et al, EPA examined both the medical costs and the lost time that result from stomach cancer. For survivors diagnosed at age 70, the direct medical costs for the 10 years following diagnosis were estimated at \$85,700 per case (present value, 1996 dollars, 7 percent discount rate).

Low Birth Weight: Low birth weight in infants can lead to a variety of medical disorders, including heart failure and severe developmental disabilities. Infants with low birth weight incur high medical costs in their first year, but also tend to continue to incur elevated medical costs throughout their life. Based on research conducted by Lewitt et. al, EPA examined these costs as well as non-medical costs stemming from the need for special education and grade repetition. The present value (discounted at 7 percent) of the costs over a lifetime were estimated as \$80,600 per case (1996 dollars).

Contaminated Water Supply: Harrington, et al. valued the losses incurred by households as a result of a water contamination episode in Luzerne County, Pennsylvania, during 1983 to 1984. As part of this analysis, they estimated the costs due to illness resulting from water contamination, including direct medical costs (doctor visits, hospital visits, emergency room visits, laboratory tests and medication), and time costs (including time spent obtaining medical care and related travel, lost work days, lost work productivity, and lost leisure time). The study relies on survey data (mail and phone) from affected households. Depending on the wage rate assumptions, the researchers found that cost-of-illness related losses averaged between approximately \$900 and \$1,300 per confirmed case of giardiasis (1984 dollars).

Although these studies are widely used for valuation, they generally do not provide estimates of willingness to pay. In many cases, cost-of-illness estimates may significantly underestimate individual willingness to pay, because they do not address the value of avoiding the pain and suffering associated with the illness, costs that an individual may have incurred in order to avoid the illness, and other factors. Cost-of-illness estimates may also occasionally overstate willingness to pay because the availability of insurance may lead people to agree to treatments that they would not willingly finance themselves.

In addition, cost-of-illness estimates do not reflect value associated with an individual's risk aversion, i.e., his or her willingness to pay to avoid future risks. Treatment also often does not return people to their original health state and hence does not address all of the benefits of avoiding the illness entirely.

3.2.4 Averting Behavior Studies

Averting behavior studies are a revealed preference method that use data on consumer behavior to estimate willingness to pay for risk reductions or other

⁴³ EPA's *Cost of Illness Handbook*; Harrington, Winston, Alan J. Krupnick and Walter O. Spofford, Jr., "The Economic Losses of a Waterborne Disease Outbreak," *Journal of Urban Economics*, Vol. 25, 1989, pp. 116-137.

effects.⁴⁴ For example, in the absence of regulation, individuals or households may avoid the health risks and aesthetic effects associated with drinking water contaminants by using bottled water, treating water at the tap, or using water softeners. Some of these studies also consider the medical treatments sought in response to particular types of contamination. If a regulation leads people to discontinue these behaviors, then the avoided costs may be one measure of the resulting benefits.

The averting actions considered in these studies often fall into three categories: (1) the purchase of a durable good (e.g., a water filter); (2) the purchase of a nondurable good (e.g., bottled water); and (3) a change in daily activities or behavior (e.g., boiling water before use or consuming less drinking water). Some averting actions allow an individual to completely eliminate exposure to the perceived contamination, while others allow the individual to mitigate the effects of potential exposure. The costs considered in such studies are sometimes referred to as defensive expenditures.

Use of these studies for benefits valuation can pose difficult problems related to separating out different motives for the behavior. For example, bottled water purchases may reflect the desire for convenience, or for better taste, as well as the desire to avoid the perceived risks of tap water ingestion. In addition, use of bottled water may reflect concerns about a wide variety of contaminants and health effects. It may be impossible to disentangle the various complex motives for engaging in these behaviors, and several of these motives may not be addressed by the regulations under consideration.

The extent to which such studies provide an estimate of willingness to pay is a subject of debate in the literature, and depends in part on the nature of the policy problem and the types of expenditures considered by the researcher. For example, bottled water expenditures may overstate the value of risk reductions if they also reflect convenience and taste. However, studies that consider only the money and time expended on boiling or purchasing water in response to drinking water contamination are likely to understate willingness to pay to avoid the contamination,

⁴⁴ For more information on averting behavior studies see: Cropper, Maureen, and A. Myrick Freeman III, "Environmental Health Effects." *Measuring the Demand for Environmental Quality* (J.B. Branden and C.D. Kolstad, eds.), Elsevier Science Publishers: The Netherlands, 1991, pp. 165 - 213; Bartik, Timothy J., "Evaluating the Benefits of Nonmarginal Reductions in Pollution Using Information on Defensive Expenditures," *Journal of Environmental Economics and Management*, Vol. 15, 1988, pp. 111-127; Courant, Paul and Richard Porter, "Averting Expenditure and the Cost of Pollution," *Journal of Environmental Economics and Management*, Vol. 8, 1981, pp. 321-329; and Desvousges, W.H., F.R. Johnson, and H.S. Banzhaf, *Environmental Policy Analysis with Limited Information: Principles and Applications of the Transfer Method*, Northampton, MA: Edward Elgar, 1998.

since they leave out other responses to these incidents and do not address the value of averting the dread of such incidents.

In theory, researchers could combine data on averting behavior with other types of information (such as data on the associated changes in risk) to estimate willingness to pay for risk reductions. They could then apply statistical methods to separate the value of the risk reduction from the value of other effects. Because separating the value of the different effects of averting behavior is difficult (requiring a relatively large amount of data and the application of complex analytic techniques), such analysis is rarely, if ever, attempted.

In Exhibit 3-5, we provide examples of various types of averting behavior studies.

Exhibit 3-5
Examples of Averting Behavior Studies⁴⁵

Lead Exposure: Agee and Crocker applied the averting behavior method to assess willingness to pay for reduced lead exposures. They assessed data for 256 Massachusetts children, considering the child's body burden of lead, parental decisions regarding treatment, and household characteristics such as the parent's educational level and income. They found that the mean value of a one percent reduction in child body lead burden ranged from \$11 to \$104 (1980 dollars).

Drinking Water Contamination -- Trichloroethylene: Abdalla, et al. researched the effect of a drinking water contamination incident in Perkasio, Pennsylvania, where trichloroethylene was detected in a well at levels far exceeding the MCL. They used a mail questionnaire to gather information about averting expenditures and behaviors in response to the contamination. They found that only 43 percent of the survey respondents knew of the contamination; of those, only 44 percent undertook averting actions such as purchasing bottled water or boiling water before use. The authors indicate that the total costs of these actions (\$61,300 - \$131,300 over 88 weeks; 1987-89 dollars) provide a conservative estimate of the benefits of avoiding the contamination.

Drinking Water Contamination -- Perchloroethylene: In another study, Abdalla quantified household level economic losses due to averting behavior in response to perchloroethylene groundwater contamination. Using a mail survey of residents in the affected Pennsylvania community, Abdalla determined the frequency and types of averting behaviors adopted in response to contamination, and estimated economic losses attributable to these behavior changes. He found that, on average, total household costs of averting behavior ranged from \$252 to \$383 (1987 dollars). Households incurred monthly costs of up to three times normal water bills as a result of behavioral changes such as home water treatment or hauling or purchasing of alternative water sources.

Drinking Water Contamination -- Giardia: The Harrington, et al. study mentioned earlier valued the costs of averting behaviors as well as the costs-of-illness resulting from a giardia contamination episode in Luzerne County, Pennsylvania. Losses due to averting behavior include water hauling or boiling, bottled water purchases, and other actions undertaken to avoid consumption of contaminated water. The study considers the time lost as well as direct expenditures, and is based on survey data (mail and phone) from the affected households. Depending on the costs included in the estimates, the researchers found that the averting behavior losses averaged between approximately \$500 and \$1,500 per household (1984 dollars).

⁴⁵ Agee, Mark D. and Thomas D. Crocker, "Parental Altruism and Child Lead Exposure: Inferences from the Demand for Chelation Therapy," *Journal of Human Resources*, Vol. 31, Summer 1996, pp. 677-691; Abdalla, Charles W., Brian A. Roach, Donald J. Epp., "Valuing Environmental Quality Changes Using Averting Expenditures: An Application to Groundwater Contamination," *Land Economics*, Vol. 68, No. 2, May 1992, pp. 163-169; Abdalla, Charles W., "Measuring Economic Losses From Ground Water Contamination: An Investigation of Household Avoidance Costs," *Water Resources Bulletin*, Vol. 26, 1990, pp. 451-463; Harrington, Winston, Alan J. Krupnick and Walter O. Spofford, Jr., (1989).

3.2.5 Avoided Cost Studies

Avoided cost studies are somewhat similar to the cost-of-illness and averting behavior studies discussed earlier, in that all three methods consider the expenditures averted (or displaced) by reduced exposure to contamination. The term "avoided cost" is generally used when the expenditures would be incurred by private sector or government organizations rather than individuals or households. Such studies often apply a relatively simple approach: they measure the expenditures likely to occur in the absence of the regulation, compare them to the likely expenditures once the regulation is promulgated, and use the difference to estimate benefits.⁴⁶ These methods are generally easy to apply and provide useful information for policy analysis. Whether they are a true measure of the value of related benefits depends on whether the researcher considers the effects of these costs on consumers.⁴⁷

The avoided cost method is commonly used to assess material damages that are reduced, prevented, or mitigated by environmental regulations. Some examples include the following:

- If contaminants damage piping or other equipment, regulating the contaminant may reduce the costs of repairing the damages as well as the frequency with which the equipment needs to be replaced.
- If contaminants affect the use of water as a production input (because of the need for purity), regulating the contaminant may reduce industry's water treatment costs.
- If contaminants lead to soiling of items requiring cleansing, regulating the contaminants may reduce the costs and frequency of cleaning.

⁴⁶ For more information on avoided cost methods, see: Adams, Richard M. and Thomas D. Crocker, "Materials Damages," *Measuring the Demand for Environmental Quality* (J.B. Branden and C.D. Kolstad, eds.), Elsevier Science Publishers: The Netherlands, 1991, pp. 271-303.

⁴⁷ As discussed earlier in this chapter, consumers benefit if they are willing to pay more than current prices for a good or service. If, for example, industry costs decline because they no longer need to treat water received from the public water system, firms may pass some of these savings onto consumers in the form of lower prices. These lower prices will increase consumer surplus and may also affect producer surplus. A full treatment of avoided costs would account for these changes in consumer and producer surplus. A more detailed discussion of these issues is provided in: U.S. Environmental Protection Agency, *Handbook for Noncancer Health Effects Valuation (draft)*, prepared by Industrial Economics, Incorporated, September 1999.

Examples of this type of study are provided in Exhibit 3-6. As is evident from the examples, such analysis includes only those costs that can be avoided by the regulations and that are not attributable to other causes.

Exhibit 3-6
Examples of Avoided Cost Studies⁴⁸

Corrosion: Many of the treatment techniques used to reduce the concentration of lead in drinking water reduce the water's acidity, and thus reduce corrosion. To support development of EPA's drinking water standards for lead, Levin reviewed the literature on the costs of corrosive damages to distribution systems and residential users and determined the per capita value of these damages. She then calculated the proportion of these damages that could be reduced by water treatment, estimating that \$8.50 in costs per capita could be avoided annually. She multiplied this cost by the population likely to be served by systems with corrosive waters, estimating the national value of avoided costs as \$525.3 million annually (1985 dollars).

Ground Water Remediation: In the absence of clean-up of hazardous waste sites, contaminants released to ground water may eventually affect drinking water supplies in surrounding areas. Water systems and private well users will then incur costs for treating the water and/or for replacing it with uncontaminated supplies. To support development of EPA's corrective action regulations, researchers reviewed the water treatment and replacement costs that might be incurred at several sample facilities in the absence of site remediation. They assessed the likely impact of these costs on water prices and the resulting change in consumer surplus. They found that only about two percent of the loss in consumer surplus (\$4.7 million) would be avoided by clean-up of the site because ground water remediation techniques may be only partially effective and can take several years to significantly reduce contaminant concentrations (1992 dollars).

3.3 Methods for Valuing Mortality, Morbidity, and Other Effects

As discussed earlier, the primary benefits of regulations establishing MCLs are effects on human health. This section provides more detailed descriptions of the particular steps needed to assess reduced mortality, morbidity, and other (non-health) effects, summarizing relevant information provided in EPA's *Guidelines for Preparing Economic Analyses* and other references cited in the footnotes.

3.3.1 Valuing Mortality Risk Reductions

The benefits of mortality risk reductions from environmental regulations are generally assessed using empirical estimates of the value of a statistical life (VSL). The value of statistical life does not refer to the value of an identifiable life, but instead to the value of small reductions in mortality risks in a population. A

⁴⁸ Levin, Ronnie, *Reducing Lead in Drinking Water: A Benefits Analysis*, prepared for the U.S. Environmental Protection Agency, 1986; Industrial Economics, Incorporated, "Chapter 9: Averted Water Use Costs," *Draft Regulatory Impact Analysis for the Final Rulemaking on Corrective Action for Solid Waste Management Units*, prepared for the U.S. Environmental Protection Agency, March 1993.

"statistical" life can be thought of as the sum of small individual risk reductions across an entire exposed population.

For example, if 100,000 people would each experience a reduction of 1/100,000 in their risk of premature death as the result of a regulation, the regulation can be said to "save" one statistical life (i.e., $100,000 * 1/100,000$). The sum of the individual willingness to pay values for the given risk reduction across the population provide a value per statistical life. Continuing with the previous example, if each member of the population of 100,000 were willing to pay \$50 for the risk reduction, the corresponding value of a statistical life would be \$5 million (i.e., $\$50 * 100,000$). Note that these estimates rely on studies of relatively small changes in risk; they are not values for saving a specific individual's life.

A variation on this approach involves accounting for the effect of risk reductions on the number of life years remaining.⁴⁹ The value of statistical life-year (VSLY) approach assigns a value to each year of life extended. In its simplest form, the VSLY approach translates the value of statistical life into annual values, implicitly assuming a linear relationship in which each discounted life year is valued equally. There is significant controversy over this approach, particularly because the value of remaining life years is likely to vary depending on the age of the individual and other factors.

Exhibit 3-7 presents the value of statistical life estimates applied in EPA's recent report to Congress, *The Benefits and Costs of the Clean Air Act, 1990 to 2010*, updated to 2000 values.⁵⁰ These estimates, derived from wage-risk and contingent valuation studies, range from \$0.8 million to \$17.8 million, with a mean of \$6.3 million.⁵¹

⁴⁹ An emerging literature takes a third approach to valuation, focusing on changes in life expectancy. However, this approach is not yet well enough developed for use in valuation of regulatory programs. See, for example: Johannesson, Magus and Per-Olov Johansson, "The Value of Life Extension and the Marginal Rate of Time Preference: A Pilot Study," *Applied Economic Letters*, Vol. 4, 1997, pp. 53-55.

⁵⁰ U.S. Environmental Protection Agency, *The Benefits and Costs of the Clean Air Act, 1990 to 2010*, EPA 410-R-99-001, November 1999.

⁵¹ To allow probabilistic modeling of mortality risk reduction benefits, analysts reviewed common distributions and selected the Weibull distribution as a best fit for the mean values from these studies. Percentile values from this distribution can be used for sensitivity analysis in cases where the analyst is interested in estimating reasonable "high" and "low" values.

Exhibit 3-7
Value of Statistical Life Estimates (Mean Values in 2000 Dollars)

Study	Method	Value of Statistical Life
Kneisner and Leeth (1991 - US)	Wage-Risk	\$0.8 million
Smith and Gilbert (1984)	Wage-Risk	\$0.9 million
Dillingham (1985)	Wage-Risk	\$1.2 million
Butler (1983)	Wage-Risk	\$1.4 million
Miller and Guria (1991)	Contingent Valuation	\$1.6 million
Moore and Viscusi (1988)	Wage-Risk	\$3.3 million
Viscusi, Magat, and Huber (1991)	Contingent Valuation	\$3.6 million
Marin and Psacharopoulos (1982)	Wage-Risk	\$3.7 million
Gegax et al. (1985)	Contingent Valuation	\$4.3 million
Kneisner and Leeth (1991 - Australia)	Wage-Risk	\$4.3 million
Gerking, de Haan, and Schulze (1988)	Contingent Valuation	\$4.5 million
Cousineau, Lecroix, and Girard (1988)	Wage-Risk	\$4.7 million
Jones-Lee (1989)	Contingent Valuation	\$5.0 million
Dillingham (1985)	Wage-Risk	\$5.1 million
Viscusi (1978, 1979)	Wage-Risk	\$5.4 million
R.S. Smith (1976)	Wage-Risk	\$6.1 million
V.K. Smith (1976)	Wage-Risk	\$6.2 million
Olson (1981)	Wage-Risk	\$6.9 million
Viscusi (1981)	Wage-Risk	\$8.6 million
R.S. Smith (1974)	Wage-Risk	\$9.5 million
Moore and Viscusi (1988)	Wage-Risk	\$9.6 million
Kneisner and Leeth (1991 - Japan)	Wage-Risk	\$10.0 million
Herzog and Schlottman (1987)	Wage-Risk	\$12.0 million
Leigh and Folson (1984)	Wage-Risk	\$12.8 million
Leigh (1987)	Wage-Risk	\$13.7 million
Garen (1988)	Wage-Risk	\$17.8 million

See Viscusi, W.K., *Fatal Tradeoffs* (Oxford University Press, 1992) or Viscusi, W.K., "The Value of Risks to Life and Health," *Journal of Economic Literature*, Vol. 31, pp. 1912-1946, 1993, for full references for these studies. Values are updated to 2000 dollars using the Consumer Price Index.

EPA analysts currently apply these values in most regulatory analyses due to the substantial research and peer review used to develop this range of estimates. However, EPA staff continue to explore options for refining this approach. An example of this approach is provided in Chapter 5.

Use of these estimates to value the mortality risks of environmental policies is an example of the use of benefit transfer techniques, since the subject of most of the

studies (i.e., job-related risks) differs from the fatal risks reduced by environmental policies (usually associated with various forms of cancer). Benefit transfer is discussed in detail in Chapter 4 of this document. As is the case in any transfer, when applying this range of estimates to a particular rule, analysts consider differences between the scenarios considered in these studies and the risk reductions addressed by the regulations, as discussed below.

Reliable methods for adjusting these values to address potential biases have not yet been fully developed or adequately tested in most cases. More empirical research is needed to determine the appropriate adjustments, and here is substantial disagreement within the economics profession about many of these issues. In addition, several of the potential biases are counterbalancing and adjusting for only some sources of bias may lead to significant over- or underestimates of actual value. At minimum, the existing literature can be used to support a qualitative discussion of the direction and magnitude of these biases and their implications for decision-making.⁵²

Sources of bias can be grouped into two general areas, including those related to the *risk characteristics* (risk perception, altruism, baseline risk, and delayed manifestation) and the *population characteristics* (income, age, and health status). Quantitative adjustment for these sources of bias is generally considered only for income and latency. As described briefly below, the other sources are usually discussed qualitatively given the status of related research.

Risk perception. The value that people place on risk reduction appears to depend in part on the nature of the risk. Individuals are likely to place different values on avoiding different types of fatal risks, even if the magnitude of the risks (e.g., a 1/100,000 change in the risk of death) is the same. These differences result, at least in part, from how individuals perceive, or feel about, risks with varying characteristics. A substantial body of literature suggests that there are nine major categories that influence individuals' perception and rankings of risks: (1) voluntariness; (2) controllability; (3) known to science; (4) known to those exposed; (5) familiarity; (6) dread; (7) certainty of being fatal; (8) catastrophic; and (9) immediately manifested.⁵³ Many of these characteristics are highly correlated with

⁵² For a more detailed discussion of each of these sources of bias as well as references to the primary research on these topics see Industrial Economics, Incorporated, *The Use of Benefit-Cost Analysis: Valuing Fatal Risk Reductions*, prepared for U.S. Environmental Protection Agency, Office of Ground Water and Drinking Water (forthcoming), as well as EPA's *Guidelines for Conducting Economic Analyses*.

⁵³ See, for example, Slovic, P., B. Fischhoff, and Sarah Lichtenstein, "Perceived Risk: Psychological Factors and Social Implications," *Proceedings of the Royal Society of London. Series A: Mathematical and Physical Sciences*, Vol. 430, No. 1878, 1981, pp. 17-34.

each other, either directly or inversely. For example, risks with a high degree of dread, such as nuclear accidents, also have a low degree of controllability and voluntariness. As a result, differences in risk ranking can be explained by relatively few of these factors. Researchers have found that one of the most important determinants may be the degree of dread.

Altruism. Another factor to consider is the presence of altruism. The existing literature focuses on individual risk tradeoffs, but there is substantial evidence that people are willing to pay to reduce risks incurred by others (e.g., the current generation may choose to bear the costs of a program that will benefit future generations). However, many researchers advocate caution in attempting to increase value of life estimates to reflect altruism, primarily because of concerns over the potential for double-counting.⁵⁴

Baseline Risk. Willingness to pay for fatal risk reduction may vary depending on the whether the affected individuals are already facing high or low levels of fatal risks. These risks can include both those that are relatively voluntary in nature (e.g., smoking, participating in extreme sports) as well as those that are less so (e.g., hereditary health conditions, other environmental hazards). Available evidence indicates that changes in willingness to pay are only significant when the level of baseline risk varies substantially; differences in baseline risk may have little effect in the case of the relatively modest risk reductions typical of many drinking water regulations.⁵⁵

Delayed Manifestation (*latency and cessation lag*). Latency generally refers to the delay between exposure and mortality or manifestation of an adverse health effect. When there is a significant delay between manifestation of an adverse health effect and death (i.e., some cancers), this period may include illness and impaired function. Latent risks are likely to be valued differently from risks that are more immediate. Cessation lag is the time between the cessation or reduction of exposure and a reduction of risk. The existence of a cessation lag implies that the physiological damage caused by the contaminant can be completely or partially repaired over a period of time once exposure ceases, thus decreasing the risk for later disease or death among populations that have already been exposed. The value placed on risks

⁵⁴ For more information on altruism, see for example, Jones-Lee, M.W., "Paternalistic Altruism and Value of Statistical Life," *The Economic Journal*, Vol. 102, 1992, pp. 80-90.

⁵⁵ Hammitt, James K., "Valuing Mortality Risk: Theory and Practice," *Environmental Science and Technology*, Vol. 34, 2000, pp. 1396-1400; and Miller, Ted R., "The Plausible Range for the Value of Life - Red Herrings Among the Mackerel," *Journal of Forensic Science*, Vol. 3, No. 3, 1990, pp. 17-39.

that decline quickly after cessation of exposure may be different from those that decline slowly or not at all.

Health risks from latent illnesses, like cancer, introduce additional valuation issues. Current valuation estimates are based on risks of relatively immediate fatality. Reducing the risk of an immediate death is generally valued more highly than reducing the risk of a delayed one, assuming the risks are identical in all other respects. If cessation lag applies to a reduction in risk, the length of the lag will also affect valuation.

Income. The most robust estimates of the value of a statistical life tend to come from samples of middle-aged workers, and the income levels associated with these studies may differ from the mean for individuals affected by most drinking water regulations. In addition, national average income is increasing over time. Making adjustments for income across population subgroups may imply that public policies should favor protection of higher income individuals. This implication clearly raises difficult ethical and legal issues and, as a result, these types of quantitative adjustments are rarely implemented. Adjusting value of statistical life estimates for changes in income over time has also been discussed.⁵⁶

Age. The studies cited in Exhibit 3-7 focus on risks incurred by the working age population, not by very young or very old individuals. Several authors have attempted to address potential differences in the value of statistical life due to differences in the average age of the affected population or the average age at which an effect is experienced. While it may seem intuitive to assume that the value of statistical life is greater for young people than older people, studies of people's willingness to engage in high risk behavior suggest a more complex relationship. For example, Jones-Lee et. al. find that the value of a statistical life for adults follows an "inverted-U" pattern, peaking around the age of 40.⁵⁷ Valuation of risks to children presents special problems.

Health Status. Individual health status (i.e., whether a person is currently in good health) also may affect the valuation of mortality risk reduction, particularly because individuals with impaired health are often the most vulnerable to death from environmental causes. Health status is distinct from age (a "quality versus quantity" distinction) but the two factors are clearly correlated and therefore are often addressed jointly.

⁵⁶ EPA's Science Advisory Board has recommended adjusting for income changes over time.

⁵⁷ Jones-Lee, Michael W., *The Economics of Safety and Physical Risk*, Basil Blackwell: Oxford, 1989.

Extensive public health literature exists on "quality adjusted life years" (QALY). This approach provides a health state scale for quality of life based on expert medical opinions and/or survey research. It involves determining, for example, that a year with a particular condition is equivalent to a specific percentage of a full year in good health. This approach is designed for use in assessing the cost-effectiveness of alternative medical treatments, and often considers levels of activity rather than the values individuals place on changes in health status.

3.3.2 Valuing Morbidity Risk Reductions

Many regulations establishing MCLs will reduce the risks of incurring nonfatal cancers or other human health effects, including both acute (short-term) and chronic (long-term) illnesses and other effects. One method sometimes used for valuing morbidity risk reductions is the cost of illness (COI) method. However, as discussed earlier, this method has several limitations. Cost-of-illness studies often include medical expenses and lost work time, but may exclude lost leisure time or unpaid work time (e.g., for those who work in the home). Willingness to pay to avoid pain and suffering and reduce future risks are also not addressed by cost-of-illness estimates. As a result, cost-of-illness estimates are usually thought to understate willingness to pay, which is the theoretically correct measure of value and captures the effects not addressed by the cost-of-illness method.⁵⁸

If available, analysts prefer to rely on estimates of willingness to pay rather than cost of illness estimates. However, analysts may at times wish to present both cost-of-illness and total willingness to pay estimates because of limitations in the available literature. Willingness to pay studies are available for only a few types of health risks and in some cases may have methodological problems (such as reliance on surveys using very small samples). Whether benefit transfer techniques (discussed in Chapter 4) can be used to address the limitations in the willingness to pay literature will depend on the effect of concern. Cost-of-illness studies provide estimates of avoided costs that generally can be interpreted as a lower bound on willingness to pay; the willingness to pay estimates may be less certain (depending on study quality and applicability) but more consistent with the theoretically correct definition of value.

Available research suggests that willingness to pay may be two to 79 times higher than cost-of-illness; this multiplier varies significantly for different illnesses.⁵⁹ For example, a study of the health effects of ozone shows that the ratio of willingness to

⁵⁸ A more detailed discussion of estimating morbidity values and benefits transfer is available in EPA's *Guidelines for Preparing Economic Analyses*.

⁵⁹ U.S. Environmental Protection Agency, *Handbook for Noncancer Health Effects Valuation (Draft)*, prepared by Industrial Economics, Incorporated, September 1999.

pay to cost-of-illness estimates may range from a factor of about two to four, while a study of minor health effects shows ratios as high as 79.⁶⁰

Because of the variety of nonfatal health effects that may be addressed and the variation in the availability of suitable studies, whether and how to address potential biases and sources of uncertainty will depend on the characteristics of the particular analysis. At a minimum, analysts usually discuss qualitatively any significant differences between the effects of the regulations and the effects addressed by the valuation studies used. Where significant differences exist and quantitative adjustments or sensitivity analysis is possible, the effects of the differences may be quantified. EPA's *Handbook for Noncancer Health Effects Valuation* provides more information on these topics, along with several valuation case studies. An example of morbidity valuation is also provided in Chapter 5 of this document.

3.3.3 Valuing Other Benefits

In addition to effects on morbidity or mortality, drinking water regulations may affect the aesthetic qualities of public water supplies (taste, odor, color) or the damages they cause to materials (corrosion, soiling, build-up, impurities). The typical approach to assessing these types of effects generally involves using avoided cost methods (described above), which often are interpreted as providing a lower bound estimate of willingness to pay to avoid these effects. The actual approach will depend on the particular effect of concern, and will usually include comparing costs in the absence of the rule to the costs assuming alternative MCLs or treatment requirements are established. In some cases, studies of individual willingness to pay for these benefits (e.g., using contingent valuation) may also be available.

Some regulations establishing MCLs will provide benefits other than those specifically addressed in this document. For example, a regulation establishing an MCL or treatment requirements may improve consumer confidence in water quality, affect the health of livestock or pets, or enhance crop production. Alternatively, source water protection measures may lead to ecological benefits. These benefits are usually explored in the context of the individual rulemaking. In some cases, they may be too small to warrant quantitative assessment, and may be discussed qualitatively when presenting the results of the analysis. To quantify these types of impacts, analysts generally apply the same concepts and types of methods as discussed above, tailored to the effects of concern for the particular rulemaking.

⁶⁰ Dickie, Mark and Shelby Gerking, "Willingness to Pay for Ozone Control: Inferences from the Demand for Medical Care," *Journal of Environmental Economics and Management*, Vol. 21, 1991, pp. 1 - 16; Berger, M.C., et al., (1987).

CONDUCTING BENEFIT TRANSFERS

CHAPTER 4

EPA analysts often use the benefit transfer technique to value the benefits of drinking water and other regulations. This technique involves using estimates from existing research (based on the methods described in Chapter 3) to value the benefits of the regulatory options under consideration.⁶¹ Existing studies usually assess effects that differ in some respects from the effects of a particular regulation. Analysts thus review the applicability, as well as the quality, of the available studies to determine whether and how to apply them to a specific regulatory scenario. EPA analysts frequently use benefit transfer techniques when estimating the value of effects on human health and the environment, and may also apply this approach when assessing effects on aesthetic properties or material damages.⁶²

Benefit transfer is considered a "secondary" methodology because it does not involve collecting primary valuation data. Rather, benefit transfer is a process for reviewing and adjusting existing data to arrive at valuation estimates for the subject under consideration. The study that is the source of existing data is typically called the "study case" and the subject under consideration is called the "policy case." The main advantage of benefit transfer is that the process is less expensive and time consuming than primary valuation techniques. Thus, benefit transfer is useful when limited time and resources preclude conducting primary research to inform policy decisions. It can also be used as part of a preliminary or screening analysis to determine whether additional primary research is warranted and to inform the early phases of the regulatory development process.

⁶¹ For general information on benefit transfer techniques, see: U.S. Environmental Protection Agency, *Guidelines for Preparing Economic Analyses*, EPA 240-R-00-003, September 2000. *Water Resources Research*, Vol. 28, No. 3, 1992 (an entire issue devoted to benefit transfer); and Desvousges, William H., et al., *Environmental Policy Analysis with Limited Information: Principles and Applications of the Transfer Method*, Edward Elgar Publishing: Northampton, Massachusetts, 1998.

⁶² The use of benefit transfer for policies affecting human health is discussed in: U.S. Environmental Protection Agency, *Handbook for Noncancer Health Effects Valuation (draft)*, prepared by Industrial Economics, Incorporated, September 1999. Additional information will be available in EPA's forthcoming *Children's Health Valuation Handbook*. The use of these techniques for natural resource damage assessment is described in: Industrial Economics, Incorporated, *Economic Analysis for Hydropower Project Relicensing: Guidance and Alternative Methods*, prepared for U.S. Fish and Wildlife Service, October 1998.

The overall quality of a benefit transfer relies heavily on the good judgement of the analyst; this chapter describes "best practices" for this type of analysis. Benefit transfer is likely to yield estimates that are less accurate than those that would result from a carefully designed and implemented primary valuation study that directly addresses the effects of concern. Hence the analyst generally presents the implications of the assumptions and uncertainties in the transfer along with the analytic results, so that policymakers can take these implications into account when making regulatory decisions.

This chapter first describes the steps for implementing benefit transfers. Next, it provides a worksheet that analysts can use when assessing the quality, applicability, and transferability of existing studies. Finally, the chapter concludes with a fictional case study that illustrates the benefit transfer technique.

4.1 Implementation Steps

Benefit transfer consists of five steps:

- **Step 1: Describe the Policy Case.** Describe in detail the health or other effects relevant to the proposed regulation, the impacts of these effects, and the demographic characteristics of the affected population.
- **Step 2: Identify Existing Relevant Studies.** Search the economics valuation literature for studies that address similar types of effects.
- **Step 3: Review Existing Studies for Quality and Applicability.** Assess the quality of the identified studies by determining whether they follow generally accepted best practices for the methods used. Assess applicability in terms of: (1) the similarity of the effects; (2) the similarity of the populations experiencing the effects; and (3) the ability to adjust for differences between the study scenario and the policy scenario.
- **Step 4: Transfer the Benefit Estimates.** Conduct the transfer, making any necessary adjustments to existing estimates and applying them to the policy scenario. The transfer may be based on the results of a single study or of several studies.

- **Step 5: Address Uncertainty.** Address uncertainties in the estimates, for example by conducting sensitivity or other types of analysis as appropriate.⁶³

Each of these steps is discussed in more detail in the following sections.

4.1.1 Step 1: Describe the Policy Case

To conduct a benefit transfer, the analyst first constructs a detailed description of the contaminant and each effect of concern; i.e., each particular type of health or other effect likely to be reduced by the regulatory options. As discussed in Chapter 1 of this document, regulations establishing Maximum Contaminant Levels (MCLs) or treatment techniques for drinking water generally provide human health benefits, reducing mortality and morbidity from various illnesses. EPA generally uses benefit transfer to value fatal risks, combining the results of several wage-risk and contingent valuation studies as discussed previously in Chapter 3. For non-fatal health effects, estimates of willingness to pay to avoid related risks are available for relatively few effects of concern. Hence, analysts often transfer values from a study of one health effect (the study case) to determine the value of a similar health effect resulting from a particular regulation (the policy case).⁶⁴

Drinking water regulations also may decrease ecological risks (e.g., if they encourage increased source water protection), reduce materials damages (e.g., corrosion of piping and equipment), and provide aesthetic benefits (e.g., improved clarity, taste or odor of drinking water). Benefits transfer may also be useful in assessing some of these other types of effects.

Health Effects

Policy analysts generally rely on health scientists, engineers, and other experts to provide information on the effects of the contaminant. The role of the analyst is to ensure that he or she develops a full understanding of each effect to be assessed, including any uncertainties in its description. This detailed description includes:

- The *physical symptoms* associated with the health effect. For example, for kidney disease, the analyst would describe in detail conditions such as

⁶³ The economics profession sometimes uses the term "uncertainty" to refer to situations where probabilities are unknowable and "risk" where probabilities are known. In this document, we use the more general definition of uncertainty as "lack of knowledge."

⁶⁴ These transferred estimates of willingness to pay may be presented along with cost-of-illness estimates. Cost-of-illness values are often available for the effect of concern and can be interpreted as providing a likely lower bound estimate of willingness to pay, as discussed in Chapter 3 of this document.

impaired mobility, muscle cramps, hypertension and infections, as well as associated lifestyle changes and emotional stresses. Emotional stresses could include effects such as depression or anxiety related to symptoms, prognosis, or other aspects of the illness. The severity of the effects and the extent to which the symptoms curtail normal activities are also considered, as well as information on the fatality rates.

- The *timing and duration* of the effect. An effect may occur immediately upon exposure, or there may be a significant delay between exposure and manifestation of a health effect (i.e., latency). Also there may be a lag (cessation lag) between the cessation or reduction of exposure and a reduction of risk. The health effect may be a short-lived (acute) or a long-term (chronic) condition.
- The *population affected*. Exposure to a contaminant may be more or less likely to lead to adverse effects depending on factors such as age and current health status. The description of the population most likely to be affected by the disease includes the factors that lead to heightened vulnerability such as lifestyle issues (e.g., smoking) or pre-existing conditions (e.g., depressed immune system). It also addresses factors that may affect willingness to pay, such as demographic or socio-economic characteristics including age, sex, geographic location, income level, or race. Analysts also describe the extent to which the health effect is likely to be prevalent, that is, likely to occur in most persons exposed to the contaminant or only in a fraction of the exposed population.

This information is accompanied by a description of the key uncertainties in the health science data related to each of these factors. Uncertainties could, for example, include a lack of knowledge about the physiology of the effect, the emotional stresses of the effect, the risk factors that make individuals or populations susceptible to the effect, or the prevalence of the effect. In addition, uncertainties related to the causative link between a drinking water contaminant and a particular health effect may be significant. It is not unusual to find that uncertainties in the risk assessment far outweigh uncertainties in other aspects of the benefit-cost analysis.

Ecological Effects

Benefit transfer is often used to value ecological effects, for which the literature includes numerous willingness to pay studies. Such a transfer may involve the application of estimates from a studied site to other sites experiencing similar effects, or the combination of values from several studies to estimate the value of such effects in other cases. When combining values for different aspects of an effect from several studies, the analyst is careful to avoid double counting. For example, the value of wildlife viewing may be related to the value of surrounding properties, and

analysts attempt to address the overlap (in quantitative or qualitative terms) if both types of benefits are considered.

The starting point for transferring these types of values is to describe the ecological effects addressed by regulatory standards. The description details the natural resources affected, their current (baseline) condition, and the characteristics and severity of the effects reduced. In addition, the services provided by the resource (such as recreational activities, commercial use, or wildlife viewing) are discussed. The description considers the timing and duration of the effects as well as the potential for natural recovery. The analyst also addresses the characteristics of the human population (for example, recreational anglers, local residents) who may benefit from the ecological improvement. This description guides the subsequent economic analysis, and addresses the characteristics of the ecological effect likely to affect willingness to pay.

Materials and Aesthetic Qualities

In cases where a regulation reduces damages to materials or improves the aesthetic qualities of drinking water, benefit transfer may also be used. For example, a few analyses of averting behavior or avoided costs are available in the literature that could be used to value certain of these types of effects. In such cases, the analyst again begins the transfer process by describing the effect of concern and baseline conditions in detail, including the characteristics and timing of the reduced effect and the population or water systems affected. In some cases, the regulations may alleviate, but not eliminate, adverse impacts, and this concern will need to be taken into account. For example, regulation of a particular contaminant may reduce or delay, but not eliminate, pipe corrosion, or may only partially mitigate taste or odor problems.

4.1.2 Step 2: Identify Existing Relevant Studies

Once the analyst completes the description of the policy case, the next step is to conduct a comprehensive literature search to identify existing valuation literature that focuses on similar effects. The analyst explores journal articles, research reports, dissertations, and published texts identified through a review of databases of environmental, economic, and medical literature, as relevant. There are several bibliographic databases available through Internet services such as Dialog, Lexis/Nexis, and Dow Jones; the databases most pertinent to benefits valuation include: Enviroline, Pollution Abstracts, EconLit (Economic Literature Index), Social SciSearch, SciSearch, Medline, ABI/Inform, IAC Business A.R.T.S, Water Resources Abstracts, and WATERNET.

In addition, for several types of effects, bibliographies of relevant studies are available. For fatal human health effects, the list of studies currently referenced by EPA is provided in Chapter 3 of this document. For nonfatal human health effects, a list of available studies is provided in EPA's *Cost of Illness Handbook* and in

EPA's *Handbook for Non-Cancer Health Effects Valuation*. For ecological effects, analysts may wish to review EPA's Environmental Benefits Database. Studies previously used by various EPA offices are identified in EPA's Environmental Economics Report Inventory.⁶⁵ Regardless of the bibliographic source used, analysts typically read the studies themselves, rather than relying on summaries in these sources, because the characteristics that may significantly affect the benefit transfer are not always easy to capture in summary form.

Finally, additional valuation information may be available in unpublished studies or in studies currently underway. To identify these studies, the analyst may contact researchers frequently cited in the published literature, who are likely to be involved in or aware of other sources of valuation estimates. Staff from agencies who frequently support valuation research (such as EPA's National Center for Environmental Economics, the Fish and Wildlife Service, and the National Science Foundation) can provide information on relevant studies. Unpublished studies (which generally have been subject to less review than the published literature) are carefully reviewed to ensure that they are of sufficient quality to support defensible benefits estimates.

4.1.3 Step 3: Review Existing Studies for Quality and Applicability

Assessing the quality of existing research and its applicability to the policy scenario is the third step in benefit transfer. The guidelines in this section can serve as a road map for the analyst to follow in evaluating studies. In addition to reviewing the quality and applicability of existing studies, the analyst considers transferability issues, which are intertwined with the concept of applicability but refer to the steps followed in conducting the transfer. To avoid repetition, these "transferability" concerns are addressed under Step 4 below. A worksheet later in this chapter summarizes the guidelines for quality, applicability, and transferability.

It is not possible to develop absolute standards for assessing a study's quality and applicability. Rather, the analyst considers all of the factors discussed below, and balances the limitations of each study against the value of using it to provide information on the benefits of concern. For those studies ultimately used in the transfer, the analyst discusses the findings of the quality and applicability review when presenting the results. As indicated under Step 5, this discussion describes the extent to which the transfer is likely to overestimate or underestimate the value of the benefits derived from the regulation, given the uncertainties in the original study and in the transfer process.

⁶⁵ Available on EPA's website at <http://www.epa.gov/economics>.

Quality Issues

Quality refers to the appropriateness of the research methodology used, the care with which this methodology was implemented, and the accuracy and reliability of the resulting estimates. Considering these quality issues allows the analyst to identify sources of uncertainty related to the methods used to estimate values, and to weigh these sources of uncertainty in determining whether and how to use each study in a benefit transfer. Assessing quality requires a high degree of judgement in order to separate sound, scientifically valid studies from studies of lesser merit. The importance of particular criteria for assessing quality will vary depending on the type of study and the type of effect. However, there are some general criteria that analysts can apply to most research, which are discussed below.⁶⁶

Opinion of the Professional Community: To a large extent, analysts rely on the opinions of the professional community in assessing the quality of a study. Analysts consider whether the research has been published in a peer-reviewed journal or has undergone other forms of peer review.⁶⁷ Analysts may also discuss the study with the original authors, leading researchers in the field, or the study's sponsor to learn more about its strengths and weaknesses and about whether these experts believe that the study conforms with "best practices" as defined by recent research.

Note that some studies that are well-respected in the field (because they explore new issues or apply innovative techniques) may not lead to reliable results in a benefit transfer; for example, if they are pilot studies that use a very small sample. In addition, there will not always be consensus on the merits of each study; analysts will need to take any areas of disagreement into consideration as part of their review and when conducting any subsequent transfer.

In some cases, the age of a study may affect its usefulness for benefit transfer due to concerns about changes in willingness to pay over time. However, use of older, well reviewed studies may be preferable to use of newer studies that have been subject to less scrutiny in some cases. Because of the need to balance these types of concerns, it is not possible to develop a universally applicable threshold for the age of studies. Rather, analysts will need to address this issue along with the other concerns discussed in this chapter.

⁶⁶ For more specific information on assessing the quality of studies using particular valuation methods, see the references noted in the beginning of this chapter as well as the discussion in Chapter 3 of this document.

⁶⁷ For peer review standards, see: U.S. Environmental Protection Agency, *Peer Review Handbook*, January 1998.

Methods and Data Sources: When considering the quality of the methods used for the study, the analyst considers the appropriateness of the approach for valuing the effect of concern, as well as the extent to which the method is likely to yield accurate estimates of willingness to pay. For example, cost of illness methods may be used to value changes in health risks, but may not represent (or may understate) an individual's actual willingness to pay to avoid these risks. The extent to which different methods will yield conceptually correct measures of the value of benefits is discussed in Chapter 3 of this document.

When reviewing data sources, the analyst considers the accuracy, reliability, and completeness of the underlying records or information. For example, researchers using the wage-risk method have employed a multitude of data sources for information on compensation and job-related risks, and these data sources vary in terms of accuracy and completeness.⁶⁸ In addition, data sources that were developed many years ago may no longer reflect values held today. In the case of survey techniques, the appropriateness of the population sampled is considered in terms of location, age, and other characteristics that may influence willingness to pay. Literature review or survey articles provide professional opinions on these data quality issues and can assist analysts in assessing these concerns.

Sampling and Survey Administration: Many studies take a statistical sample of either data records or individuals. In these cases, analysts generally prefer studies that use probability sampling and sample sizes that are large enough to allow extrapolation to the underlying population with a reasonable level of confidence. Probability sampling allows the researcher to compute the chance that any particular individual within the population would be included in the sample and to develop appropriate weighting factors for extrapolating from the sample to the total population. While statistical measures of sampling error should be used to provide a more rigorous indicator of appropriate sample size, a rough guideline is that samples of less than 200 observations may result in unreliable estimates.⁶⁹

⁶⁸ See Viscusi, Kip, *Fatal Tradeoffs: Public and Private Responsibilities for Risk* (New York: Oxford Press, 1992) for an assessment of various data sources for wage-risk analyses.

⁶⁹ For contingent valuation surveys, Mitchell and Carson suggest that at least 600 useable responses are needed; the Water Resources Council recommends a sample size of 200. See: Mitchell, Robert Cameron and Richard D Carson, *Using Surveys to Value Public Goods: The Contingent Valuation Method*, Washington, DC: Resources for the Future, 1989; and U.S. Department of the Interior, Water Resources Council, *Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies*, 1983.

Analysts consider the response rate (for surveys) or the extent to which complete records are available (for other types of studies). In the case of surveys, the response rate will vary depending on the method of survey administration: well-designed studies using personal interviews may achieve an 80 to 90 percent response rate, phone interviews may achieve an 85 percent response rate, and mail surveys may achieve a 60 to 75 response rate.⁷⁰ However, many surveys achieve lower response rates, and such rates will need to be considered along with other factors affecting the quality and applicability of a study when determining whether to use it for benefit transfer.

"Best practices" for survey development and administration, when contingent valuation or other survey methods are used, are discussed in the references provided in Chapter 3 of this document. In particular, extensive pre-testing of the survey instrument is generally needed to ensure that it is well understood and believable. Analysts interested in applying the results may wish to examine the survey instrument themselves to ensure that it is asking appropriate questions for valuation of the effect of interest and for control of confounding factors.

Data Analysis: Once the data are collected, researchers often analyze them using econometric or other statistical techniques.⁷¹ Key concerns may include whether the theoretically correct variables are included in the analysis, the measures (or specification) of each variable, and the functional form of the equations or calculations employed.

If the original data set is available from the researchers, additional analyses may be conducted as part of the benefit transfer process, both to better understand the data and to adjust the estimates (or equations) for the transfer. For example, if the original study includes data on the age of respondents but does not explicitly assess the effects of this variable on the resulting values, the analyst conducting the transfer may explore these effects.

Evidence of Accuracy and Reliability: Finally, the analyst looks for evidence of the accuracy and reliability of the estimates. Accuracy refers to how precise, or correct, the findings are; for example, how well the sample results mirror the value in the underlying population. Reliability refers to the extent to which the findings can be replicated; for example, whether applying the survey to a second sample would result in the same or similar estimates. At the most basic level, accuracy and reliability may be assessed based on information from the researchers on how they designed the study, checked the data, calculations, and results, and addressed key

⁷⁰ Dillman, Don A., *Mail and Telephone Surveys: The Total Design Method*, New York: John Wiley and Sons, 1978.

⁷¹ See, for example: Greene, W.H., *Econometric Analysis, 4th Edition*, New Jersey: Prentice-Hall, 2000.

sources of uncertainty. The analyst may also consider whether the study yields estimates that are in the range found by other studies of similar effects; evidence that study findings have been replicated by other researchers is often the best test of reliability. Finally, the analyst generally assesses whether the results are consistent with general economic theory. For example, he or she may question the quality of a study that found lower values for mitigation of severe adverse effects than for mild effects.

Applicability Issues

In the context of benefit transfer, applicability refers to the extent to which the existing research (the study case) matches the policy case. Applicability therefore involves comparing the effect studied to the description developed under Step 1 above, which again requires a high degree of judgement on the part of the analyst. Three main areas of concern are the similarity of the effect, the population, and the baseline conditions.

Similarity of Effect: The similarity of the effect can be determined by an "item-by-item" comparison of the description of the policy case (developed under Step 1) to the description of the case addressed in each existing study. The analyst generally considers the divergence in physical attributes, severity, timing and duration, etc., as well as the magnitude of the differences. For example, if the contaminant in question is associated with developmental effects, and the existing research focuses on the effects of lead, the analyst would consider the extent to which the developmental problems caused by lead are similar to developmental problems caused by the contaminant.

In reviewing the similarity of the effects, analysts generally consider dimensions of risk in addition to the physical manifestation of the effect, such as the following:

- voluntary/involuntary
- ordinary/catastrophic
- delayed/immediate
- natural/man-made
- old/new
- controllable/uncontrollable
- necessary/unnecessary
- occasional/continuous
- acute/chronic

These risk dimensions may affect willingness to pay to reduce different types of risks. For example, individuals may hold different values for reducing lung cancer risk from smoking (e.g., if they perceive it as a personal lifestyle choice) than from environmental causes (e.g., if they perceive these risks as beyond their control).⁷² The impact of risk characteristics on the valuation estimates are generally discussed qualitatively because the empirical data needed to adjust for these impacts have not yet been developed.

For certain effects, high quality valuation literature on similar effects may not exist, and the analyst will have to make judgments about the suitability of other valuation studies. For example, EPA recently used data on chronic bronchitis to value the benefits of avoiding non-fatal bladder cancer associated with regulating drinking water disinfectant by-products.⁷³ The researchers did not find any willingness to pay studies for non-fatal bladder cancers or other similar cancers. They decided to use chronic bronchitis as a proxy effect, on the grounds that chronic bronchitis and bladder cancer have certain commonalities, such as severity and long-term impacts. They compared the resulting willingness to pay values to cost of illness values for non-fatal bladder cancers as a check on the reasonableness of the estimates.

This use of proxy effects that have dissimilar manifestations to the effects of the policy case may provide useful information for decision-making (e.g., by indicating the range or potential magnitude of benefit values). However, this approach is controversial and requires careful consideration of the limitations of the analysis. Decisions regarding whether to use valuation information for dissimilar effects are made on a case-by-case basis because they will depend on the nature of the issues being addressed as well as the available valuation data. In these situations, analysts work to clearly communicate the advantages and drawbacks of using the chosen study case, and the implications of these concerns for related decision-making. For example, analysts may list and compare characteristics of the proxy and the policy effects, and discuss their expected net impact on willingness to pay, when describing the results of the analysis.

Similarity of Population: In addition to reviewing the similarity of the effects, the analyst compares the population studied to the population affected in the policy case. Populations can differ by geographic location as well as by demographic or socio-economic factors such as age, sex, income and race. The analyst generally focuses

⁷² Fischhoff, B. et al., "How Safe is Safe Enough? A Psychometric Study of Attitudes Towards Technological Risks and Benefits," *Policy Sciences*, Vol. 9, 1978, pp. 127-152.

⁷³ The Cadmus Group and Science Applications International Corporation, *RIA for the Stage 1 Disinfectants/Disinfection Byproducts Rule*, prepared for the U.S. Environmental Protection Agency, 1998.

on those dimensions that are associated with potentially significant differences in willingness to pay.⁷⁴

In some cases, the analyst can adjust for population-specific factors by including relevant variables in a valuation function or by only using part of a data set (if possible without adversely affecting the statistical validity of the sample). In other cases, such adjustments will not be possible, and the differences between the populations introduce another layer of uncertainty into the benefit transfer process that can be discussed when presenting the results. For example, if the policy case is exploring the effects of a particular contaminant on children's health, and the study case has analyzed adult health values, the analyst considers whether there is a scientifically valid way to adjust for the difference in effects between the two populations. EPA is currently addressing the many complex issues that arise in this case, and is developing guidance focused particularly on valuing children's health effects.

Similarity of Baseline: The third major area to consider is whether baseline health status, or in the case of an ecological effect, environmental quality, is similar between the policy case and the study case. Willingness to pay to avoid health effects may vary depending on whether the individuals affected are in good or poor health, or have a particularly high risk of being affected compared to others exposed.⁷⁵ This difference in baseline health status may be particularly important for sensitive populations (such as those with suppressed immune systems, the elderly, or children) who are more vulnerable to the effects of drinking water contaminants. Individuals are also likely to hold different values for ecological effects resulting from a marginal decrease in contamination in routinely polluted waters than for the same decrease in contamination in more pristine areas.

4.1.4 Step 4: Transfer the Benefit Estimates

The fourth step of the benefit transfer process is to derive values from the study case and apply them to the policy case. The researcher can adjust and transfer values in a number of different ways, but the techniques generally fall into three categories: (1) applying a point estimate (i.e., a single value); (2) using a valuation function (an equation that relates values to characteristics of the effect and/or the population affected); or, (3) using meta-analysis or Bayesian approaches (which combine the results of several studies). These approaches are listed in order of increasing complexity, and (all other things being equal), the more complex approaches will often lead to better estimates. However, the available literature may not be sufficient

⁷⁴ Addressing some of these factors may be controversial. For example, if willingness to pay appears to vary by income or race, consideration of this variation may raise environmental justice concerns as discussed in previous chapters of this document.

⁷⁵ As noted in the discussion of fatal risk valuation in Chapter 3, the consideration of altruistic values is somewhat controversial and should be approached with caution.

to support use of the more sophisticated approaches, and analysts generally assess these transferability issues when reviewing the available studies.

Point Estimate. A point estimate refers to the process of taking a single estimate for a particular value (often the mean or median) and using it to directly approximate the value in the policy case. Reasonable high and low values (e.g., the 10th and 90th percentile of a distribution) may also be used for bounding or sensitivity analysis. In the most simple case, the analyst will take the mean or median value from the study case and multiply it by the number of statistical cases avoided (for health effects) or the population affected (for ecological effects) by the regulations.^{76,77} This type of simple transfer may be useful particularly for initial screening analysis, but does not account for any dissimilarities in the nature of the effects, the population characteristics, or the baseline status. Hence its use is generally limited to cases where the underlying research will not permit a more sophisticated approach. In such cases, the differences between the policy case and the study case are usually discussed quantitatively when presenting the results.

A more sophisticated approach involves tailoring point estimates to the particulars of the policy case through simple adjustments; for example, adjusting for changes in income over time. This type of tailoring improves the transferability of the estimates, and may be the only technique an analyst can employ when the valuation function for the study case is not available.

Benefit Function. The benefit function approach is possible when a valuation function is provided in the study case or can be calculated from the data set. For example, the study may include age and income in an econometric equation that predicts willingness to pay. The benefit function approach utilizes the additional information provided by the function and tailors it by substituting values from the policy case into the function. In other words, data on the age and income of individuals affected by a particular regulation can replace the data from the study case to yield an appropriate value or range of values. In some cases, the valuation function provided in the original study will include information not available for the policy case, such as attitudinal variables. In this case the analyst may wish to re-estimate the equation based on the variables for which data are available if appropriate given the nature of the study.

⁷⁶ A statistical case is calculated by multiplying the number of individuals affected by quantified risk factors. An example of this calculation is provided in the discussion of mortality risks in Chapter 3.

⁷⁷ When using benefit transfer to value ecological effects, the analyst often addresses difficult issues regarding the population assumed to value the change, referred to by economists as the "extent of market." For example, for recreational benefits, the study case may focus on households located within a set distance of the site, and the analyst conducting the transfer determines whether this assumption is appropriate for the policy case sites, and if not, how to adjust appropriately.

Because the benefits function approach is better tailored to the policy case than the point estimate approach, it can provide an improved estimate of the value of the benefits. However, one potential problem with this approach is its reliance on the equality of coefficients between the study and policy cases. This approach will still involve additional uncertainty if the two cases differ in ways that are not addressed by the valuation function (e.g., if baseline health conditions differ but are not included in the function resulting from the original case).

Meta-Analysis or Bayesian Approaches. The most complex transfers use statistical methods such as meta-analysis or Bayesian approaches, which combine estimates from several studies of similar effects.⁷⁸ Meta-analysis can be used to integrate the results when many relevant studies are available; the Bayesian approach includes data on the policy case as well as from existing studies.⁷⁹ These approaches have been used more frequently for ecological effects than for health effects because of the availability of larger numbers of applicable studies. Because these approaches draw on more data sources than a single study and use statistical techniques to explore the variation in the results, the resulting estimates may be more accurate and reliable than point estimates or valuation functions. However, meta-analysis and Bayesian approaches require a high level of technical expertise and can be very time consuming to implement. These approaches are also data intensive and may not be feasible for many effects due to the lack of relevant studies. Thus, analysts generally apply these techniques with caution and involve relevant experts in developing and reviewing the analysis.

With all of these transfer techniques, the analyst need to aggregate individual estimates over the population experiencing the effect. The aggregation process may be designed to take into consideration such issues as bias and distributional effects. For example, if separate values are available for a sensitive sub-population and for the remainder of the general population (minus the sensitive sub-population), the total value of the benefits for each group can be calculated separately and then added together to estimate benefits for the entire population.

4.1.5 Step 5: Address Uncertainty

Uncertainty permeates all the steps of the transfer process, from selecting appropriate studies and manipulating data to establishing a range of values. Each of the existing studies used in the transfer will itself contain uncertainties that result both from the

⁷⁸ For more information see Desvousges (1998), and Atkinson et al., "Bayesian Exchangeability, Benefit Transfer, and Research Efficiency," *Water Resources Research* 28(3) 715 - 722, March 1992.

⁷⁹ For an example of meta-analysis, see Boyle, K.J., G.L. Poe, and J.C. Bergstrom. "What do We Know about Groundwater Values? Preliminary Implications from a Meta-Analysis of Contingent-Valuation Studies," *American Journal of Agricultural Economics*, Vol. 76, pp. 1055-1061, December 1994.

data and analytic approach used as well as from difficulties related to thoroughly understanding the preferences of the individuals studied. However, the presence of uncertainty does not imply that the resulting values are random or indeterminable. By using techniques such as sensitivity analysis or more complex models such as Monte Carlo simulations, the analyst can, to a certain degree, quantify the effects of uncertainties in the estimates used in the benefit transfer.⁸⁰ As noted earlier, those uncertainties that cannot be quantified are generally discussed in qualitative terms when presenting the findings of the benefit transfer. In this discussion, analysts describe the relative importance of each source of uncertainty as well as the direction of the possible bias, if known.

4.2 Benefit Transfer Worksheet

The worksheet presented on the next pages summarizes the key questions discussed in the previous sections on quality, applicability, and transferability. Because it is designed as a general tool, the worksheet does not provide a comprehensive framework appropriate for every benefit transfer situation. Rather, it categorizes the most common issues in a format to facilitate further analysis.

⁸⁰ For more information on uncertainty analysis, see: Morgan, Granger M., and Max Henrion, *Uncertainty: A Guide to Dealing with Uncertainty in Quantitative Risk and Policy Analysis*, Cambridge University Press: New York, 1990.

**Exhibit 4-1
Sample Worksheet For Review of Valuation Studies**

GUIDELINE	QUESTIONS TO ASK	COMMENTS
Quality Issues		
Opinion of the Professional Community	Has the study been published in a peer-reviewed journal or been subject to other types of peer review? What are the strengths and weaknesses of the study according to experts in the field?	
Methods and Data Sources	Is the methodology used appropriate for the subject of the study? Has the methodology been widely used in similar studies? What are the strengths/weaknesses of the methodology? Are the study's data sources appropriate for the subject? What are the strengths/weaknesses of the data sources used?	
Sampling and Survey Administration	Does the study use appropriate probability sampling techniques? Is the sample size large enough? Is the response rate reasonably high? If a survey was conducted, was it adequately pre-tested? Was the survey administration technique (mail, phone, or in- person) employed following standard "best practices"?	
Data Analysis	Are the appropriate variables correctly specified and included in the analysis ? Is the appropriate functional form used for the calculations? Is the data set available for further analysis?	

**Exhibit 4-1
Sample Worksheet For Review of Valuation Studies**

Evidence of Accuracy and Reliability	<p>Is the study well documented?</p> <p>How were data, calculations, and results validated by the researcher?</p> <p>Are the effects of key uncertainties thoroughly described? Was a quantitative uncertainty analysis performed?</p> <p>When compared to other studies, are the findings reasonable?</p> <p>Are the findings consistent with economic theory?</p>	
Applicability Issues		
Similarity of Effect	<p>How does the effect analyzed in the study case compare to the effect of the policy case? What is the magnitude of the difference?</p> <p>Are the timing and duration of the effects similar?</p>	
Population Affected	<p>How does the population addressed in the study case compare to the population addressed by the policy case (e.g., in terms of age, geographic location, income, etc.)?</p>	
Baseline Conditions	<p>How similar is the policy case baseline (e.g., health status or environmental quality) to the study case conditions?</p> <p>Are there any characteristics of the individuals, ecological systems, or water systems in the policy case that render them more or less susceptible to the effect than the subject of the study case?</p>	
Transferability Issues		
Opportunities for Adjustment	<p>Does the data set from the original study contain information that allows for better tailoring of the study case to the policy case?</p> <p>Is a valuation function reported that can be transferred to the policy case?</p> <p>Are enough studies of similar effects available to use meta-analysis or Bayesian approaches to combine the results?</p>	

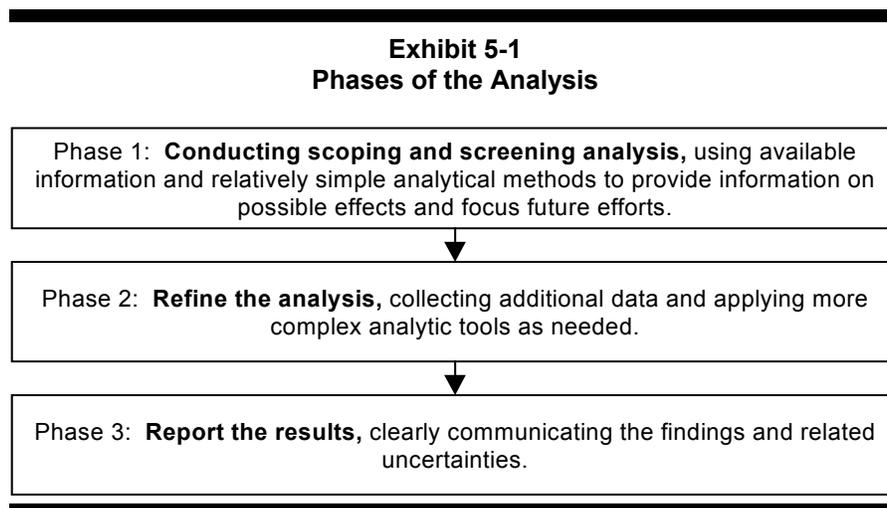
IMPLEMENTING BENEFITS ANALYSES CHAPTER 5

The previous chapters provide information on the requirements and methods for benefits assessment; this chapter discusses considerations related to implementing these types of analysis. It discusses issues related to sequencing the analysis, such as using screening tools to develop preliminary benefits estimates and to focus subsequent research. It also describes the basic steps in conducting benefits analyses, including identifying potential benefits, quantifying physical effects, and determining the monetary value of the effects. It then discusses some issues that relate to both the cost and benefit analyses, such as the definition of the baseline and the selection of discount rates.

5.1 Sequencing The Analysis

The EPA regulatory development process includes several phases of analysis and decision-making that often occur over several months or years depending on the complexity of the rulemaking. Both the internal EPA work group and stakeholder groups involved in developing and evaluating regulatory alternatives often find information on the potential benefits (and costs) of the options under consideration useful in their deliberations throughout this process.

To meet this need for early information on the benefits of different regulatory approaches as well as to focus resources on key issues, analysts generally find it helpful to adopt a sequential approach to data collection and analysis. Under this approach, the analyst begins with available data and relatively simple analyses, then refines the data and analyses as needed. The approach is illustrated in Exhibit 5-1 and discussed in the following sections.



Note that while the exhibit identifies reporting the results as a distinct final step for simplicity, the principles discussed below also apply to interim briefings or preliminary reports on earlier phases of the benefits analysis.

A critical advantage of sequential analysis is that it allows analysts and decision makers to apply an informal "value of information" approach to the performance of the benefits assessment, considering whether the time and expense of additional research and data collection are warranted at each stage in the analysis. In some cases, screening analysis alone may prove sufficient to support a regulatory decision. For example, the results of a screening analysis of benefits may be clear, persuasive, and certain enough to justify establishing the MCL at the lowest feasible level without additional analysis. In other cases, the conclusions of the analysis may not clearly support the choice between the lowest feasible level and less stringent alternatives. Analysts can then use the results of a screening study to focus subsequent efforts on those areas where more detailed investigation is most needed. In each stage, analysts work to clearly document the methods used in the analysis, its findings, and related uncertainties.

5.1.1 Conduct Scoping and Screening Analysis

The first step in conducting a benefits assessment is to collect and evaluate readily available information on the nature and extent of potential benefits associated with the proposed regulation. Because this information is typically used to define the scope of the overall assessment, this step is often referred to as "scoping analysis." This stage includes both review of the available literature and informal discussions with other EPA staff and management, outside experts, and stakeholders.

Once the available information has been collected and reviewed, the next step may involve performing a "screening" analysis to develop initial benefits estimates and identify areas where more investigation is needed. Screening analyses will often involve the use of benefit transfer techniques to value selected effects, as discussed in the Chapter 4. The results of these analyses may be used to provide decision-makers with preliminary information on the potential benefits of alternative MCLs or treatment requirements, as well as to define more clearly those areas where additional research is most needed to support decision-making. For example, analysts may find that uncertainties in the risk estimates are substantial and far outweigh uncertainties in the economic valuation data. Additional research could then be focused on refining the risk assessment rather than the valuation estimates.

5.1.2 Collect and Analyze Additional Data as Needed

Following completion of the screening analysis, the next step in the benefits assessment is to collect and analyze additional data that will reduce uncertainties or gaps in the preliminary benefits estimates. The exact steps undertaken will depend

on the nature and importance of the issues to be addressed as well as the time and resources available for the analysis. Options for collecting additional data may include conducting a census or survey, developing case studies, or interviewing pertinent experts.⁸¹ New supporting analysis may also be developed; for example, analysts may commission more primary research on the value of key benefits or use more formal techniques (such as meta-analysis, which uses statistical methods to combine the results of similar studies) in applying the results of available studies. In addition, analysts may attempt to better define areas of uncertainty, either by conducting additional bounding or sensitivity analysis or by applying probabilistic methods (such as Monte Carlo modeling).⁸²

Decisions about when to stop the analysis (i.e., when do we have enough information on benefits, with an appropriate level of certainty?) involve interaction between the EPA staff responsible for the cost and benefits analyses and senior managers. The costs and time required for additional analysis is balanced against the likely value of new information for decision-making. Analysts may consider the probability that the new information will significantly reduce uncertainty or improve the ability of decision-makers to select among alternative MCLs or treatment requirements.

5.1.3 Communicate the Results

As the benefits assessment proceeds through the phases described above, analysts are likely to be asked periodically to brief others involved in the regulatory development process (such as Agency management, work group members, and stakeholders) on their findings. In many cases, these audiences may be unfamiliar with the theory and methods of benefits analysis and with the advantages and limitations of various approaches. Communicating effectively to all of these groups involves tailoring the presentation to each audience's level of understanding and interests. An audience composed of EPA economists, for example, is likely to have different interests (as well as a differing level of familiarity with the topics) than would a citizens' group concerned with children's health risks.

⁸¹ All data collection must be conducted in compliance with the Paperwork Reduction Act, under which OMB approval is needed for efforts that pose the same or similar questions to more than nine respondents.

⁸² For more information on applying this framework to policy analysis, see: Morgan, Granger M., and Max Henrion, *Uncertainty: A Guide to Dealing with Uncertainty in Quantitative Risk and Policy Analysis*, Cambridge University Press: New York. 1990. For specific guidance on Monte Carlo analysis, see: U.S. Environmental Protection Agency, *Guiding Principles for Monte Carlo Analysis*, March 1997.

Regardless of the background or interests of the audience, analysts generally focus on presenting the results of the benefits assessment in plain English, using simple charts and graphics as appropriate to help communicate key findings. In addition, the presentation may note the uncertainties in the analysis and their implications for decision-making. For example, analysts may both point out the limitations ("the valuation estimates do not include several minor health effects") and to note the implications for decision-making ("these minor impacts may mean that total benefits exceed total costs by a greater amount than indicated by the quantified values").

Text discussions of these concerns are usually accompanied by tables and graphics that summarize key findings. Exhibit 5-2 provides an example of a table that presents analytic results, key uncertainties, and nonquantified effects. This table may be expanded to include costs for comparative purposes, or costs may be presented in a similar, but separate, format.

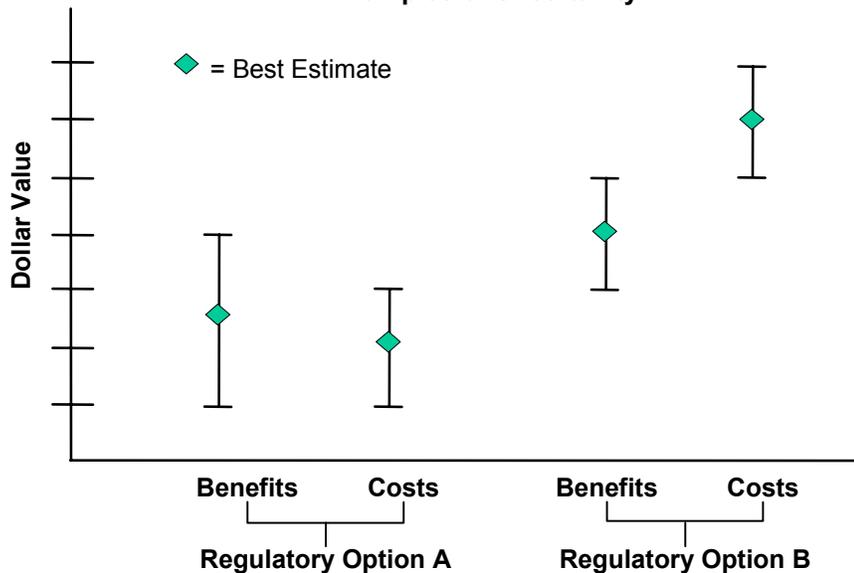
Exhibit 5-2
Sample Summary Table

Regulatory Option	Type of Benefit	Best Estimate	High End Estimate	Low End Estimate
MCL = X μ /L	Stomach Cancer	\$X million	\$XX million	\$0.X million
	Kidney Disease	\$X million	\$XX million	\$0.X million
	Developmental Effects	Not quantified. Limited available research suggests possible association with low birth weight.		
MCL = Y μ /L	Stomach Cancer	\$Y million	\$YY million	\$0.Y million
	Kidney Disease	\$Y million	\$YY million	\$0.Y million
	Developmental Effects	Not quantified. Limited available research suggests possible association with low birth weight.		

This type of table may be used to report the absolute value of the benefits for the baseline and each regulatory option, and/or the incremental change between options of increasing stringency.

An example of a graphic presentation of the uncertainty in the estimates is presented in Exhibit 5-3.

**Exhibit 5-3
Examples of Uncertainty**



Note: Nonmonetized costs and benefits should be identified in the notes on the exhibit.

The final results of the analysis are documented as part of the regulatory impact analysis (now generally referred to as the "economic analysis") prepared for the proposed and final regulations and placed in the public docket. This report is written in plain English for a general audience and includes simple tables and graphs that clearly communicate the approach, the results (including nonquantified effects), related uncertainties, and implications. All sources are referenced, and appendices are often used to report detailed analytic results as necessary. In general, the results of the risk assessment are presented separately from the economic valuation of benefits, due both to the importance of the risk data and the complexity of the issues that must be addressed.⁸³

5.2 Steps in the Benefits Analysis

In each phase described above, the benefits analysis generally includes three steps: (1) identify the types of benefits; (2) quantify physical effects; and (3) estimate the monetary values of these effects. Exhibit 5-4 illustrates the relationship between the

⁸³ For more information regarding the presentation of the benefits valuation analysis, see U.S. Environmental Protection Agency, *Guidelines for Preparing Economic Analyses*, EPA 240-R-00-003, September 2000.

phases of the analysis described above and these three steps. We discuss these steps in greater detail below.

Exhibit 5-4

Relationship Between Phases and Steps

Phase 1: Conduct scoping and screening analysis	Step 1: Identify potential types of benefits, including the full range of possible effects.
	Step 2: Quantify physical effects, focusing on key benefits and using available information.
	Step 3: Estimate the dollar value of the effects for key benefits, based on available valuation studies.
Phase 2: Refine the analysis as needed	Step 1: Refine the understanding of potential types of benefits, extending the analysis to include additional types of benefits if relevant.
	Step 2: Refine the estimates of physical effects, collecting additional data and/or performing additional analysis to address key uncertainties.
	Step 3: Refine the estimates of the value of the effects, collecting additional data and/or performing additional analysis to address key uncertainties.
Phase 3: Communicate the results	Step 1: Discuss the process and rationale used to select benefits for analysis, including information on any benefits that were not quantified or monetized.
	Step 2: Describe the methods used to quantify physical effects and the analytic results, including information on related uncertainties.
	Step 3: Describe the methods used to estimate the dollar value of the effects and the analytic results, including information on related uncertainties.

5.2.1 Identify Potential Benefits

In Chapter 1, we introduced three main categories of benefits related to regulations establishing MCLs or treatment requirements: human health effects, aesthetic effects, and effects on materials. Regulations leading to increased source water protection may also have ecological effects. Effects on human health are assessed for all regulations establishing MCLs, and that other effects are generally assessed as relevant to the particular regulation.

The first step in the benefits analysis is to develop a list of the effects in these categories that may be mitigated by the particular regulation, based on review of the relevant literature and consultations with experts. These experts may include risk assessors as well as others knowledgeable about the physical impacts of the contaminants.

In developing this list, analysts generally consider both the types of effects associated with the contaminant and the contaminant concentrations that are necessary to cause the effect. In some cases the regulations will not be sufficient to alter the effect of concern. For example, some health effects may not occur even in the baseline because contaminant concentrations are below the threshold levels for incidence of the effect. In other cases, the difference between baseline concentrations and alternative MCLs may not be sufficient to change the incidence of the health effect. Thus, in addition to identifying the potential effects of the contaminant, this step includes assessing whether each type of effect might be mitigated by the regulatory options under consideration.

At the outset of the analysis, information on baseline concentrations and possible MCLs may be sketchy and presented as broad ranges. Hence the range of possible beneficial effects may be relatively large. For example, the initial list of benefits potentially resulting from controlling a particular contaminant may include several types of fatal and nonfatal health effects, as well as some aesthetic effects. As more information becomes available on baseline and post-regulatory contaminant concentration levels, the list may be trimmed to exclude those types of benefits not likely to accrue.

While it is useful to develop a comprehensive list of possible benefits, some of these benefits may not be subject to detailed assessment. The detailed analysis generally focuses on significant benefits, including those effects that meet one or more of the following criteria: (1) there are likely to be observable changes in the effects when comparing alternative MCLs to each other and to the baseline; (2) the effects may account for a major proportion of the total benefits of the rulemaking; and/or, (3) stakeholders or decision-makers are likely to require information on the effects, even if their magnitude is relatively small. For example, if the contaminant is linked to an illness that particularly affects children, analysts may assess the effect of the regulation on the illness even if the number of cases is relatively small, given the emphasis of SDWA and other mandates on children's health effects. Any benefit categories that are not quantified or valued are discussed qualitatively when presenting the results of the analysis.

5.2.2 Quantify Physical Effects

The next step in the analysis involves quantifying the physical effects of the regulations -- e.g., determining the effect of the regulations on the risks of incurring specific diseases or on the level of corrosion in water system piping. These estimates are generally obtained from health scientists and risk assessors in the case of health effects, and physical scientists or engineers for other types of impacts. EPA's framework for risk assessment and other references provide detailed guidance on risk

assessment; analysts generally review the available literature and consult with relevant experts as needed to determine how to quantify other types of effects.⁸⁴

For health effects, this step results in detailed descriptions of the physical effects likely to be avoided by the regulations -- e.g., the types and severity of the illnesses. For each type of health effect, detailed data are also developed on the change in risk and the change in the number of statistical cases (including mortality rates) attributable to the regulation, the timing of the changes, and the demographics of the affected population. The uncertainty associated with these estimates is also explored.

For example, risk assessors may indicate that a specific MCL will reduce the annual, average individual risk of incurring a particular type of kidney disease by 1/10,000, decreasing the number of statistical cases (given the size of the population affected by the regulation -- in this example, 50,000) by the equivalent of five cases per year. Risk assessors may also note that about half of these cases would be fatal, and that the fatalities reduced by the regulation would primarily be among elderly members of the population. Furthermore, uncertainty analysis may indicate that the number of cases avoided may be understated or overstated by a factor of four.

Analysts generally develop similar types of information for other types of effects. For example, for corrosive contaminants, engineers may be asked to estimate the miles of piping affected, the degree of decrease in corrosion attributable to setting the MCL at different levels, the effect of the decrease on the timing and extent of pipe replacement, and the amount of uncertainty in these estimates.

As noted earlier, some benefits may not be quantified, either because the scientific basis for quantifying them is not well-established (e.g., data are lacking on the link between exposure and disease incidence) or because the time and resources required to perform the analysis outweigh the usefulness of gathering the additional information for decision-making. These benefits are discussed qualitatively when presenting the results of the benefits analysis.

5.2.3 Estimate the Value of the Effects

Once the physical effects of the regulation are quantified, analysts may use the methods described in Chapters 3 and 4 to estimate the dollar value of these effects. Below, we provide simplified examples of this step for mortality, morbidity, and other impacts. These examples are intentionally brief to illustrate the types of

⁸⁴ See, for example, U.S. Environmental Protection Agency, *Risk Assessment Guidance for Superfund, Volume I: Human Health Evaluation Manual (Part A)*, EPA/540/1-89/002, December 1989; U.S. Environmental Protection Agency, *Guidance for Risk Assessment*, prepared by the Risk Assessment Council, November 1991.

approaches that may be used. In reality, assessing these impacts is likely to be substantially more complex due to limitations in the available data and other factors.

Example 1: Mortality Valuation. As discussed in Chapter 3, available research provides value of statistical life estimates ranging from \$0.8 million to \$17.8 million, with a mean value of \$6.3 million (2000 dollars).⁸⁵ Using a Weibull distribution, the 10th and 90th percentile values are \$1.6 million and \$12.3 million respectively. These values apply to small changes in the risk of premature mortality among a population; they are not values for saving the life of a particular individual.

In the screening phase of the analysis, these estimates can be simply applied to initial estimates of the number of statistical lives saved to provide a preliminary indicator of the value of these benefits. The results of this analysis, for a regulation that reduces the risks of premature death by the equivalent of five statistical lives per year, would be as follows.

Exhibit 5-5
Example of Screening Analysis for Valuing Mortality Effects
(2000 Dollars)

Low End Estimate (10th percentile value)	Mid-Range Estimate (mean value)	High End Estimate (90th percentile value)
\$8.0 million (5*\$1.6 million)	\$31.5 million (5*\$6.3 million)	\$61.5 million (5*\$12.3 million)

The above example is intentionally simplified and an actual benefits analysis may be significantly more complicated. For example, analysts may perform a sensitivity analysis to account for uncertainty in the risk estimates; e.g., using reasonable upper and lower estimates of the number of statistical lives saved to help bound the benefits estimates, or applying a probabilistic model to estimate the likelihood of different outcomes. In addition, the biases that are introduced by using the available valuation literature (which largely addresses fatalities from work place accidents rather than environmental contaminants) may be addressed qualitatively or quantitatively, as discussed previously in Chapter 3.

Example 2: Morbidity Valuation. As Chapter 3 notes, values for avoiding nonfatal health effects will vary greatly depending on the nature and severity of the effect. Monetary values for several of the health effects associated with drinking water contaminants are provided in EPA's *Cost of Illness Handbook* and *Handbook*

⁸⁵ U.S. Environmental Protection Agency, *The Benefits and Costs of the Clean Air Act: 1990 to 2010*, EPA 410-R-99-001, November 1999.

on Noncancer Health Effects Valuation. These estimates include both cost of illness (COI) and willingness to pay (WTP) values; willingness to pay estimates are available for a relatively small number of health effects.

For the purpose of this example, we assume that the regulations will reduce, by 15 statistical cases, a specific type of kidney disease per year. We further assume that available COI estimates indicate that the costs of this illness (medical expenses and lost work time) average about \$25,000 per case. In addition, we assume that WTP values for similar (but not identical) illnesses are approximately \$45,000 per case. The results of a very simple screening analysis using these estimates is provided in Exhibit 5-6.

Exhibit 5-6
Example of Screening Analysis for Valuing Morbidity Effects
(1999 Dollars)

Cost-of-Illness (COI) Estimate	Willingness to Pay (WTP) Estimate
\$375,000 (15*\$25,000)	\$675,000 (15*\$45,000)
Note: The COI estimate is likely to understate the actual value of reducing these health effects, because it does not address pain and suffering or other effects associated with the disease. The WTP estimate accounts for these other effects, but is for a disease similar but not identical to the illness reduced by these regulations.	

In this case, the note in the exhibit would be explained in detail in the text; this discussion could address the likely direction and magnitude of the associated biases to the extent possible. Issues related to the quality, applicability, and transferability of the studies used to develop these estimates may be discussed in detail, as described in Chapter 4. For example, the WTP estimate may understate actual willingness to pay if it is for a less severe form of the illness or for a form with shorter duration. In this example, total benefits would be at least \$375,000, but could exceed \$675,000 since the WTP estimates probably understate the actual value. Sensitivity or probabilistic analysis could be performed to account for uncertainty in the risk (or valuation) estimates. This simple example does not reflect many of the considerations that might be addressed in an actual analysis, such as the rationale for using a point estimate to value these effects rather than a function that relates this value to the characteristics of the population affected and other determining factors. In subsequent stages of the analysis, this approach to valuation could be refined.

More information on valuing morbidity effects, including several examples, is provided in EPA's *Handbook on Noncancer Health Effects Valuation*.⁸⁶

Example 3: Valuation of Other Impacts. Chapter 3 also describes methods for valuing other types of benefits, such as reduced damages to materials and aesthetic effects. In many cases, the non-health effects of drinking water regulations may be valued using the avoided cost method. This method compares expenditures with and without the regulations to estimate the value of related benefits.

To illustrate this approach, consider a regulation that reduces the corrosion of pipes, which in turn will decrease the frequency of needed repairs and/or replacement. The value of this decreased maintenance and replacement (e.g., per mile of piping) could be estimated by engineers with relevant expertise, then applied to estimates of the length of piping potentially affected by the regulations. As in the mortality and morbidity examples, a simple approach could be applied for screening purposes, then refined if needed to provide better information for decision-making in subsequent phases of the analysis. For example, one refinement would be to consider the extent to which changes in costs would lead to changes in prices, and to re-estimate the benefits values to take into account the resulting change in consumer or producer surplus.

5.3 Cross-Cutting Issues

The previous discussion has focused primarily on issues that relate to the benefits analysis. There are also several cross-cutting issues that are addressed in both the cost and benefits analyses. We discuss two key considerations in more depth — discounting and inflation — and then provide a short overview of several other cross-cutting issues for benefits analyses under SDWA.

5.3.1 Discounting and Inflation

Analyses of the costs and benefits of drinking water regulations may be conducted on an annual basis, or may consider impacts over a number of years. The appropriate time frame for the analysis is determined on a case-by-case basis. In general, the annual approach may be most appropriate in cases where costs and benefits are expected to be relatively constant from year to year once the regulation is implemented. If costs and benefits accrue in different time periods or are likely to change significantly over time, the analysis may cover a multi-year period. For example, if EPA is considering whether to allow water systems to gradually comply with a new standard over a several year period, analysts may wish to compare the

⁸⁶ U.S. Environmental Protection Agency, *Handbook on Noncancer Health Effects Valuation (draft)*, prepared by Industrial Economics, Incorporated, September 1999.

costs and benefits of the phased approach to the effects of requiring more immediate compliance.

Regardless of the time period selected, analysts are likely to need to work with data on monetary values that were collected at different points in time. For example, recent compliance cost data may be available, but benefits valuation studies may be several years old. Two important factors affect the dollar value of costs and benefits over time — discounting and inflation. These terms apply to two very different concepts. Discounting is a method that accounts for alternative, productive uses of funds over time. Inflation refers to an overall rise in price levels. Below, we discuss each of these factors in more detail and provide an overview of EPA and OMB guidance on selecting a discount rate.

Inflation

Inflation refers to an overall rise in general prices throughout the economy; it is often measured by comparing the average prices of a standard bundle of goods and services across time. Inflation does not reflect a real increase in value; rather it indicates that the same goods and services now command higher prices. Information on inflation rates is available in the *Economic Report of the President*, which is published annually by the Executive Office of the President. This report includes both general inflation rates (the best known of which is the consumer price index or CPI) as well as rates for specific types of goods and services (e.g., the CPI-medical); the appropriate rate depends on the types of goods or services under consideration. These factors can be used to inflate prices incurred in prior years to the present or to decrease (deflate) current prices to a prior level.

For example, if a valuation study reports estimates as 1990 dollars, and an analyst wishes to convert to 1999 dollars using the CPI, he or she would first determine the change in the CPI over this time period. According to the 2000 *Economic Report of the President*, the CPI rose from 130.7 to 166.6 over this time period, or about 127 percent. The analyst would multiply the 1990 value by 1.27 to determine the 1999 equivalent.

To compare costs and benefits through time, analysts remove the effects of inflation from the estimates. Otherwise, it is difficult to disentangle real changes in value from changes that are attributable only to inflation. The OMB guidance recommends deflating benefit and cost estimates that are in nominal dollars by an appropriate inflation index to get constant dollar estimates.⁸⁷ In other words, cost and benefit estimates should be presented in real terms based on a specific year. Because of the

⁸⁷ U.S. Office of Management and Budget, "Guidelines to Standardize Measures of Costs and Benefits and the Format of Accounting Statements" Appendix 4 in *Report to Congress on the Costs and Benefits of Federal Regulations*, March 22, 2000.

uncertainties related to estimating future inflation, both costs and benefits are generally reported as of the most recent completed year for which inflation rates are available. For example, an analysis completed in 2001 might be reported in 2000 dollars.

Discounting

Discounting differs from inflation in that it measures real changes in value over time. When a water system invests in new treatment technology, or an individual invests in a home water filter, the investment means that the funds are not available for other productive uses. These alternative uses are referred to as "opportunity costs" by economists. In general, individuals prefer to have resources available in the near term rather than in the future, because they can invest the resources and receive a return on their investment. The same is true of consumption, individuals would generally prefer to consume desired goods or services soon rather than waiting.

Discounting is a method for adjusting monetary values to reflect these time preferences. Discounting future costs or benefits involves multiplying the value in each year by a factor that adjusts for both the length of time between the present and when the event occurs and the degree to which current investment (or consumption) is valued over future investment (or consumption). Discounting allows costs and benefits that occur in different time periods to be compared by stating them all in current year terms, referred to as the "net present value." The net present value of a stream of costs and benefits is calculated by multiplying the costs and benefits in each year by a time-dependent weighting factor and summing the results. The rate of change assumed over time is referred to as the "discount rate."

For example, if an analyst wishes to estimate the present (2001) value of costs incurred in year 2002 with an annual seven percent discount rate, he or she would multiply the costs in the year 2002 by 0.93 (the weighting factor for one year at seven percent) to determine the 2001 equivalent.⁸⁸

Both OMB and EPA require that economic analyses discount future costs and benefits to a present value equivalent when presenting the results. While concept of discounting is relatively straightforward, much controversy surrounds the choice of an appropriate discount rate. OMB and EPA currently recommend use of a seven percent discount rate, which "approximates the marginal pretax rate of return on an

⁸⁸ Most financial calculators and spreadsheet packages contain the formula for estimating these values, which is expressed as: $Net\ Present\ Value = NB_0 + d_1NB_1 + d_2NB_2 + \dots + d_nNB_n$, where NB_t is the net difference between benefits and costs that accrue in time period t (e.g., 0,1,2... n), and n is the final period for which the analyst has estimated benefits and costs. The discounting weights (d) are determined by $d_t = 1/(1+r)^t$ where r is the discount rate and t is the time period (or number of years from the present).

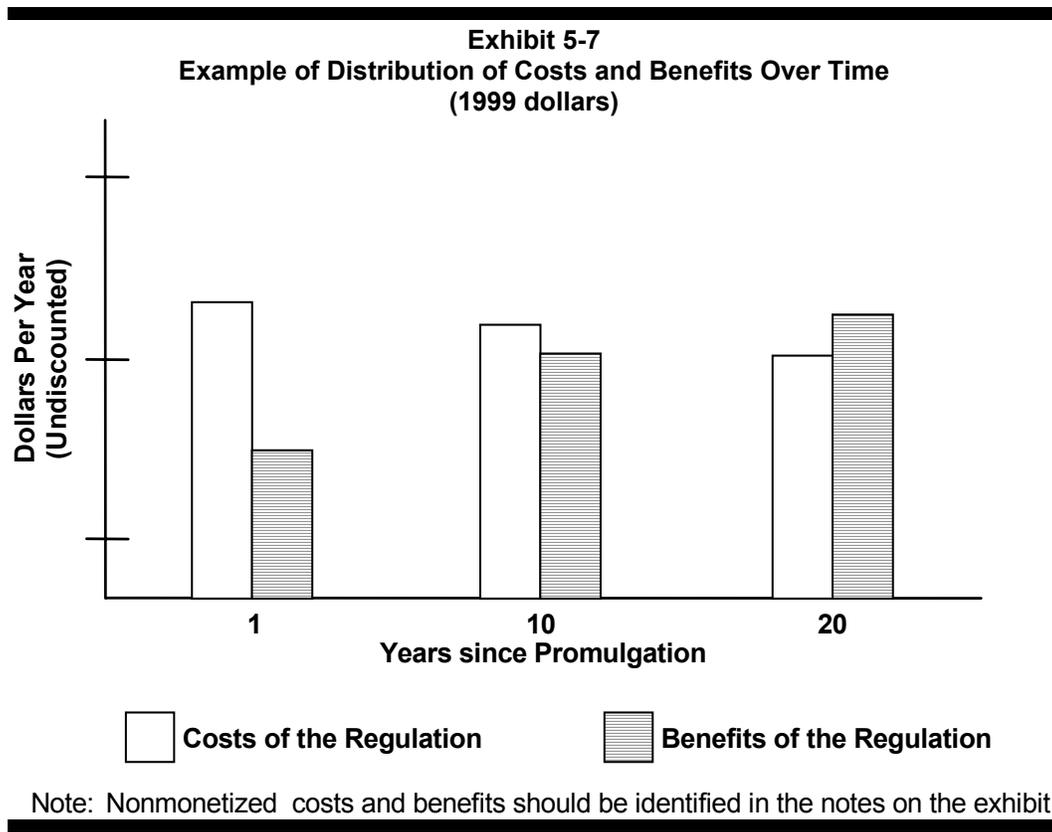
average investment in the private sector in recent years," unless a different rate is clearly justified.⁸⁹ This rate essentially assumes that government programs are displacing private investment. EPA suggests that analysts also present the results using a rate of two to three percent, which represents the consumption rate of interest, as discussed in more detail in the EPA *Guidelines for Preparing Economic Analyses*.⁹⁰ This rate essentially assumes that the programs are using funds that would otherwise be expended on current consumption. These are "real" discount rates; i.e., net of inflation. Any inflation adjustments needed to bring cost and benefit estimates into the same year are made prior to discounting. Regardless of the discount rate chosen, analysts use the same rate for both the cost and benefit analysis to ensure comparability.

Both OMB and EPA also recommend that analysts present the undiscounted stream of costs and benefits over time. Exhibit 5-7 presents an example of this type of

⁸⁹ U.S. Office of Management and Budget, *Guidelines and Discount Rates for Benefit-Cost Analysis of Federal Programs*, October 29, 1992, p. 9.

⁹⁰ This suggestion is echoed in the OMB Guidance, which discusses the use of a three percent rate.

graphic



5.3.2 Other Issues

In addition to discounting and inflation, there are several other cross-cutting issues analysts address in both the cost and benefits analyses. We provide a brief overview of these issues below; more information on many of these topics is provided in EPA's *Guidelines for Preparing Economic Analysis*.

Establishing a Baseline. The "baseline" in regulatory analysis refers to conditions now and in the future in the absence of the regulation. The effects of the regulatory options are then compared to this baseline to determine the costs and benefits of each option. Correct specification of the baseline is needed to accurately capture the effects of the regulation; for example, a baseline that exaggerates the deleterious effects of contaminants on the environment without the regulation may overstate the benefits of the regulation, and vice versa. A consistent baseline definition is used in both the cost and benefit analyses to ensure comparable results.

Rule Sequencing. When establishing the baseline conditions from which to assess the benefits of a regulation, another key issue is the sequencing of new regulations. EPA analyses generally assume that the baseline includes the effects of all rules that have been promulgated to date, but do not anticipate the implementation of new rules. However, in cases where several rules with interactive effects are being promulgated jointly, analysts may assess the combined effects of the rules as well as each rule's individual impact.

Risk Trade-Offs: In some cases, techniques to control contamination levels will produce risks. For example, disinfection techniques to control microbial contaminants may create disinfection by-products that pose other risks to human health. Both increases and decreases in various risks may be assessed and presented.⁹¹

Co-occurring Contaminants: SDWA explicitly requires that analysts consider the effects of co-occurring contaminants [(SDWA, Section 1412(b)(3)(c)(i))]. This issue refers to cases where treatment used to achieve the MCL under consideration also reduces the concentrations of other contaminants. The effects of reducing other contaminant concentrations should be assessed and presented with the overall results. Note, however, that because control of these other contaminants is not required by the regulation, related benefits are generally discussed separately from the benefits

⁹¹ This discussion refers to direct impacts of the regulations on risks. Economists debate whether the effects of regulatory costs on the resources available for other risk-reducing activities (such as health care) are significant and warrant inclusion in these types of analyses. See, for example, Viscusi, W.K., ed., "The Mortality Costs of Regulatory Expenditures," *Journal of Risk and Uncertainty*, Vol. 8, No. 1, 1994 (a special issue devoted to this topic).

associated directly with the MCL, so that decision-makers can consider these impacts independently. This approach is used because the MCL does not require system operators to achieve and maintain the assumed level of removal for the co-occurring contaminants. For example, the level of control of co-occurring contaminants may decrease over time if new treatment techniques are implemented that only target the contaminants for which MCLs are established.

Double-Counting. Throughout the entire analysis, it is important to assess and minimize the extent of double-counting in the benefit and cost estimates. For example, if a rule results in reduced corrosion of water system pipes, it could be assessed as a benefit to the rule. The cost analysis, however, could also assess this impact as a cost savings, resulting in double-counting. In addition, combining certain benefit valuation methods will also lead to double-counting. For example, a property value study may reflect perceived health risks as well as other factors, overlapping with more direct estimates of the value of risk reductions.

Comparing Costs and Benefits. While SDWA requires an assessment of benefits and costs, it does not require EPA to base decisions solely on quantified effects. Rather, it indicates that the quantified and non-quantified benefits must be considered and compared to the costs of the MCL [(SDWA Section 1412(b)(3)(c)(i)]. In many cases, regulatory analyses may include qualitative information for consideration by decision-makers, or may include information on physical effects but no dollar values. In these cases, techniques such as cost-effectiveness analysis or break-even analysis may be used to inform related policy decisions. In a case where the quantified benefits are less than the costs, decision-makers consider whether it is likely that the non-quantified benefits would bridge the gap between costs and benefits, or vice-versa.

These and other issues mean that benefits analysts generally work closely with other members of the regulatory development team. Coordination is needed to ensure that both the cost and the benefit analyses use consistent assumptions regarding baseline conditions and the effects of different regulatory options. In addition, both cost and benefits analysts need to ensure that they address the issues of concern to work group members, senior EPA managers, and stakeholders. Information from the cost analysis is also required for the analysis of benefits, such as data on the population served by systems likely to be affected by the potential regulatory requirements. Successful efforts often involve weekly or more frequent conversations among lead analysts and regulation managers to discuss the implications of preliminary findings and changes in the options under consideration, supplemented by more formal periodic meetings to report on progress and discuss next steps.

REPORT OF THE BENEFITS WORKING GROUP

APPENDIX A

A.1 Introduction

This appendix summarizes the deliberations of the National Drinking Water Advisory Council's (NDWAC's) Benefits Working Group. This group involved a wide variety of stakeholders, including utility company staff, environmentalists, health professionals, state water program staff, an elected official, economists, and members of the general public. Over the course of two meetings and two teleconferences during 1998, the Benefits Working Group discussed issues that arise in developing a new framework for evaluating the benefits of proposed drinking water regulations. This framework is being created by EPA's Office of Ground Water and Drinking Water (OGWDW) as part of the Office's efforts to implement the 1996 Safe Drinking Water Act (SDWA) amendments. The amendments require that EPA fully consider both quantifiable and non-quantifiable benefits that accrue as a result of drinking water regulations, and compare the benefits with the projected costs of the regulations.

The Benefits Working Group was charged with reviewing those quantifiable and non-quantifiable benefits that could be considered when developing drinking water regulations and provide recommendations to the Agency on which benefits should be evaluated in developing its regulations. In addressing the charge, the group considered the following questions:

1. What categories of benefits (qualitative and non-qualitative) should EPA routinely consider in the process of developing its drinking water regulations?
2. How (specifically) should EPA consider qualitative (non-monetizable) benefits in its rulemaking process?
3. How should EPA ultimately compare the results of its benefits evaluations with its cost analysis when developing drinking water regulations?

Numerous other questions and issues pertaining to benefits assessment were also raised for group discussion. Recommendations developed by the Benefits Working Group were presented to NDWAC on November 17, 1998.

This appendix: (1) lists the participants in the Benefits Working Group; (2) provides its recommendations as approved by NDWAC; and (3) includes the report it prepared on its deliberations. Additional information on the activities of the group (including meeting notes and handouts) is available from OGWDW staff.

A.2 NDWAC Benefits Working Group Participants

NDWAC Representatives

Walter Bishop
General Manager
Contra Costa Water District
1331 Concord Avenue
Concord, CA 95424

Diana Gale
Director, Seattle Public Utilities
710 Second Avenue, 10th Floor
Seattle, WA 98104

Valerie Lemmie
City Manager
City of Dayton
101 W. Third Street, Box 22
Dayton, OH 45401-0022

Designated Federal Officer

John B. Bennett
U.S. EPA-- Mail Code 4607
Office of Ground Water and
Drinking Water
401 M Street SW
Washington, D.C. 20460
(202) 260-0446
e-mail:
bennett.johnb@epamail.epa.gov

Members

Bill Allan
Program Director, Kickapo Tribe
Box 271
Horton, KS 66439

Jack DeMarco, Superintendent
Water Quality and Treatment
Division
Cincinnati Water Works
5651 Kellogg Avenue
Cincinnati, OH 45228

Thomas Dietz, Ph.D.
Department of Sociology and
Anthropology
George Mason University
Fairfax, VA 22030

Greg Evans, Director
Northern Virginia Soil & Water
Conservation District
12055 Government Center
Parkway, Suite 905
Fairfax, VA 22035-5512

Willy Fontenot
Louisiana Environmental Action
Network
632 Drehr Avenue
Baton Rouge, LA 70806

Dave Monthie, Program
Manager
Drinking Water Division
Department of Health
P.O. Box 47822
Olympia, WA 98504

Richard Moser
American Water Works Service
Company, Inc.
1025 Laurel Oak Road
P.O. Box 1770
Voorhees, NJ 08043

Jerome Paulson, MD
Division of Pediatrics
Department of Health Care
Services
George Washington University
School of Medicine & Health
2150 Pennsylvania Avenue, NW
Washington, DC 20036-2396

Director, Weld County Health
Department
1517 16th Avenue Ct.
Greeley, CO 80631

Dr. Robert Raucher
Hagler, Bailly Services, Inc.
P.O. Drawer O
Boulder, CO 80306-1906

Teresa Rissmiller
Mount Joy Township Authority
157 Merts Drive
Elizabethtown, PA 17022

John Schofield, Asst. District
Engineer
Division of Water Supply
Engineering
Department of Health
131 Walker Street
Lexington, VA 24450

Mark Smith
Resource and Environmental
Policy Branch
Resource Economics Division
Economic Research Service,
USDOA
1800 M Street NW
Washington, D.C. 20036-5831

Velma Smith
Friends of the Earth
1025 Vermont Avenue, N.W.,
Suite 300
Washington, D.C. 20005

Members (continued)

Members (continued)

John Pickle, MSEH

A.3 NDWAC Benefits Analysis Recommendations

On November 17, 1998, the National Drinking Water Advisory Council (NDWAC) approved a series of recommendations for EPA's Office of Ground Water and Drinking Water to consider in its analysis of the benefits of proposed regulations. These recommendations were based upon a report from the NDWAC Benefits Working Group.

The National Drinking Water Advisory Council (NDWAC) recommends that:

- (1) EPA should focus its benefits analysis efforts primarily on assessing effects on human health, defining these effects as clearly as possible and using the best available data to value them. It is also recommended that EPA should also consider, where appropriate, taste and odor improvements, reduction of damage to water system materials, commercial water treatment cost reductions, benefits due to source water protection (e.g., ecological benefits and non-use benefits), and benefits derived from the provision of information on drinking water quality (e.g., a household's improved ability to make informed decisions concerning the need to test or filter tap water);
- (2) EPA should devote substantial efforts to better understanding the health effects of drinking water contaminants, including the types of effects, their severity, and affected sensitive subpopulations. Better information is also needed on exposures and the effects of different exposure levels, particularly for contaminants with threshold effects. These efforts should pay particular attention to obtaining improved information concerning impacts on children and other sensitive populations;
- (3) EPA should clearly identify and describe the uncertainties in the benefits analysis, including descriptions of factors that may lead the analysis to significantly understate or overstate total benefits. Factors that may have significant but indeterminate effects on the benefits estimates should also be described;
- (4) EPA should consider both quantified and non-quantified benefits in regulatory decision-making. The information about quantified and non-quantified (qualitative) benefits should be presented together in a format, such as a table, to ensure that decision-makers consider both kinds of information;

- (5) EPA should consider incremental benefits and costs, total benefits and costs, the distribution of benefits and costs, and cost-effectiveness in regulatory decision-making. This information should be presented together in a format, such as a table, to ensure its consideration by decision-makers;
- (6) Whenever EPA considers regulation of a drinking water contaminant, it should evaluate and consider, along with water treatment requirements to remove a contaminant, source water protection options to prevent such a contaminant from occurring. The full range of benefits of those options should be considered.

A.4 Benefits Working Group

Report to the National Drinking Water Advisory Council

Charge to the Benefits Working Group

The specific charge for the Benefits Working Group was to *"consider the range of quantifiable and non-quantifiable benefits that could be considered when developing drinking water regulations and provide recommendations to the Agency on which benefits should be routinely considered in developing its regulations."* Questions to be addressed by the Working Group in carrying out the charge follow:

- What categories of benefits (both qualitative and quantitative) should EPA routinely consider in the process of developing its drinking water regulations?
- How (specifically) should EPA consider qualitative (non-monetizable) benefits in its rulemaking process?
- How should EPA ultimately compare the results of its benefits assessments with its cost analysis when developing drinking water regulations?

Summary of Benefits Working Group Recommendations

Recommendation #1: Categories of Benefits

The Working Group identified six categories of benefits that can result from drinking water regulations: (1) health risk reductions; (2) taste and odor improvements; (3) reduction of damage to water system materials; (4) commercial water treatment cost reductions; (5) benefits due to source water protection (e.g., ecological benefits and non-use benefits); and (6) benefits derived from the provision of information on drinking water quality (e.g., a household's improved ability to make informed decisions concerning the need to test or filter tap water). The members agreed on the following recommendation:

- EPA should focus its benefits analysis efforts primarily on assessing effects on human health, defining these effects as clearly as possible and using the best available data to value them.

Recommendation #2: Assessing Health Risks and Valuing Benefits

The analysis of health risks is central to EPA's ability to establish the appropriate MCLG and to assess the benefits of alternative levels for the MCL. The Benefits Working Group discussed several concerns related to the valuation of health benefits, and agreed on the following recommendation:

- EPA should devote substantial efforts to better understanding the health effects of drinking water contaminants, including the types of effects, their severity, and affected sensitive subpopulations. Better information is also needed on exposures and the effects of different exposure levels, particularly for contaminants with threshold effects. These efforts should pay particular attention to obtaining improved information concerning impacts on children and other sensitive populations.

Recommendation #3: Addressing Uncertainty

The Benefits Working Group discussed several concerns related to addressing uncertainty in benefits analysis, and agreed on the following recommendation:

- EPA should clearly identify and describe the uncertainties in the benefits and costs analysis, including descriptions of factors that may lead the analysis to significantly understate or overstate total benefits and costs. Factors that may have significant but indeterminate effects on the benefits and costs estimates should also be described.

Recommendation #4: Addressing Non-Quantified Benefits

The Benefits Working Group discussed several issues related to addressing non-quantified benefits, and agreed on the following recommendation:

- EPA should consider both quantified and non-quantified benefits in regulatory decision-making. The information about quantified and non-quantified (qualitative) benefits should be presented together in a format, such as a table, to ensure that decision-makers consider both kinds of information.

Recommendation #5: The Presentation of Information on Benefits and Costs

The Benefits Working Group discussed a number of issues related to the presentation of information on benefits and costs, and agreed on the following recommendation:

- EPA should consider incremental benefits and costs, total benefits and costs, the distribution of benefits and costs, and cost-effectiveness in regulatory decision-making. This information should be presented together in a format, such as a table, to ensure its consideration by decision-makers.

Recommendation #6: Source Water Protection Options

The Benefits Working Group discussed several issues related to addressing increasing source water protection, and agreed on the following recommendation:

- Whenever EPA considers regulation of a drinking water contaminant, it should evaluate and consider, along with water treatment requirements to remove a contaminant, source water protection options to prevent such a contaminant from occurring. The full range of benefits of those options should be considered.

Background and Overview of Working Group Discussions

The Benefits Working Group was established to help shape how EPA should best meet the new benefits analysis requirements that are specified in the 1996 SDWA amendments, as new program regulations are developed over the next few years. Since its inception, EPA has performed benefits analysis, usually as part of a benefit/cost analysis, as one of many sources of information on the potential effects of its regulations. EPA views benefit/cost analysis as a method to organize information in a way that informs the decision. These analyses may contain significant uncertainty and provide only one perspective on the merits of alternative policy choices. Other types of analysis are needed to address concerns about equity, for example.

Several statutes, Presidential Executive Orders, and guidance documents govern the conduct of benefit/cost and related regulatory analyses at EPA. Benefit/cost analyses undertaken by Federal agencies are expected to

adhere to "best practices" as defined by the economics profession. Federal agencies must also address several specific concerns related to imposing costs or other burdens on private industry, state and local government, and other entities, such as avoiding unfunded mandates or requirements that are particularly burdensome for small businesses or local government. Other government-wide requirements focus on protecting certain groups of potentially affected individuals, such as minorities, low income populations and children. In the case of drinking water regulations, SDWA also contains several requirements related to the performance of benefit/cost analysis and its use in decision-making.

I. Categories of Benefits

A. Background

Most drinking water regulations promulgated under SWDA focus on establishing the maximum allowable concentration of a particular contaminant (or group of contaminants) for drinking water supply systems used by the public. For these types of regulations, the "costs" of the standards generally include expenditures on monitoring and treatment (or, in some cases, source water protection) and related market impacts such as the effects on water price increases. The "benefits" include the effects of reducing the concentration of the contaminants in drinking water. Drinking water regulations may also increase the availability of information on water quality.

In 1997, EPA conducted a detailed review of the potential benefits of drinking water regulations, as reported in "*Valuing Drinking Water Quality: Theory, Methods, and Research Needs.*" Based on this research, EPA identified four major categories of benefits that may warrant routine consideration for individual rules:

- Reduced health risks, including decreased risks of premature death, illness or other health impacts.
- Improved aesthetic qualities, including tap water taste, odor, and appearance.
- Reduced damages to materials, primarily related to reduced corrosion of water system piping and equipment.

- Improved qualities for commercial and industrial use, for example, in cases where contaminants would adversely affect production processes if not removed by the water supplier.

While effects on health risks are assessed for most drinking water regulations, many of the other categories are considered only when relevant to a particular contaminant. For example, many contaminants do not affect the taste, odor, or appearance of tap water. In addition, some drinking water regulations will address categories not directly included in the above list. For example, regulations requiring increased source water protection may have ecological benefits, such as enhanced recreational fishing and bird-watching opportunities due to improved productivity of the fish and wildlife stock.

B. Working Group Discussion Overview (Recommendation #1: Categories of Benefits)

A key question raised by EPA for the Benefits Working Group was "what categories of benefits should EPA routinely consider in the process of developing its drinking water regulations?" EPA asked the Working Group members to review the potential benefits categories described above, both to determine whether EPA has excluded important categories and to identify which categories are most important to formally assess and quantify. In response to this request, the Working Group identified six categories of benefits that can result from drinking water regulations: (1) health risk reductions; (2) taste and odor improvements; (3) reduction of damage to water system materials; (4) commercial water treatment cost reductions; (5) benefits due to source water protection (e.g., ecological benefits and non-use benefits); and (6) benefits derived from the provision of information on drinking water quality (e.g., a household's improved ability to make informed decisions concerning the need to test or filter tap water). The members agreed on the following recommendation:

- EPA should focus its benefits analysis efforts primarily on assessing effects on human health, defining these effects as clearly as possible and using the best available data to value them.

During the group's discussions of potential benefits categories, the following points were mentioned by at least one member of the group as important considerations for EPA.

- When assessing health-related benefits, EPA should ensure that adequate attention is paid to impacts on vulnerable groups (e.g., children, pregnant women, the elderly, individuals with immune deficiencies, Native Americans). Additional research (and funding) is needed to better understand and value these impacts.
 - Benefits categories other than health should be considered in cases where they may affect EPA decision-making, e.g., if the benefits are likely to be significant or if consideration of the benefit category could influence the selection of the MCL.
 - The analysis should consider both positive and negative changes in each benefit category.
-
- EPA should consider all relevant benefits categories in its decision-making regardless of whether the benefits are quantified or valued. However, some members of the group expressed concern that EPA may overemphasize the value of assessing benefits other than health effects.
 - Some of the benefits that would be derived from a decrease in health problems for children include less time lost from school, less parental time lost from work, and less family disruption. Children also have more potential years of life to lose, and their earning potential could be affected.
 - EPA should conduct retrospective analysis to assess the extent to which predicted benefits are consistent with the actual benefits realized.
 - Working Group members agreed that at least six categories of benefits result from drinking water regulations. Of the six, four categories of benefits result from drinking water treatment improvements: health risk reductions, taste and odor improvements,

materials damage reduction (of water systems), and commercial water treatment cost reductions. The other benefits categories arise from source water protection efforts and the provision of information on drinking water quality.

II. Methods for Assessing Health Risks and Valuing Benefits

A. Background

A.1 Assessing Health Risks

EPA requires information on health risks to establish the MCLG, and to assess the benefits of establishing the MCL at or above the “feasible” level. The MCLG is generally set at “zero” for contaminants that pose risks of physiological damage at all doses (i.e., nonthreshold toxicants, including most carcinogens). For threshold toxicants, the MCLG is generally set at the level where there are no observable effects (with a margin of safety).

To estimate the risks associated with particular contaminants, EPA may derive information from epidemiological studies of human populations or from animal studies. Epidemiology generally involves developing statistical relationships between estimates of exposure and the incidence of health effects. The advantage of these studies is that they use data on human effects; the disadvantage is that the results of some studies can be difficult to interpret because of confounding factors such as exposure to other contaminants, and may not provide an understanding of the physiological basis for the effect. Data from animal studies address confounding factors by using a controlled environment, but may be difficult to translate into human terms.

A.2 Methods for Valuing Benefits

From the perspective of economic theory, the appropriate measure of value is willingness to pay for the benefits. Willingness to pay is the maximum amount of money an individual would voluntarily exchange to acquire something or obtain an improvement (e.g. in drinking water quality). An individual’s willingness to pay necessarily includes that individual’s ability to pay because the resources available to any individual are limited. An individual may wish to pay more than the total value of the resources available to him or her, but economic willingness to pay is limited to that amount the individual can actually allocate for the benefit in question. Because “improved drinking water quality” is not directly bought and sold in the marketplace, information on willingness to pay must be derived from the markets for related goods or from surveys or similar data collection efforts.

The particular methods used vary depending on the benefit category assessed. Below, we discuss the approaches used for the major benefit categories discussed by the Working Group: reduced mortality risks, reduced morbidity risks, avoided damages to materials, and effects on commercial and industrial water use.

A.2.1 Valuing Mortality Risks

Drinking water regulations may decrease the risks of contracting a potentially fatal disease, such as certain cancers. The most commonly used approach for valuing these changes in mortality risk focuses on the "value of a statistical life." This term refers to the value of relatively small changes in the risk of death among a population. For example, if 100,000 people are each willing to pay \$100 to reduce their own risk of death by 1 in 10,000, then as a group their willingness to pay for a program that would save 10 lives in the population is \$10 million, or \$1 million per statistical life. This value refers to the sum of individuals' willingness to pay for risk reductions. Presently, the value of statistical life most often used in EPA regulatory analyses includes a best estimate of \$5.8 million (in 1997 dollars) per statistical life saved, with a lower bound of \$0.7 million and an upper bound of \$16.3 million. These values are derived from 26 studies, including 21 wage-risk studies and five contingent valuation studies, and have been subject to substantial peer review.

While this range of values provides the best estimates currently available, applying this range has several limitations. First, there are many differences between the risks addressed by the available studies and the risks associated with environmental regulations. The studies address risks that are incurred voluntarily, and that often accrue from accidents rather than lingering illnesses. Second, drinking water regulations may also affect people with different demographic characteristics than those studied, e.g., different age or income groups, or people whose initial health condition differs.

A.2.2 Valuing Morbidity Risks

The contaminants addressed by drinking water regulations can cause a variety of illnesses, including acute illness, nonfatal cancers, and other chronic diseases, as well as nonfatal reproductive and developmental effects. The most common approach to valuing morbidity is the cost-of-illness method, which derives values from the medical costs and lost work time associated with an illness. While this approach is relatively easy to understand and implement, it is not a complete measure of willingness to pay. The availability of insurance affects people's willingness to incur these costs, and this approach excludes the value placed on avoiding pain and

suffering and reducing the risk of illness. Under most plausible conditions, cost of illness studies understate total willingness to pay, with the degree of understatement varying depending on the nature and severity of the disease.

For many health effects, only cost of illness estimates may be available; studies of total willingness to pay have been undertaken for only some of the health effects of concern.

A.2.3 Valuing Other Effects (avoided damages to materials, and effects on commercial and industrial water use)

The other types of benefits likely to be considered for drinking water regulations include avoided materials damages (e.g., reduced corrosion) and improved water quality for commercial and industrial use. This latter category focuses on water as an input to production processes rather than its use as drinking water, e.g., for cooling or for mixing with other materials. In either case, the method most commonly used to measure the value of related benefits is to assess avoided costs. This approach considers the costs incurred in the absence of the regulation, and assesses the extent to which these costs would be reduced under alternative regulatory levels. These avoided costs may include expenditures on replacing corroded distribution system piping or industrial equipment, or on additional treatment by an industrial plant prior to use.

B. Working Group Discussion Overview **(Recommendation #2: Assessing Health Risks and Valuing Benefits)**

The analysis of health risks is central to EPA's ability to establish the appropriate MCLG and to assess the benefits of alternative levels for the MCL. The Benefits Working Group discussed several concerns related to the valuation of health benefits, and agreed on the following recommendation:

- EPA should devote substantial efforts to better understanding the health effects of drinking water contaminants, including the types of effects, their severity, and affected sensitive subpopulations. Better information is also needed on exposures and the effects of different exposure levels, for all populations, and especially vulnerable populations, particularly for contaminants with threshold effects.

During the group's discussion on methods for assessing health risks and valuing benefits, the following points were mentioned by at least one member of the group as important considerations for EPA.

- Affordability tends to be the deciding factor in determining whether a customer is willing to pay for a product. EPA should develop clear affordability criteria; for example, by looking at the percentage of disposable income spent on different goods and services.
- As ability to pay and willingness to pay are constrained by income, other kinds of analyses on equitability should be conducted.
- Consumers view water as a non-discretionary product, not consistent with economic principles. The compelling issue is whether WTP is equated with fairness. Affordability is more closely linked to fairness. EPA should consider the consumer's decision-making process for a non-discretionary product and review the available literature on this topic.
- Affordability pertains to equity concerns and WTP to efficiency concerns. Economics tends to ignore equity. Affordability and ability to pay are important for social issues, but not important for cost-benefit analysis which focuses on the most efficient approach to risk reduction. Affordability and WTP involve separate issues, and should be analyzed separately.
- The effects on vulnerable populations, such as fetuses, infants and children, the elderly and the immunosuppressed should be explicitly evaluated.
- Data on health effects should be derived from careful consideration of the quality of available studies, and additional research should be conducted when needed to refine or expand available data.

- EPA should separately evaluate exposure risks to children and other sensitive subpopulations. In the absence of adequate exposure data for these subgroups, EPA should not simply extrapolate from data on the general population.
- The EPA should develop strong working relationships with other components of the Federal Government involved with the collection and study of health information, such as the National Center for Health Statistics and the National Center for environmental health.
- Working Group members disagree on the use of epidemiological studies. Some argue that these studies should not be used as the sole basis for developing regulations if data are lacking on the cause and effect relationship for a particular contaminant and health effect. Others argue that it is reasonable to use the correlations found in well-conducted epidemiological studies when developing regulations.
- Regardless of the particular benefit being valued, EPA should use well-conducted, unbiased studies to estimate the value. While many high quality studies have been conducted in this area, additional research on these values is still necessary. However, the need to address the more significant uncertainties in the health risk data should be a higher priority for EPA.
- EPA should ensure that the approach to valuing morbidity addresses all elements of willingness to pay (not just medical costs), but care should be taken to ensure that the resulting values are not overstated due to difficulties in obtaining estimates for components of willingness to pay such as pain and suffering.
- EPA should support and conduct research to adapt existing methods so that they can be applied to valuing mortality and morbidity risks to children, pregnant women, those with preexisting chronic diseases and the elderly, rather than relying on estimates developed for adults when considering these effects. In considering these groups, one should value the costs to not only the individual involved but to others in their family/social

group as well. A problem in a child usually involves not only the loss of the child's time from school but the parents' time from work. In the case of those with preexisting chronic disease or the elderly, there is often some third party who must also be involved in taking the individual to the doctor or for other services. Most of these costs should be measurable.

III. Methods for Addressing Uncertainty

A. Background

Benefits and costs analyses of drinking water regulations often contain significant uncertainty. The appropriate method for addressing uncertainty depends in part on the source of the uncertainty and on the types of data available. In addition, the method selected will depend on the information needed for decision-making. Simple and inexpensive methods may be adequate for determining appropriate regulatory levels if they clearly support a particular option despite remaining uncertainties (e.g., demonstrate that the benefits analysis clearly supports setting an MCL at the lowest feasible level), or if the value of additional information is outweighed by the costs or time needed to acquire it.

Regardless of the method chosen, EPA believes that uncertainties in the analysis must be clearly stated, with a discussion of the implications for decision-making. The methods and data used in the analysis should be clearly described and justified. The results of the benefits and costs analysis are often best described as a range of values. Benefits and costs that are not quantified, or that are quantified but not assigned a monetary value, also should be included in the presentation of results.

B. Benefits Working Group Discussion Overview **(Recommendation #3: Addressing Uncertainty)**

The Benefits Working Group discussed several concerns related to addressing uncertainty in benefits analysis, and agreed on the following recommendation:

- EPA should clearly identify and describe the uncertainties in the benefits and costs analysis, including descriptions of factors that may lead the analysis to significantly understate or overstate total benefits and costs. Factors that may have significant but indeterminate effects on the benefits and costs estimates should also be described.

During the group's discussion on methods for addressing uncertainty, the following points were mentioned by at least one member of the group as important considerations for EPA.

- Presentations of quantitative results should be combined with discussions of any benefits that were not quantified or monetized.
- EPA should strive to reduce the uncertainties in health effects studies and exposure data.
- Members disagree about the level at which the MCL should be set in cases where the remaining uncertainty in the analysis does not clearly argue for a particular level. Some believe a stringent level should be selected to be protective, while others argue that a less stringent level is desirable to avoid imposing potentially unwarranted costs.

IV. Cost-benefit Analysis and Qualitative (Non-quantified) Benefits: the Presentation of Information

A. Background

Drinking water regulations often may have benefits that cannot be easily quantified or valued. In some cases, the inability to quantify benefits stems from the status of the underlying scientific research. For example, available studies in the health science literature may suggest that a contaminant is associated with a particular illness, but may not provide data on the relationship between changes in exposure and changes in the incidence of the illness. As a result, it may not be possible to quantify the changes in risk associated with different MCLs (e.g., to determine the number of cases avoided) nor may it be possible to value, in dollar terms, these changes in risk. In other cases, the lack of quantification may result from the need to focus limited time and resources on the most significant issues; EPA may not be able to fund studies of less significant effects especially if they require the use of expensive research techniques over long time periods.

EPA and OMB guidance requires the consideration of non-quantified effects in regulatory analyses, and SDWA explicitly notes that non-quantified benefits should be weighed in determining the appropriate MCL. Information on these effects can be discussed qualitatively using text and graphics to indicate their possible importance in terms of incidence and dollar value. In addition, analysts can use breakeven analysis or measures of cost-effectiveness to provide information on the relationship of the non-quantified

effects to the quantified costs and benefits. For example, analysts can indicate the number of cases that would need to be avoided, or the dollar value per case that would be needed, for the total benefits to equal the total costs associated with alternative MCLs.

**B. Benefits Working Group Discussion Overview
(Recommendation #4: Addressing Non-Quantified Benefits; also Recommendation #5: The Presentation of Information on Benefits and Costs)**

The Benefits Working Group discussed several issues related to addressing non-quantified benefits, and presenting information on costs and benefits, and agreed on the following two recommendations:

- EPA should consider both quantified and non-quantified benefits in regulatory decision-making. The information about quantified and non-quantified (qualitative) benefits should be presented together in a format, such as a table, to ensure that decision-makers consider both kinds of information.
- EPA should consider incremental benefits and costs, total benefits and costs, the distribution of benefits and costs, and cost-effectiveness in regulatory decision-making. This information should be presented together in a format, such as a table, to ensure its consideration by decision-makers.

During the group's discussion of qualitative information, the following points were mentioned by at least one member of the group as important considerations for EPA.

- Information on potential benefits should be presented even in cases where the available evidence is weak or contradictory, to ensure that decision-makers weigh all available information in establishing regulatory levels.

- This information should include calculation of breakeven points or similar measures to indicate the extent to which the non-quantified effects may bridge the gap between costs and benefits, in cases where quantified benefits are less than quantified costs.
- The analysis should clearly indicate the areas where additional research is needed, and explicitly discuss the limitations and uncertainties in the available data. Where possible, additional research should be conducted to increase EPA's ability to quantify the potential benefits of alternative MCLs.
- When health effects cannot be quantified (e.g., the change in risks or in number of cases cannot be determined from available data), EPA should not attempt to assign dollar values to these effects. Monetizing these effects may mask the gaps in the data and is not likely to provide credible results.

V. Consideration of Source Water Protection Options

A. Background

Although the Working Group's main charge was to consider methods for assessing benefits, many members felt that EPA's focus on the process for selecting among alternative MCLs (i.e., on treatment) was too narrow. The members believe that EPA should be considering a wider range of options for addressing contaminants in water supplies. The Working Group indicated that it is particularly important for EPA to focus more attention on options for source reduction, and developed the recommendation discussed below.

B. Benefits Working Group Discussion Overview **(Recommendation #6: Source Water Protection Options)**

The Benefits Working Group discussed several issues related to addressing increasing source water protection, and agreed on the following recommendation:

- Whenever EPA considers regulation of a drinking water contaminant, it should evaluate and consider, along with water treatment requirements to remove a contaminant, source water protection options to prevent such a contaminant from occurring. The full range of benefits of those options should be considered.

During the group's discussion, the following points were mentioned by at least one member of the group as important considerations for EPA.

- EPA should consider the full range of regulatory and non-regulatory approaches available for addressing drinking water contamination, including improving public education, issuing health advisories, and providing bottled water or filters for household use, as well as protecting water sources from contamination (e.g., cleaning up industrial sites which are contributors to drinking water contamination).
- Approaches to addressing drinking water contamination, other than establishing an MCL or treatment technique, may maximize benefits and/or lower costs.
- The protection of wetland habitats should be considered, as well as point source reduction.

VI. Additional Issues

During the group's discussion of various issues, the following points, which related to additional issues, were mentioned by at least one member of the group as important considerations for EPA.

- EPA should place additional emphasis on ensuring racial and economic diversity when involving stakeholders in its work groups, including more members of minority and low income groups and Indian tribes. Other Working Group members disagreed with this.
- Affordability, for both households and water systems, should be an important consideration in determining

appropriate regulatory levels or alternative technologies.

- The effect of contaminants on sensitive subpopulations should be a key consideration in establishing the MCLG and MCL for threshold toxicants.
- EPA should improve communication regarding the risks associated with drinking water contaminants by working with local public health departments, state public health departments, state and elected officials, regional offices, grassroots organizations, and local communities, including families and health care providers. EPA should develop clearer information on scientific findings, and improve access to this information through the World Wide Web and other media.
- EPA should ensure that regulatory requirements to monitor for the presence of contaminants in drinking water take into account both the costs and benefits of the monitoring effort. In addition, EPA should compile monitoring data in an accessible, computerized format that supports ready analysis of exposure to contaminants, related health risks, and the potential benefits of proposed regulations.

REFERENCES

- Abdalla, Charles W. "Measuring Economic Losses From Ground Water Contamination: An Investigation of Household Avoidance Costs." *Water Resources Bulletin*. Vol. 26, pp. 451-464, 1990.
- Abdalla, C.W., B.A. Roach, and D.J. Epp. "Valuing Environmental Quality Changes Using Averting Expenditures: An Application to Groundwater Contamination." *Land Economics*. Vol. 68, pp. 163-169, May 1992.
- Adamowicz, W., et al. "Combining Revealed Preference and Stated Preference Methods for Valuing Environmental Amenities." *Journal of Environmental Economics and Management*. Vol. 26, pp. 271-292, 1994.
- Adamowicz, W., et al. *Introduction to Attribute-Based Stated Choice Methods*. Prepared for the National Oceanic and Atmospheric Administration. January 1998.
- Adams, R.M. and T.D. Crocker. "Materials Damages." *Measuring the Demand for Environmental Quality*. (J.B. Branden and C.D. Kolstad, eds.) Elsevier Science Publishers: The Netherlands. pp. 271-303, 1991.
- Agee, M.D. and T.D. Crocker. "Parental Altruism and Child Lead Exposure: Inferences from the Demand for Chelation Therapy." *Journal of Human Resources*. Vol. 31, pp. 677-691, Summer 1996.
- Atkinson, S.E., T.D. Crocker, and J.F. Shogren. "Bayesian Exchangeability, Benefit Transfer, and Research Efficiency." *Water Resources Research*. Vol. 28, pp. 715-722, March 1992.
- Bartik, T.J. "Evaluating the Benefits of Non-Marginal Reductions in Pollution Using Information on Defensive Expenditures." *Journal of Environmental Economics and Management*. Vol. 15, pp. 111-127, 1981.
- Berger, M.C., G.C. Blomquist, D. Kenkel, and G.S. Tolley. "Valuing Changes in Health Risks: A Comparison of Alternative Measures." *Southern Economic Journal*. Vol 53, pp. 967-984, 1987.
- Bjornstad, D.J. and J.R. Kahn. *The Contingent Valuation of Environmental Resources: Methodological Issues and Research Needs*. Edward Elgar: Brookfield, VT. 1996.

- Boyle, K.J., G.L. Poe, and J.C. Bergstrom. "What do We Know about Groundwater Values? Preliminary Implications from a Meta-Analysis of Contingent-Valuation Studies," *American Journal of Agricultural Economics*. Vol. 76, pp. 1055-1061, December 1994.
- The Cadmus Group and Science Applications International Corporation. *RIA for the Stage 1 Disinfectants/Disinfection Byproducts Rule*. Prepared for the U.S. Environmental Protection Agency. 1998.
- Carson, R.T. "Contingent Valuation: A User's Guide." *Environmental Science and Technology*. Vol. 34, pp. 1413-1418, 2000.
- Council on Environmental Quality. *Guidance for Addressing Environmental Justice Under the National Environmental Policy Act (NEPA)*. March 1998.
- Courant, Paul and Richard Porter. "Averting Expenditure and the Cost of Pollution." *Journal of Environmental Economics and Management*. Vol. 8, pp. 321-329, 1981.
- Cropper, M. and A.M. Freeman III. "Environmental Health Effects." *Measuring the Demand for Environmental Quality*. (J.B. Branden and C.D. Kolstad, eds.) Elsevier Science Publishers: The Netherlands. 1991.
- Cropper, M.L. and F.G. Sussman. "Valuing Future Risks to Life." *Journal of Environmental Economics and Management*. Vol. 19, pp. 160-174, 1990.
- Cummings, R.G. and G.W. Harrison. "The Measurement and Decomposition of Nonuse Values: A Critical Review." *Environmental and Resource Economics*. Vol. 5, pp. 225-247, 1995.
- Desvouges, W.H., et al. *Environmental Policy Analysis with Limited Information: Principles and Applications of the Transfer Method*. Edward Elgar Publishing: Northampton, MA. 1998.
- Dickie, M. and S. Gerking. "Willingness to Pay for Ozone Control: Inferences from the Demand for Medical Care." *Journal of Environmental Economics and Management*. Vol. 21, pp. 1-16, 1991.
- Dillman, Don A. *Mail and Telephone Survey: The Total Design Method*. John Wiley and Sons: New York. 1978.
- Executive Order 12866. "Regulatory Planning and Review." September 30, 1993.

- Fischhoff, B. et al., "How Safe is Safe Enough? A Psychometric Study of Attitudes Towards Technological Risks and Benefits." *Policy Sciences*. Vol. 9, pp. 127-152, 1978.
- Freeman, A. Myrick III. *The Measurement of Environmental and Resource Values: Theory and Methods*. Resources for the Future: Washington, DC. 1993.
- Greene, W.H. *Econometric Analysis, 4th Edition*. Prentice Hall: New Jersey. 2000.
- Hammit, J.K. "Valuing Mortality Risk: Theory and Practice." *Environmental Science and Technology*. Vol. 34, pp. 1396-1400, 2000.
- Hanemann, W. Michael, "Valuing the Environment through Contingent Valuation," *Journal of Economic Perspectives*. Vol. 8, pp.19-43, Fall 1994.
- Hanemann, W.M., "Willingness to Pay and Willingness to Accept: How Much Can They Differ?" *American Economic Review*. Vol. 81, pp. 635- 647, 1991.
- Harrington, W., A.J. Krupnick, and W.O. Spofford, Jr. "The Economic Losses of a Waterborne Disease Outbreak." *Journal of Urban Economics*. Vol. 25, pp. 116-137, January 1989.
- Hartunian, N.S., C.N. Smart, and M.S. Thompson. *The Incidence of Economic Costs of Major Health Impairments*. Lexington Books: Lexington, MA. 1981.
- Hu, T. and F.H. Sandifer. *Synthesis of Cost-of-Illness Methodology: Part I*. Report to the National Center for Health Services Research, U.S. Department of Health and Human Services. 1981.
- Industrial Economics, Incorporated. "Averted Water Use Costs." Chapter 9 in *Draft Regulatory Impact Analysis for the Final Rulemaking on Corrective Action for Solid Waste Management Units*. Prepared for the U.S. Environmental Protection Agency. March 1993.
- Industrial Economics, Incorporated. *Economic Analysis for Hydropower Project Relicensing: Guidance and Alternative Methods*. Prepared for U.S. Fish and Wildlife Service. October 1998.

- Johannesson, Magus and Per-Olov Johansson. "The Value of Life Extension and the Marginal Rate of Time Preference: A Pilot Study," *Applied Economic Letters*. Vol. 4, pp. 53-55, 1997.
- Jones-Lee, M. W. *The Economics of Safety and Physical Risk*. Basil Blackwell: Oxford. 1989.
- Jones-Lee, M.W. "Paternalistic Altruism and Value of Statistical Life." *The Economic Journal*. Vol. 102, pp. 80-90, 1992.
- Jones-Lee, M. W., M. Hammerton and P.R. Phillips. "The Value of Safety: Results of a National Sample Survey." *Economic Journal*. Vol. 95, pp. 49-72, March 1985.
- Just, R.E., D.L. Heuth, and A. Schmitz. *Applied Welfare Economics and Public Policy*, Prentice Hall: Englewood Cliffs, NJ. 1982.
- Kopp, R.J. "Why Existence Value *Should* be Used in Cost-Benefit Analysis." *Journal of Policy Analysis and Management*. Vol. 11, pp. 123-130, 1992.
- Kopp, R., W.W. Pommerehne, and N.T. Schwarz (eds.). *Determining the Value of Non-Marketed Goods*. Kluwer Academic Publishers: Boston, MA. 1997.
- Levin, Ronnie. *Reducing Lead in Drinking Water: A Benefits Analysis*. Prepared for the U.S. Environmental Protection Agency. 1986.
- Miller, T.R. "The Plausible Range for the Value of Life - Red Herrings Among the Mackerel." *Journal of Forensic Science*. Vol. 3, pp. 17-39, 1990.
- Mitchell, R. and R.T. Carson. *Using Surveys to Value Public Goods: The Contingent Valuation Method*. Resources for the Future: Washington, DC. 1989.
- Moore, Michael J. and W. Kip Viscusi. "Doubling the Estimated Value of Life: Results Using New Occupational Fatality Data." *Journal of Policy Analysis and Management*. Vol. 7, pp. 476-490, 1988.
- Morgan, Granger M., and Max Henrion. *Uncertainty: A Guide to Dealing with Uncertainty in Quantitative Risk and Policy Analysis*. Cambridge University Press: New York. 1990.
- National Oceanic and Atmospheric Administration (NOAA). "Appendix I - Report of the NOAA Panel on Contingent Valuation." 58 FR 4602, January 15, 1993.

- Powell, John R., David J. Allee, and Charles McClintock. "Groundwater Protection Benefits and Local Community Planning: Impact of Contingent Valuation Information." *American Journal of Agricultural Economics*. Vol. 76, pp. 1068-1075, December 1994.
- Research Triangle Institute. *Valuing Drinking Water Quality: Theory, Methods, and Research Needs: Final Draft Report*. Prepared for the U.S. Environmental Protection Agency. April 1998.
- Slovic, P., B. Fischhoff, and Sarah Lichtenstein. "Perceived Risk: Psychological Factors and Social Implications." *Proceedings of the Royal Society of London, Series A: Mathematical and Physical Sciences*. Vol. 430, pp. 17-34, 1981.
- Smith, V.K. "Pricing What is Priceless: A Status Report on Non-Market Valuation of Environmental Resources." *The International Yearbook of Environmental and Resource Economics 1997/1998: A Survey of Current Issues*. (H. Folmer and T. Teitenberg, eds.) Edward Elgar: Lyme, NH. 1997.
- Stavins, Robert N., Chair, Science Advisory Board's Environmental Economics Advisory Committee, and Morton Lippman, Interim Chair, Science Advisory Board. Letter to EPA Administrator Carol Browner. *An SAB Report on EPA's White Paper: Valuing the Benefits of Fatal Cancer Risk Reduction*. July 17, 2000.
- Tolley, G., D. Kenkel, and R. Fabian (Eds). *Valuing Health for Policy: An Economic Approach*. University of Chicago Press: Chicago, IL. 1994.
- U.S. Congressional Budget Office. *The Safe Drinking Water Act: A Case of an Unfunded Federal Mandate*. September 1995.
- U.S. Department of the Interior. Water Resources Council. *Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies*. Washington, D.C., 1983.
- U.S. Environmental Protection Agency. *1999 Update to Elements of a Reg Flex Analysis*. 1999.
- U.S. Environmental Protection Agency. *Announcement of Small System Compliance Technology Lists for Existing National Primary Drinking Water Regulations and Findings Concerning Variance Technologies*. 63 FR 42032. August 6, 1998.
- U.S. Environmental Protection Agency. *The Benefits and Costs of the Clean Air Act, 1970 to 1990*. EPA 410-R-97-002. October 1997.

- U.S. Environmental Protection Agency. *The Benefits and Costs of the Clean Air Act, 1990 to 2010*. EPA 410-R-99-001. November 1999.
- U.S. Environmental Protection Agency. *Children's Health Valuation Handbook*. forthcoming.
- U.S. Environmental Protection Agency. "Comments on Proposed Regulations on Natural Resource Damage Assessment." 1994.
- U.S. Environmental Protection Agency. *Community Water Systems Survey, Volumes 1 and 2*. EPA/815/R-97/001a/b. January 1997.
- U.S. Environmental Protection Agency. *Cost of Illness Handbook*. February 2001.
- U.S. Environmental Protection Agency. *Environmental Justice Strategy: Executive Order 12898*. April 1995.
- U.S. Environmental Protection Agency. *EPA's Rule Writer's Guide to Executive Order 13045: Guidance for Considering Risks to Children During the Establishment of Public Health-Related and Risk-Related Standards*. Review Draft. April 21, 1998.
- U.S. Environmental Protection Agency. *Guidance for Risk Assessment*. Prepared by the Risk Assessment Council. November 1991.
- U.S. Environmental Protection Agency. *Guidelines for Preparing Economic Analysis*. EPA 240-R-00-003. September 2000.
- U.S. Environmental Protection Agency. *Guiding Principles for Monte Carlo Analysis*. March 1997.
- U.S. Environmental Protection Agency. *Handbook for Noncancer Health Effects Valuation (Draft)*. Prepared by Industrial Economics, Incorporated. September 1999.
- U.S. Environmental Protection Agency. *Interim Final Guidance for Incorporating Environmental Justice Concerns in EPA's NEPA Compliance Analyses*. April 1998.
- U.S. Environmental Protection Agency. "National Primary Drinking Water Regulations: Consumer Confidence; Proposed Rule." 63 *FR* 7605, February 13, 1998.
- U.S. Environmental Protection Agency. *National Water Quality Inventory: 1994 Report to Congress*. 1994.

- U.S. Environmental Protection Agency. *Peer Review Handbook*. January 1998.
- U.S. Environmental Protection Agency. *Revised Interim Guidance for EPA Rulewriters: Regulatory Flexibility Act as Amended by the Small Business Regulatory Enforcement Fairness Act*. March 1999.
- U.S. Environmental Protection Agency. *Risk Assessment Guidance for Superfund, Volume I: Human Health Evaluation Manual (Part A)*. EPA/540/1-89/002. December 1989.
- U.S. Geological Survey. *Estimated Water Use in the United States 1995*. 1997.
- U.S. Office of Management and Budget. "Guidelines to Standardize Measures of Costs and Benefits and the Format of Accounting Statements" in Appendix 4: *Report to Congress on the Costs and Benefits of Federal Regulations*. March 22, 2000.
- U.S. Office of Management and Budget. *Guidelines and Discount Rates for Benefit-Cost Analysis of Federal Programs*. October 29, 1992.
- U.S. Office of Management and Budget. Memorandum from Sally Katzen, *Guidance for Implementing Title II of S.1*. March 31, 1995.
- U.S. Office of Management and Budget. *Report to Congress On the Costs and Benefits of Federal Regulations*. September 30, 1997.
- U.S. Small Business Administration. *Implementation Guide for the RFA*. February 1998.
- Viscusi, W.K. *Fatal Tradeoffs: Public and Private Responsibilities for Risk*. Oxford University Press: New York. 1992.
- Viscusi, W.K., ed. "The Mortality Costs of Regulatory Expenditures." *Journal of Risk and Uncertainty*. Vol. 8, pp. 5-18, 1994 (a special issue devoted to this topic).
- Viscusi, W.K. "The Value of Risks to Life and Health," *Journal of Economic Literature*. Vol. 31, pp. 1912-1946, 1993.
- Viscusi, W.K., W.A. Magat, and J. Huber. "Pricing Environmental Health Risks: Survey Assessments of Risk-Risk and Risk-Dollar Tradeoffs." *Journal of Environmental Economics and Management*. Vol. 201, pp. 32-57, 1991.
- Water Resources Research*. Vol. 28, No. 3, 1992.

INDEX

- aesthetic effects
 - (amenities) 1-4 to 1-7, 3-27, 4-5, 5-11
- affordability 3-3, 3-5
- averting behavior 3-14 to 3-17, 4-5
- avoided costs 3-18 to 3-19, 4-5
- baseline, establishing 5-15
- Bayesian approaches 4-14
- benefit transfer function 4-13 to 4-14
- benefit transfer Chapter 4
- Benefits Working Group 1-1, Appendix A
- benefits, types of 1-4 to 1-7, 5-6 to 5-7, Appendix A
- children's health 2-5, 2-14 to 2-16
- conjoint analysis 3-11
- Consultation and Coordination with Indian Tribal Governments (see Executive Order 13084)
- consumer surplus 3-4
- contingent valuation (CV) 3-9 to 3-12
- co-occurring contaminants 2-5, 5-15
- cost-of-illness (COI) 3-13 to 3-14, 3-25 to 3-26
- costs and benefits, comparing 2-6, 5-16, Appendix A
- discounting 5-11 to 5-14
- double-counting 4-4, 5-16
- ecological benefits 1-4 to 1-7, 4-4 to 4-5
- environmental justice 2-13 to 2-14
- EPA Guidelines for Preparing Economic Analyses 2-8 to 2-9
- Executive Order 12866 2-6 to 2-8
- Executive Order 12898 2-13 to 2-14
- Executive Order 13045 2-15 to 2-16
- Executive Order 13084 2-9(fn)
- Executive Order 13132 2-9(fn)
- Federal Actions to Address Environmental Justice in Minority Populations and Low Income Populations (see Executive Order 12898)
- human health risk assessment 5-7 to 5-8
- inflation 5-11 to 5-14
- material damages 3-27, 4-5, 5-11
- meta-analysis 4-14
- morbidity valuation 3-25 to 3-26, 4-3 to 4-4, 5-9 to 5-10
- mortality valuation 3-19 to 3-25, 4-3 to 4-4, 5-9
- National Drinking Water Advisory Council (NDWAC) 1-1, Appendix A
- nonquantified effects 2-5, 3-6 to 3-7, 5-4, Appendix A
- nonuse values 1-7, 3-9
- OMB guidance 2-6 to 2-8
- Protection of Children From Environmental Health Risks and Safety Risks (see Executive Order 13045)
- quality adjusted life year (QALY) 3-25
- Regulatory Flexibility Act (RFA) 2-11 to 2-12
- Regulatory Planning and Review (see Executive Order 12866)
- revealed preference methods 3-8, 3-12 to 3-19
- risk trade-offs 3-11, 5-15
- rule sequencing 5-15
- sample surveys 4-8
- Safe Drinking Water Act (SDWA) 2-1 to 2-6
- scoping and screening analysis 5-1 to 5-2
- Small Business Regulatory Enforcement Fairness Act (SBREFA) 2-11 to 2-12
- source water protection 3-27, Appendix A
- stated preference methods 3-8 to 3-12
- uncertainty analysis 4-15, 5-3 to 5-5, 5-8, Appendix A
- Unfunded Mandates Reform Act (UMRA) 2-10 to 2-11
- value of a statistical life (VSL) 3-19 to 3-25
- value of statistical life year (VSLY) 3-20
- wage-risk (hedonic) studies 3-12 to 3-13, 3-21 to 3-26
- willingness to pay (WTP) 3-2 to 3-4