United States
Environmental Protection
Agency

Office of Water
(4607)

EPA 815-B-98-002
November 1998

# REGULATORY IMPACT ANALYSIS FOR THE STAGE 1 DISINFECTANTS/DISINFECTION BYPRODUCTS RULE

# Regulatory Impact Analysis for the Stage 1 Disinfectants/Disinfection Byproducts Rule

**PREPARED FOR:**

**U.S. ENVIRONMENTAL PROTECTION AGENCY**
**Office of Ground Water and Drinking Water**
**Ms. Valerie Blank, Task Order Project Manager**
**Ms. Maggie Javdan, Technical Manager**

**PREPARED BY:**

**THE CADMUS GROUP, INC.**
**4900 Seminary Road**
**Alexandria, VA 22311**

**SCIENCE APPLICATIONS INTERNATIONAL CORPORATION**
**1710 Goodridge Drive**
**Mclean, VA 22102**

**US EPA CONTRACT: 68-C6-0059**
**Work Assignment: 118-6**

**November 12, 1998**

**Final Stage 1 DBPR RIA**

12698

# Regulatory Impact Analysis for the Stage 1 Disinfectants/Disinfection Byproducts Rule

## Errata sheet

1. Chapter 5, page 5-3

   Exhibit 5.1 "Summary of Costs under the Stage 1 DBPR"

   Change title to read "Summary of Costs under the Stage 1 DBPR *($000)*"

2. Chapter 5, page 5-22

   Exhibit 5.11 "Regulatory Flexibility Act Cash Flow Analysis for Small Ground Water Systems"

   Add "($000)" to the headers of the following columns: Total Revenue, Op. Exp., Net Total Rev., Total DBP Cost, Incr. DBP Op. Exp, Post-DBP Net Rev.

# Contents

# Exhibits

## ACKNOWLEDGMENTS

This document was prepared for the U.S. Environmental Protection Agency, Office of Ground Water and Drinking Water (OGWDW) by Science Application International Corporation (SAIC) (Contract No. 68-C6-0059) and its subcontractor, The Cadmus Group, Inc. Overall planning and management for the preparation of this document was provided by Maggie Javdan of OGWDW and Tom Carpenter of SAIC.

EPA acknowledges the valuable contributions of those who wrote and reviewed this document. They include: John Cromwell of Hagler Bailly Services, Inc.; James Albright, Curtis Haymore, Rosemarie Odom, and Elena Ryan of The Cadmus Group, Inc.; Tom Carpenter of SAIC; Stig Regli, Michael Messner, Maggie Javdan, Michael Cox, Melonie Williams, and John Bennett of U.S. EPA. EPA also thanks the following external peer reviewers for their excellent review and valuable comments on the draft manuscript: Charles Abdalla (University of California at Berkeley), Gunther Craun (G. Craun and Associates), and Joe Jacangelo (Montgomery Watson).

# Executive Summary

## ES.1 Protection of Public Health

The primary mission of the Environmental Protection Agency (EPA) is to safeguard human health and the environment. This document addresses the expected impacts—both improvements to public health and the costs to industry and consumers—of one EPA regulation that will make water safer to drink.

Many water systems treat their water with a chemical disinfectant to prevent disease. The public health benefits of common disinfection practices in preventing infectious diseases from microbiological contaminants are significant and well-recognized. Disinfection, however, may pose risks of its own. Disinfectants and their byproducts have been associated with potential health risks that include cancer and reproductive and developmental effects. EPA has identified ways to significantly lessen these potential risks at reasonable costs. To implement these changes, EPA is publishing a final Stage 1 Disinfectants/Disinfection Byproducts Rule (Stage 1 DBPR) that contains the new requirements for water systems and this Regulatory Impact Analysis (RIA), which documents the costs and benefits of the rule.

In exercising its responsibility to protect public health, EPA must often make regulatory decisions with less than complete information and with uncertainties in the available information. This is because a public health risk is often first identified as a "potential" health risk. At this level of understanding, it is sometimes not clear whether the risk will, in fact, materialize. And, it is often the case that the risk could materialize at varying degrees of severity ranging from trivial to significant. Preventive decisions can be difficult because they often have to be made before all the facts are known. If action is delayed to obtain a perfect understanding, it may be too late to prevent the damage. But if action is premature and over-zealous, it can drain resources from other beneficial public health measures. Thus, a keen sense of balance is required in each decision.

In the classic paradigm of public health decisionmaking, it is necessary to decide upon a prudent course of action despite confounding factors. The decision process consists of weighing the available evidence to gain as much insight as possible into expected or possible health outcomes while also weighing the costs and technological realities of available responses. At one end of the spectrum, a "No Action" option might be justified when the balance of health evidence suggests low exposure, low probability, and low severity while the response technologies imply high costs and limited effectiveness. At the opposite extreme, urgent and forceful action might be warranted when the health evidence suggests high exposure, high probability, and high severity while the response technologies have modest costs and good effectiveness. The Stage 1 DBPR lies in the middle of this spectrum. On balance, however, EPA believes the weight of evidence suggests there is sufficient exposure, probability, and severity on the health side to warrant a public health decision to accept the cost and technology impacts of the rule in order to obtain the projected exposure reduction. Highlights of this balancing analysis are summarized in the following discussion.

effects of alternative technologies that have not yet been fully studied. In addition, avoiding such shifts minimizes the need for capital expenditure until the risk from DBPs is better understood. Only 6.5 percent of utilities are projected to have to change technologies in order to comply with the Stage 1 DBPR.

## ES.10 Conclusion

In the final analysis, the various benefit/cost comparisons developed in this RIA are quite useful in assisting the balancing and weighing analyses that must be performed to support public health decisionmaking. While the uncertainties prevent the various approaches to economic analysis from producing definitive or deterministic answers, these analyses are nonetheless very informative. Based on a careful weighing of the projected costs against the potential quantified and non-quantified benefits, EPA has determined that the benefits of the rule justify its costs.

**Exhibit ES.1**
**Summary of Costs under the Stage 1 DBPR**
**Notes**

Costs for the Stage 1 DBPR are estimates of what the rule may cost over 20 years, expressed as an annual figure. The rule includes requirements for additional treatment, construction of new facilities, where necessary, and monitoring compliance. Both States and utilities bear the costs of the rule, although State costs compose a relatively minor portion of the annual cost. These costs were estimated by engineers and economists familiar with equipment, process, and labor costs using available data and expert judgement.

Costs are provided for large and small surface and ground water systems. The exhibit tabulated the total estimated cost (over 20 years) of purchasing and implementing required treatments. These "capital costs" are then annualized (multiplied by a capitalization factor), the "cost of capital," that determines what the cost might be per year. The breakout of annualized costs are based on a 7 percent cost of capital, which is the rate required by the Office of Management and Budget for benefit/cost analyses. Also shown are the annualized capital costs using the 3 percent and 10 percent cost of capital. The annualized capital costs (Row B) are then added to the operation and maintenance (O&M) costs (Row A) to derive the total annual treatment costs of the rule (Row C).

The cost of a required treatment usually varies by the scale of the treatment. Therefore, for most treatments, costs are estimated separately for each size category of system (in terms of the number of people served by the system). Costs are usually expressed as dollars per 1,000 gallons of water ($/kgal). These costs represent the marginal costs to systems to change treatment practices. This analysis estimates the number of systems in each size category that might have to modify their treatment to meet the MCLs or that might have to implement an approved technology. In addition to the capital costs of the treatment techniques implemented, each system will incur annual O&M costs. The annual capital costs (annualized over 20 years at each of the three costs of capital) are added to the O&M costs to estimate an annual cost of the Stage 1 DBPR.

Each utility must monitor their own compliance with EPA regulations (Row E), and the State must review this compliance (Row G). There are also costs ("start-up costs") associated with implementation of a new regulation, for both utilities (Row D) as well as States (Row F). These annualized start-up costs, added to the annual monitoring the treatment costs, form the basis for the total national compliance costs (Row H).

At a 7 percent cost of capital, the Stage 1 DBPR is expected to result in annual costs of $701 million. At 3 percent, the annual costs are an estimated $626 million. At 10 percent, the annual costs are an estimated $756 million.

## Exhibit ES.1
## Summary of Costs under the Stage 1 DBPR ($000)

| | | Small | Large | Subtotal | Small | Large | Subtotal | Total |
|---|---|---|---|---|---|---|---|---|
| | **Utility Costs** | | | | | | | |
| | **Treatment Costs** | | | | | | | |
| | **Total Capital Costs** | **$ 242,652** | **$ 554,564** | **$ 797,216** | **$ 997,537** | **$ 528,539** | **$ 1,526,076** | **$ 2,323,292** |
| A | *Annual O&M* | 23,068 | 201,308 | 224,376 | 83,910 | 54,243 | 138,153 | 362,530 |
| B | *Annualized Capital Costs* | 22,786 | 62,355 | 85,141 | 94,403 | 50,046 | 144,449 | 229,590 |
| A+B | **Annual Utility Treatment** | **$ 45,855** | **$ 263,663** | **$ 309,518** | **$ 178,313** | **$ 104,289** | **$ 282,602** | **$ 592,120** |
| | **Monitoring and Reporting Cost** | | | | | | | |
| D | **Start-Up Costs** | 82 | 39 | 121 | 946 | 36 | 982 | 1,103 |
| E | **Annual Monitoring** | 10,867 | 14,619 | 25,485 | 38,803 | 26,326 | 65,129 | 90,615 |
| | **State Costs** | | | | | | | |
| F | **Start-Up Costs** | | | | | | | 4,099 |
| G | **Annual Monitoring** | | | | | | | 13,243 |
| C+D+E+F+G | **Total Annual Costs at 7 Percent Cost of Capital** | | | | | | | **$ 701,180** |
| | **Total Annual Costs at 3 Percent Cost of Capital** | | | | | | | **$ 626,484** |
| | **Total Annual Costs at 10 Percent Cost of Capital** | | | | | | | **$ 755,773** |

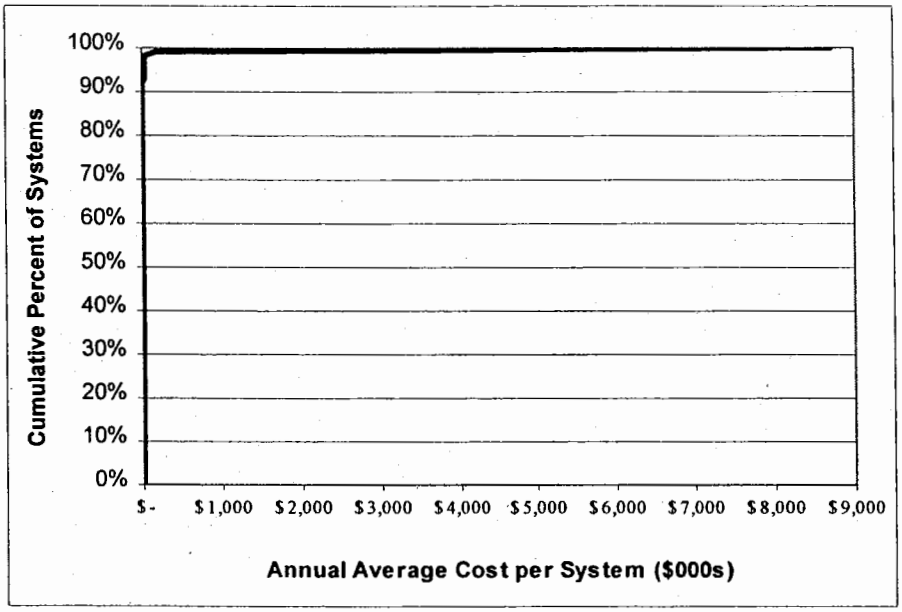
**Exhibit ES.2**
**Cumulative Distribution of Annual Average Systems Costs and Household Costs for All Systems**
**Notes**

Average annual cost per system for all surface and ground water systems is displayed in Exhibit ES.2. Because each system will implement a different treatment technique and will undertake different monitoring activities depending on its current water quality characteristics, most systems will incur different annual costs under the Stage 1 DBPR. Additionally, while 12,988 systems will have to modify their treatment techniques to meet the requirements of the rule, all 76,051 systems will have to perform annual monitoring. Thus, 12,988 systems will incur both treatment and monitoring costs, and 63,063 systems will incur only monitoring costs.

Under the Stage 1 DBPR household will face increases in annual costs, since at a minimum, all systems are required to monitor. As shown in the cumulative distribution of households affected by the rule, however, a large number (95 percent) of households may face an estimated *maximum* increase in cost of $12 per year ($1 per month). In other words, 110 million household may incur no more than a $1 increase in their monthly costs and most substantially less. Slightly more than 3 million households (3 percent) may face an increase in costs of between $12 and $60 per year ($1 to $5 per month). The highest estimated costs is approximately $400 per year, and less than 2 percent of households may incur costs ranging from $60 a year to $400 a year ($5 to $33 per month).

**Exhibit ES.2**
**Cumulative Distribution of Annual Average System Costs and Household Costs for All Systems**

**Annual Average Cost per System**




**Annual Average Cost per Household**

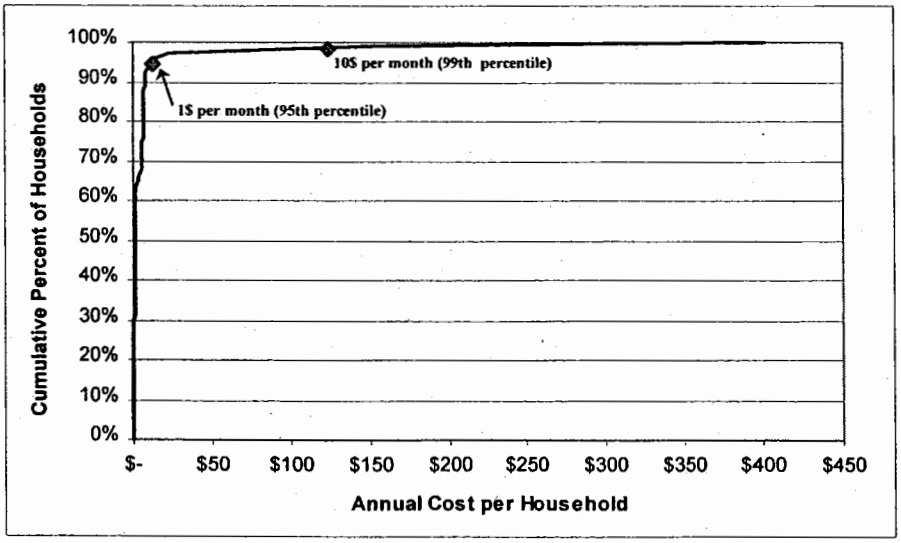


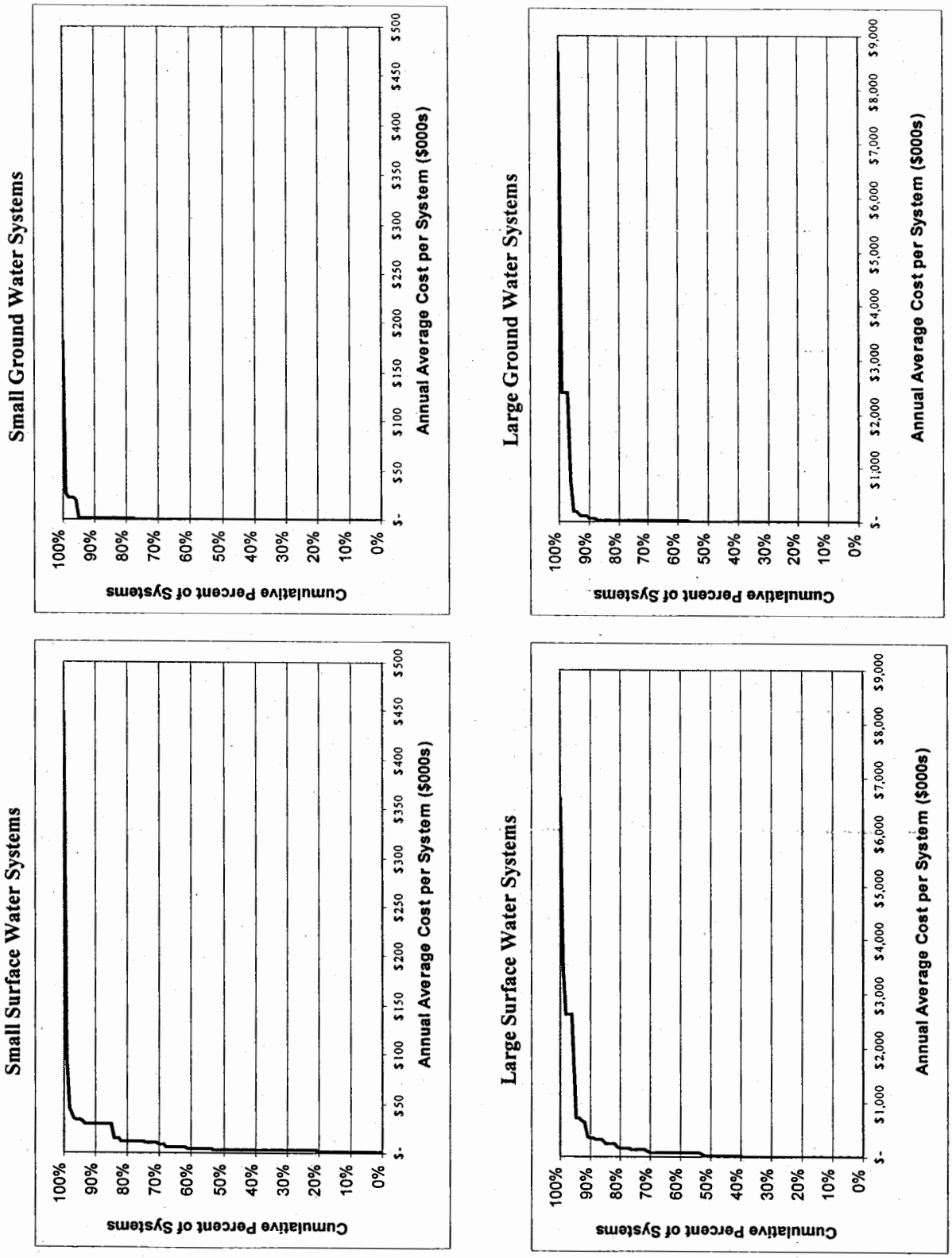
**Exhibit ES.3**
**Detail of Cumulative Distribution of Annual Average System Costs**
**Notes**

Exhibit ES.3 displays the cost per system for large and small surface and ground water systems. The methodology for estimating these costs is identical to that for Exhibit ES.2.

For small systems, the highest costs may be incurred by those systems employing membrane technology. Fifty percent of small surface water systems may incur average annual costs of less than $3,000. The highest average annual costs is $450,000 incurred by approximately 10 systems. Fifty percent of small ground water systems may incur average annual costs of less than $500, with the highest average annual costs being incurred by approximately 100 systems ($181,000).

As with small systems, the highest costs in large systems may be incurred by systems using membranes as their treatment technique. Fifty percent of large surface water systems may incur average annual costs of less than $500. Approximately 3 systems may face costs of $7 million per year. Fifty percent of large ground water systems may face average annual costs of approximately $10,000. Approximately 2 systems may face costs as high as $9 million.

## Exhibit ES.3
## Cumulative Distribution of Annual Average Costs per System



## Exhibit ES.4
## Cumulative Distribution of Annual Household Costs for All Systems
## Notes

Exhibit ES.4 displays the annual increase in cost per household for large and small surface and ground water systems. Below each graph of the cumulative distribution for all systems in that size category, a detail of the 90$^{th}$ to 100$^{th}$ percentiles is displayed. The methodology for estimating these costs is identical to that for Exhibit ES.2.

Seventy percent of household served by small surface water systems may face a monthly increase of no more than $1 per month under the Stage 1 DBPR. Ninety-nine percent of households may incur no more than a $10 increase in monthly costs.

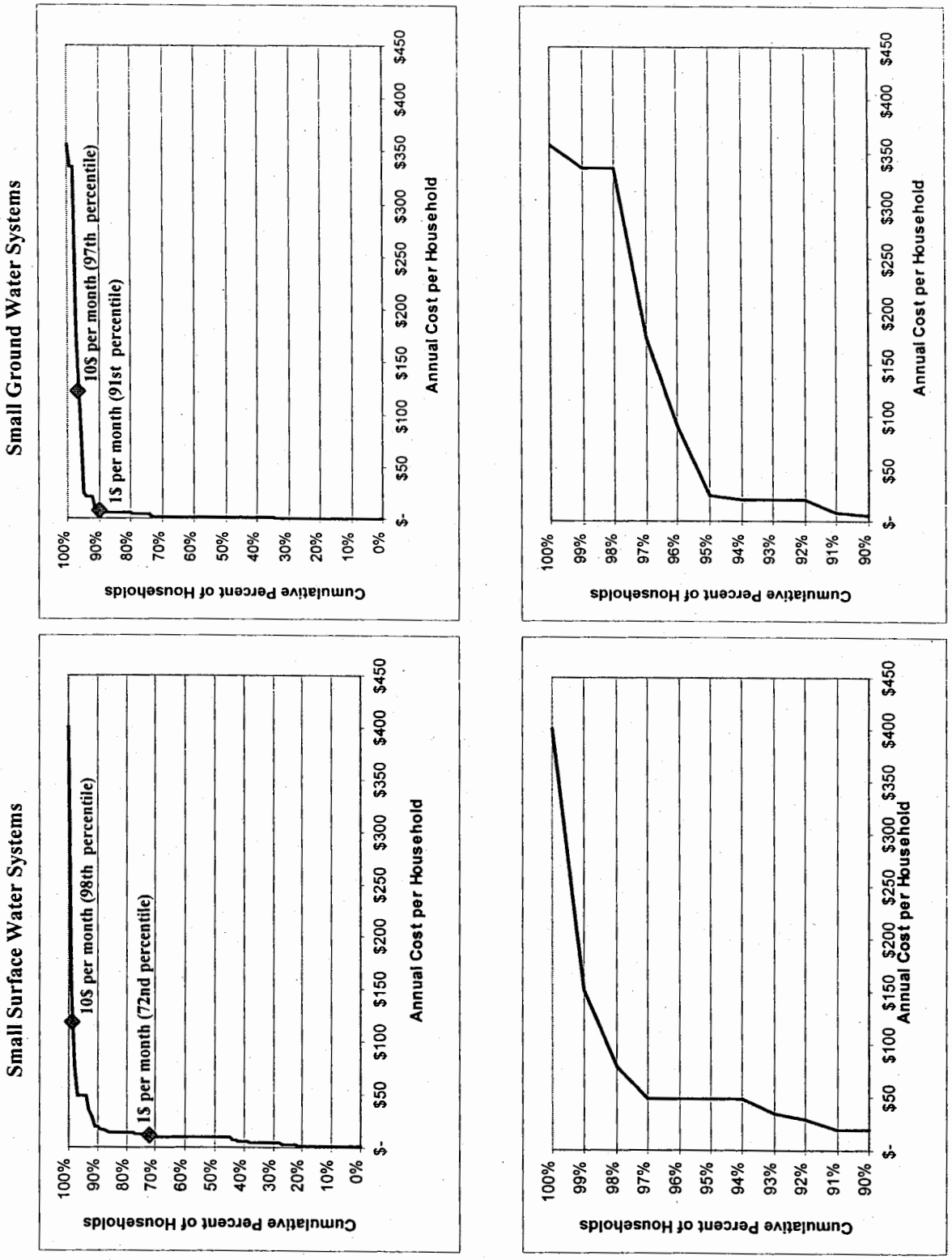
In large surface water systems, 98 percent of households may face an increase of no more than $1 per month in expenses. Almost 100 percent may face an increase of no more than $10 per month.

Most households served by small ground water systems, 91 percent, may face an increase of no more than $1 per month. Ninety-six percent may face an increase of no more than $10 per month.

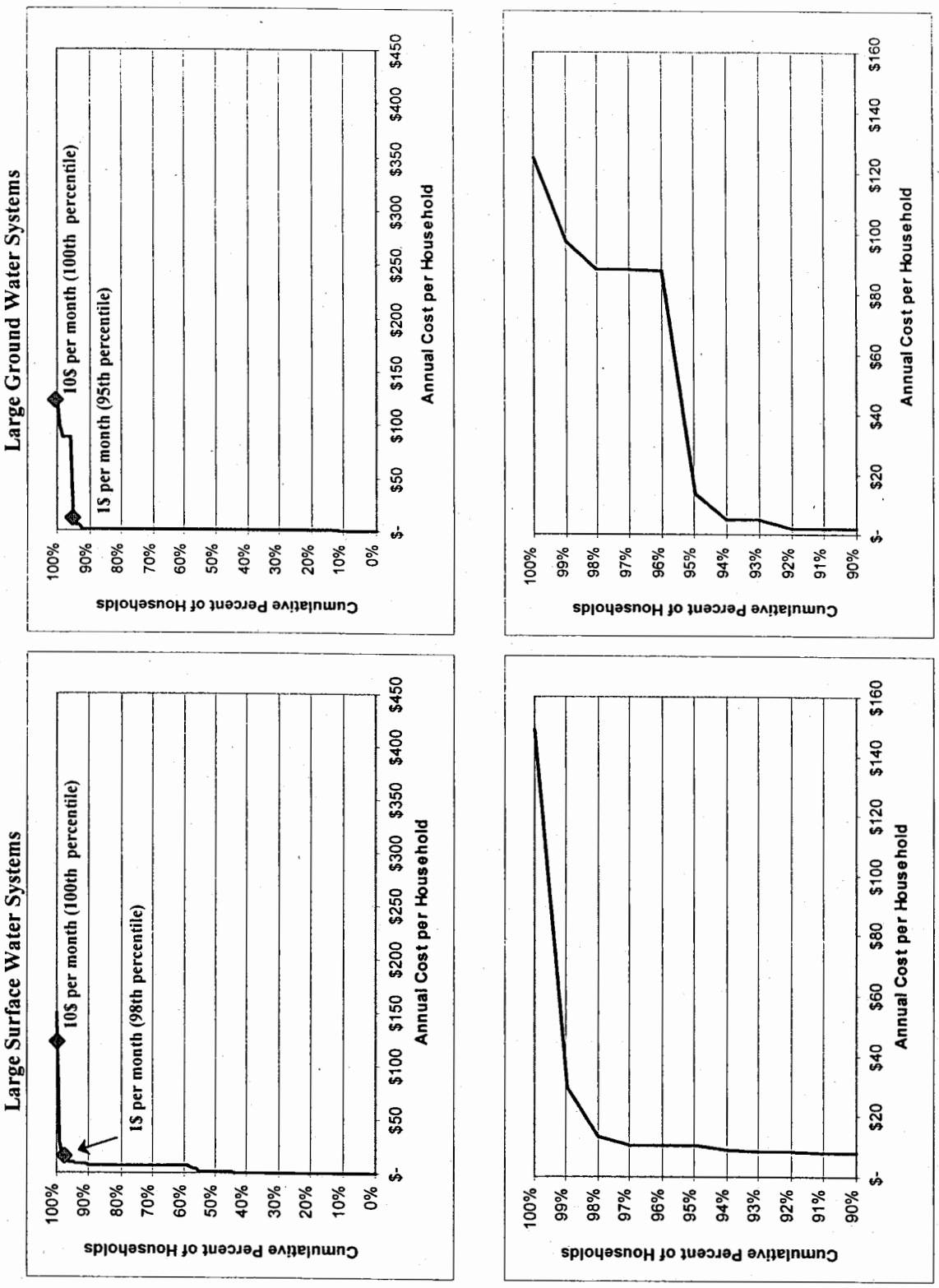
Ninety-five percent of households served by large ground water systems may face no more than $1 of increase monthly cost. Ninety-nine percent may face a monthly cost increase of no more than $10. These results are summarized below.

| | Total Households | $0 to $1 per month increase | $1 to $10 per month increase | $10 to $33 per month increase |
|---|---|---|---|---|
| **Small surface water systems** | 4,267,000 | 71 percent<br>3,009,000 households | 28 percent<br>1,204,000 households | 1 percent<br>54,000 households |
| **Large surface water systems** | 71,378,000 | 98 percent<br>69,870,000 households | 2 percent<br>1,489,000 households | 0.03 percent<br>20,000 households |
| **Small ground water systems** | 15,671,000 | 91 percent<br>14,245,000 households | 5 percent<br>755,000 households | 4 percent<br>671,000 households |
| **Large ground water systems** | 24,174,000 | 95 percent<br>22,969,000 households | 4 percent<br>939,000 households | 1 percent<br>266,000 households |
| **Total** | 115,490,000 | 95 percent<br>110,093,000 households | 4 percent<br>4,382,000 households | 1 percent<br>1,011,000 households |

## Exhibit ES.4
## Cumulative Distribution of Annual Costs per Household in Small Systems



## Exhibit ES.4
## Cumulative Distribution of Annual Costs per Household in Large Systems



## Exhibit ES.5
## Characteristics of Water Systems
## Notes

Exhibit ES.5 summarizes several key characteristics of the water systems analyzed in this RIA.

While small ground water systems are the most numerous, most people are served by large surface water systems. Additionally, 68 percent of surface water systems will have to modify their treatment, though only 12 percent of ground water systems will have to implement a new treatment technique.

## Exhibit ES.5
## Characteristics of Water Systems that Disinfect

### Surface Water Systems

| System Size | Number of Systems | Number of Plants | Number of Systems to Modify Treatment | Number of Systems to Monitor Only | Number of Households |
|---|---|---|---|---|---|
| 25-100 | 1,046 | 1,046 | 732 | 314 | 21,000 |
| 100-500 | 1,010 | 1,010 | 707 | 303 | 88,000 |
| 500-1K | 845 | 845 | 592 | 253 | 265,000 |
| 1K-3.3K | 1,103 | 1,103 | 772 | 331 | 926,000 |
| 3.3K-10K | 1,161 | 1,161 | 813 | 348 | 2,966,000 |
| 10K-25K | 569 | 569 | 347 | 222 | 4,361,000 |
| 25K-50K | 328 | 328 | 200 | 128 | 5,986,000 |
| 50K-75K | 157 | 157 | 96 | 61 | 5,043,000 |
| 75K-100K | 108 | 216 | 66 | 42 | 5,125,000 |
| 100K–500K | 175 | 350 | 107 | 68 | 17,246,000 |
| 500K-1M | 43 | 86 | 26 | 17 | 18,834,000 |
| >1M | 15 | 30 | 9 | 6 | 14,783,000 |
| **Total** | **6,560** | **6,901** | **4,466** | **2,094** | **75,644,000** |

## Ground Water Systems

| System Size | Number of Systems | Number of Plants | Number of Systems to Modify Treatment | Number of Systems to Monitor Only | Number of Households |
|---|---|---|---|---|---|
| 25-100 | 30,476 | 30,476 | 3,721 | 26,755 | 623,000 |
| 100-500 | 22,934 | 22,934 | 2,800 | 20,314 | 2,009,000 |
| 500-1K | 6,508 | 6,508 | 795 | 5,713 | 2,043,000 |
| 1K-3.3K | 5,882 | 5,882 | 718 | 5,164 | 4,938,000 |
| 3.3K-10K | 2,371 | 2,371 | 290 | 2,081 | 6,058,000 |
| 10K-25K | 866 | 1,299 | 130 | 736 | 6,638,000 |
| 25K-50K | 288 | 432 | 43 | 245 | 5,256,000 |
| 50K-75K | 78 | 156 | 12 | 66 | 2,505,000 |
| 75K-100K | 29 | 58 | 4 | 25 | 1,376,000 |
| 100K–500K | 53 | 159 | 8 | 45 | 5,223,000 |
| 500K-1M | 5 | 15 | 1 | 4 | 2,191,000 |
| >1M | 1 | 3 | 0 | 1 | 986,000 |
| **Total** | **64,491** | **70,293** | **8,522** | **60,969** | **39,845,000** |

# 1: Introduction

## 1.1 Introduction

This document analyzes the impact of the final Stage 1 Disinfectants/Disinfection Byproducts Rule (Stage 1 DBPR). Executive Order 12866, *Regulatory Planning and Review*, requires EPA to estimate the costs and benefits of the Stage 1 DBPR in a *regulatory impact analysis* (RIA) and to submit the analysis in conjunction with publishing the final rule.

This RIA provides background on the rule, summarizes the key components, discusses alternatives to the rule, and estimates costs and benefits to the public and State governments. This chapter summarizes the technical and regulatory issues associated with the rule. It explains the nature of disinfection byproducts (DBPs), identifies the public health concerns addressed by the rule, and summarizes the key components of the rule.

The subsequent chapters are intended to meet the requirements of the Executive Order by responding to specific analytical questions. Chapter 2 reviews alternative approaches considered as the rule was being developed. Chapter 3 presents public water system data and discusses the changes utilities would have to make as a result of this rule to establish a baseline of information for use in the following three chapters. Chapter 4 examines the rule's potential benefits, reviewing epidemiological and toxicological data. Chapter 5 presents an estimate of the costs to implement the rule. Chapter 6 explores different approaches to confirm positive net benefits. The analysis concludes in Chapter 7 with an examination of the economic rationale for regulating DBPs.

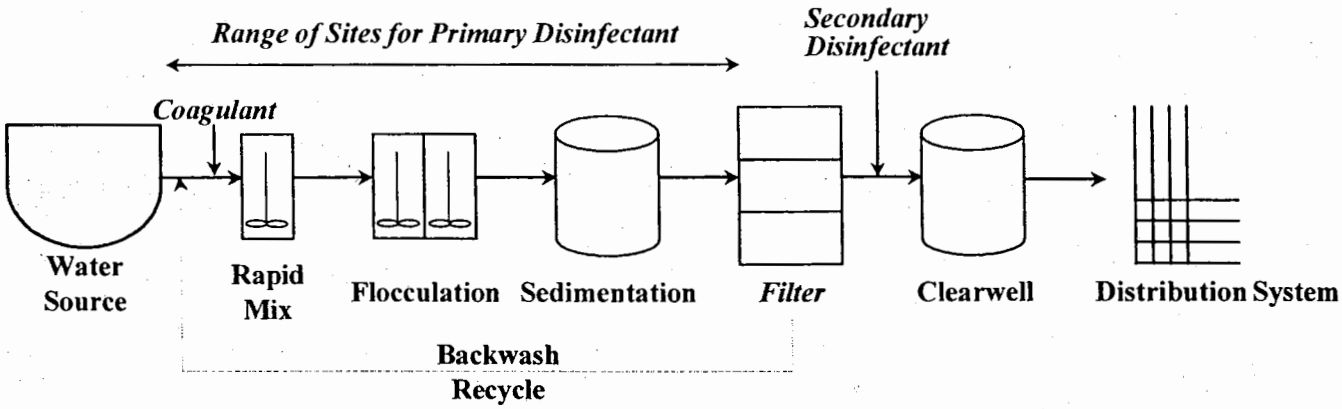
This rule is part of a larger process of improving drinking water quality through the development of a series of related rules. Each rule is accompanied by several analyses, required either by law or executive order. The analyses include reviewing impacts on small systems, examining unfunded mandates imposed by this rule, and determining whether minority or low-income populations are disproportionately affected by the requirements of this rule.

## 1.2 Description of the Issue

There are over 76,000 utilities (public water systems) in the United States that disinfect their water. Utilities are supplied through either ground water sources (tapped through wells) or surface water sources (lakes, reservoirs, and rivers). Ground water systems greatly outnumber surface water systems, although most people are served by a small number of large surface water systems.

Since most water is not pure enough to be ingested directly from the source, utilities usually apply some form of contaminant control. Disinfection is one important and widespread (but not universal) practice used to meet the public health goal of providing safe water to the public. Utilities disinfect drinking water supplies by adding chemicals to kill or inactivate microbial contaminants. Exhibit 1.1 shows a schematic of a typical conventional treatment plant.

**Exhibit 1.1**
**Typical Treatment Plant Model (Conventional)**




***Potential Changes in Treatment Processes Under the Stage 1 DBPR***

Disinfection remains a critical treatment process for addressing microbial contamination. Although chemical disinfection has been used for decades, EPA's Science Advisory Board (SAB), an independent panel established by Congress, cited drinking water contamination as one of the highest ranking environmental risks as recently as 1990. The SAB reported that microbiological contaminants (e.g., bacteria, protozoa, viruses) are likely the greatest remaining risk-management challenge for drinking water suppliers.

Disinfection, however, poses health risks of its own. Byproducts may result from chemical interactions between DBP precursors in water and chemical disinfectants in plants and distribution systems of public water systems. Source water often carries substantial levels of organic material that, when mixed with disinfectants, form new compounds. Some of these byproducts, including those that are the subject of this rule (total trihalomethanes—TTHM—and five haloacetic acids—HAA5), are potentially associated with health risks, such as cancer and reproductive and developmental effects. However, because disinfection is effective in reducing microbial contamination, reducing disinfection to decrease DBPs can increase the risk to the public from microbial contamination. This is known as a "risk-risk tradeoff."

Plants can use the following changes in treatment processes to reduce the level of DBPs:

- Choice of disinfectants;
- Sequence of disinfectant application;
- Timing and duration of disinfectant application; and,
- Choice of equipment.

The analysis of this risk-risk tradeoff is a continuing process. The inconclusiveness of past scientific research has made the development of regulations difficult. New research concerning water quality standards and DBPs will continue to improve the quantification of health risks. Recent research results concerning the health risks associated with DBPs (discussed further in Section 2.2) supports the development of the Stage 1 Disinfectants/Disinfection Byproducts Rule. Previous regulatory efforts concerning this problem are outlined in the following section.

## 1.3 Regulatory History

The primary responsibility for regulating the quality of drinking water lies with EPA. The Safe Drinking Water Act (SDWA) establishes this responsibility and defines the mechanisms at the Agency's disposal to protect public health. EPA sets water quality standards by identifying which contaminants should be regulated and establishes which levels of the contaminant are to be attained by utilities.

To regulate a contaminant, EPA first establishes a maximum contaminant level goal (MCLG), which establishes the contaminant level at which no known or anticipated adverse health effects occur. MCLGs are unenforceable health goals. EPA then sets an enforceable maximum contaminant level (MCL) as close as technologically possible to the MCLG. If it is not feasible to measure the contaminant, a treatment technique is specified.

Additionally, EPA identifies maximum concentrations of disinfectant residual concentrations and sets maximum residual disinfectant level goals (MRDLGs) and maximum residual disinfect levels (MRDLs). Residual levels of disinfectants are maintained in the distribution system following treatment in order to assure microbial safety all the way to the customer's tap. Like MCLGs and MCLs, MRDLGs are unenforceable while MRDLs are enforceable.

For utilities, compliance with a regulation means not exceeding the MCL. However, when MCLs are not economically or technologically feasible, an approved treatment technique can be used. A treatment technique requirement is a regulatory approach that specifies a technology that reduces exposure to contaminants to the extent feasible.

Several drinking water regulations predate the current regulatory effort, including rules controlling levels of trihalomethanes, total coliform, and microbial pathogens. The first of these, the 1979 Total Trihalomethane (TTHM) Rule, set an interim MCL of 0.10 mg/L (100 $\mu$g/L), based on an annual average. Trihalomethanes have long been recognized as potential carcinogens. The 1979 TTHM Rule applies only to utilities (using either ground or surface water) serving 10,000 or more people that disinfect their water. The Total Coliform Rule (1989) applies to all utilities. It regulates the levels of coliform bacteria permissible in drinking water systems. Coliform bacteria also serve as indicators for other microbes that may be pathogenic. In 1989, EPA also promulgated the Surface Water Treatment Rule (SWTR), the primary control for microbial pathogens in surface water. The SWTR established treatment technique requirements for *Giardia lamblia*, viruses, and *Legionella*, and included regulations for all utilities using surface waters (or ground water sources under the direct influence of surface water).

To address the complex issues associated with regulating DBPs, EPA launched a rule-making process in 1992 and convened a regulatory negotiation advisory committee (RegNeg) under the Federal Advisory Committee Act (FACA), representing a range of stakeholders affected by possible regulation. The RegNeg Committee met repeatedly over a period of 10 months and arrived at a consensus proposal for taking progressive steps toward addressing both DBPs and microbial pathogens. The 1992 consensus-building process resulted in the three following regulatory proposals—

1) A staged approach to regulation of disinfectants and DBPs (referred to as the Stage 1 and Stage 2 DBPRs) incorporating MCLs, MRDLs, and treatment technique requirements;

2) A companion Interim Enhanced Surface Water Treatment Rule (IESWTR) designed to improve control of microbial pathogens and prevent inadvertent reductions in microbial safety as a result of DBP control efforts, and;

3) An Information Collection Rule (ICR) to collect information necessary to reduce many key uncertainties prior to subsequent negotiations regarding the Stage 2 DBPR requirements.

In 1997, a similar FACA process was implemented with the Microbial-Disinfectants/Disinfection Byproducts (M-DBP) Advisory Committee. The M-DBP Committee convened to analyze new data available since 1994, review previous assumptions made during the RegNeg process, and move the rule forward on the expedited schedule mandated under the 1996 Amendments to the SDWA. The efforts of this committee resulted in the drafting of the Stage 1 DBPR.

## 1.4 Public Health Concerns to be Addressed

EPA's main mission is the protection of human health and the environment. When carrying out this mission, EPA must often make regulatory decisions with less than complete information and with uncertainties in the available information. When making regulatory decisions, EPA believes it is appropriate and prudent to act to protect public health when there are indications that exposure to a contaminant could present a risk to public health, rather than take no action until risks are unequivocally proven.

In regard to the Stage 1 DBPR, EPA recognizes that the assessment of public health risks from disinfection of drinking water currently relies on inherently difficult and preliminary empirical analysis. On one hand, epidemiologic studies of the general population are hampered by difficulties of design, scope, and sensitivity. On the other hand, uncertainty is involved in using the results of high-dose animal toxicological studies of a few of the numerous byproducts that occur in disinfected drinking water to estimate the risk to humans from chronic exposure to low doses of these and other byproducts. In addition, such studies of individual byproducts cannot characterize the entire mixture of disinfection byproducts in drinking water. While recognizing these uncertainties, EPA continues to believe, for the reasons cited below, that the Stage 1 DBPR is needed for protection of public health from exposure to DBPs.

A fundamental component in risk assessment is the number of people that may be exposed to a particular parameter of concern. In this case, there is a very large population potentially exposed to DBPs via drinking water in the U.S. Over 200 million people in the United States are served by public water systems that apply a disinfectant (e.g., chlorine) to water in order to provide protection against microbial contaminants. While these disinfectants are effective in controlling many harmful microorganisms, they combine with organic matter in the water and form DBPs, some of which may pose health risks. One of the most complex questions facing water supply professionals is how to minimize the risks from these DBPs and still control microbial contaminants. Because of the large number of people exposed to DBPs, there is a substantial concern for any risks that may be associated with DBPs.

Numerous toxicological studies have been conducted with regard to the public health endpoint or symptoms of concern have shown several DBPs to be carcinogenic in laboratory animals (such as bromodichloromethane, bromoform, chloroform, dichloroacetic acid, bromate, and MX). Some DBPs have also been shown to cause reproductive or developmental effects in laboratory animals (such as

chlorite and certain haloacetic acids). While many of these studies have been conducted at high doses, EPA believes the studies provide evidence that DBPs present a potential public health problem that needs to be addressed.

In the area of epidemiology a number of additional studies have also been completed investigating the relationship between exposure to chlorinated drinking water and cancer. These studies have suggested an association, albeit uncertain, between bladder, rectal, and colon cancer and exposure to chlorinated drinking water. Several epidemiology studies have also been completed evaluating the association between exposure to chlorinated drinking water and reproductive and developmental effects. While there are fewer of these studies than for cancer, more recent, better designed studies have suggested an association between early term miscarriage and neural tube defects and exposure to drinking water with elevated trihalomethane levels.

While EPA recognizes there are data deficiencies in the information on the health effects from DBPs and the levels at which adverse health effects occur, EPA believes the weight-of-evidence represented by the available epidemiological and toxicological studies on DBPs and chlorinated surface water support a potential hazard concern and warrant regulatory action at this time. Because of this deficiency, EPA believes the incremental two-stage approach agreed upon during the RegNeg process is prudent and necessary to protect public health and meet the requirements of the 1996 SDWA.

In conclusion, because of the large number of people exposed to DBPs and because of the different risks that may result from exposure to DBPs, EPA believes the Stage 1 DBPR is needed to further prevent potential health effects from DBPs (beyond that controlled for by the 1979 TTHM Rule). This is in agreement with the recommendations of the RegNeg for the 1994 proposed rule and the M-DBP Advisory Committee, that while additional information is needed for the Stage 2 DBPR, especially on health effects, the Stage 1 DBPR is currently necessary to reduce risks from DBPs.

## 1.5 Summary of the Rule

The Stage 1 DBPR uses a combination of new MCLs, MRDLs, and a treatment technique requirement to improve control of disinfectants and DBPs. The rule applies to all utilities defined as community or non-transient/non-community systems that treat their water with a chemical disinfectant. (Community systems are public water systems that regularly serve at least 25 year-round residents; non-transient/non-community systems generally include businesses and other fixed establishments, such as schools in remote areas.) The IESWTR, promulgated concurrently with the Stage 1 DBPR, will further control for microbial contamination and prevent increases in microbial risk. These rules were developed *in tandem* since microbial contamination and disinfection are directly related. Both rules will be promulgated in November 1998.

In the Stage 1 DBPR, EPA establishes MCLGs and MCLs for previously unregulated byproducts (except in the case of TTHMs). EPA is setting MCLGs of 0 for chloroform, bromodichloromethane, bromoform, bromate, and dichloroacteic acid, and MCLGs of 0.06 mg/L for dibromochloromethane, 0.3 mg/L for trichloracetic acid, and 0.8 mg/L for chlorite. In addition, EPA is setting MRDLGs for chlorine and chloramines at 4.0 mg/L and 0.8 mg/L for chlorine dioxide.

The Stage 1 DBPR sets a new, more restrictive MCL for TTHMs at 0.08 mg/L (80 $\mu$g/L). EPA is adding MCLs for HAA5 of 0.06 mg/L (60 $\mu$g/L), for bromate of 0.01 mg/L, and for chlorite of 1.0 mg/L. In

addition to these byproduct MCLs, EPA is setting MRDLs for chlorine and chloramines of 4.0 mg/L and 0.8 mg/L for chlorine dioxide.

EPA identifies several technologies that utilities can use to meet the MCLs and MRDLs. These include using alternative disinfectants, such as ozone, or alternative treatment practices, such as enhanced coagulation/enhanced softening or membrane filters.

Enhanced coagulation (or enhanced softening in systems that soften their water) is specified as a treatment technique for systems with source water qualities that exceed certain parameters, (e.g., Total Organic Carbon—TOC—is above 2.0 mg/L) unless certain exception criteria are met. Enhanced coagulation is when systems increase their use of a coagulant, such as alum, to improve the removal of precursors and compounds that react with disinfectants to form DBPs. Precursors are generally identified as total organic carbon (TOC) and bromide. One purpose of the enhanced coagulation and softening requirements is to control for DBPs not controlled through compliance with the MCLs. Another purpose is to decrease the reliance on alternative disinfection practices to help comply with the MCLs for DBPs and MRDLs for disinfectants.

## 1.6 Environmental Justice

National drinking water regulations apply uniformly to utilities, and although not all have to modify treatment or operations to reach a particular standard, all must comply with the water quality standards as promulgated. Thus, the level of protection is consistent across all populations served by utilities. Traditionally developed environmental justice analyses are, therefore, not appropriate in this case.

One indicator that the concerns and issues of affected communities, including sensitive populations, are included in the Stage 1 DBPR was the undertaking of the RegNeg and M-DBP processes to craft the regulation. Both committees were chartered under the FACA and included a broad cross-section of regulators, the regulated communities, industry, and consumers. Extensive discussion on setting levels that provided the maximum protection feasible took place, and the final consensus on recommendations to EPA for the Stage 1 DBPR considered issues of affordability, equity, and safety.

## 1.7 Unfunded Mandates Reform Act Analysis

Title II of the Unfunded Mandates Reform Act (UMRA) of 1995, P.L. 104-4, establishes requirements for Federal agencies to assess the effects of their regulatory actions on State, local, and tribal governments and the private sector. Under UMRA section 202, EPA must prepare a written statement including a benefit/cost analysis, for proposed and final rules with Federal mandates that may result in expenditures to State, local, and tribal governments, in the aggregate, or to the private sector, of $100 million or more in any one year.

Because EPA believes that this rule may result in expenditures of $100 million or more for State, local, and tribal governments, in the aggregate, or the private sector, in any one year, it has prepared *Unfunded Mandates Reform Act Analysis for the Stage 1 Disinfectants/Disinfection Byproducts Rule* to accompany this RIA. This document reviews the benefit/cost analysis, estimates potential disproportionate budgetary effects, and summarizes State, local, and tribal government input. The analysis identifies the selected regulatory options as the least costly, most cost-effective, and least burdensome that accomplish the objectives of the Stage 1 DBPR.

## 1.8 Regulatory Flexibility Analysis

The Regulatory Flexibility Act provides that if a rule has a significant impact on a substantial number of small entities, its proposal must be accompanied by a Regulatory Flexibility Analysis (RFA) to be made available for public comment. Under current policy, EPA regards any impact as a significant impact and any number of small entities as a substantial number. Thus, a Regulatory Flexibility Analysis is clearly required for the Stage 1 DBPR. The Regulatory Flexibility Analysis can be incorporated within other analyses—as is the case here—so long as it is clearly stated how the requirements are being met.

Both Advisory Committees sought to provide quantitative characterization of small system impacts throughout the RegNeg process. The RegNeg and M-DBP Committees evaluated regulatory alternatives that span the complete range of considerations required by Agency guidance for implementation of the Regulatory Flexibility Act, encompassing extended timetables, performance versus design standards, exemption-based alternatives, and relaxed standards for small entities. The discussion in Chapter 5.6, *Small System Impacts—Regulatory Flexibility Analysis,* summarizes the small system impact analysis, regulatory alternatives relevant to small systems, and impact mitigation measures considered in the RegNeg process.

# 2: Consideration of Regulatory Alternatives

## 2.1 Chronological Review of Regulatory Options Considered

### 2.1.1 Alternative Development Process

The central requirement of regulatory analyses under Executive Order 12866 is to perform an analysis of net benefits and to consider the regulatory alternatives in light of a criterion of maximizing net benefits. This chapter discusses the regulatory alternatives considered.

The 1994 Disinfectants/Disinfection Byproducts Rule (DBPR) proposal attempted to balance the control of health risks from compounds formed during drinking water disinfection against the risks from microbial organisms to be controlled by the Interim Enhanced Surface Water Treatment Rule (IESWTR). The 1997 modifications sought the same balance but were enhanced by new data and the 1997 Microbial Disinfectants/Disinfection Byproducts (M-DBP) Advisory Committee process. Although in many aspects the 1994 proposal and the 1997 rule are similar, important differences exist.

Regulatory impact analysis (RIA) was a major focal point of the RegNeg and M-DBP Technologies Working Groups (TWGs). The TWGs (involving stakeholder representatives) developed consensus analyses of the impact of regulatory alternatives throughout the negotiating process. Representatives of the TWGs typically presented regulatory impact analysis briefings at the beginning of negotiating committee meetings. As the consensus process progressed, the TWG impact analyses progressed through a series of alternatives proposed and modified by the negotiating committee.

The impact analyses developed by the TWGs covered all of the major regulatory alternatives considered. Impacts were characterized in terms of both cost and effects on public health. Because health impacts are less quantifiable, the analysis tended toward a cost-effectiveness framework rather than a cost-benefit framework. The scope of analysis performed by the TWG nonetheless encompassed all of the general substance of regulatory impact analysis required under EO 12866 and current EPA guidelines.

In general, the TWGs provided evaluations of the specific regulatory alternatives. Analysts prepared the cost estimates based on agreed upon assumptions and provided the estimates to the TWGs and Committees for review and feedback. Often, the cost estimates provoked discussion and debate, with the TWGs and Committees asking for further research and refinements of the estimates before reaching a consensus on the proposed regulation.

At each phase of the process, the Committees reviewed the findings and analyses of the TWG and further refined the proposal. As a result, a variety of alternatives were discussed and costed. A chronological review of these alternatives provides an understanding of the goals and direction of the EPA proposal.

The RegNeg Committee and TWG focused initially on surface water systems that filter, but do not soften. This was selected primarily because it is perhaps the most relevant category to choose for detailed study of regulatory alternatives to control DBPs. There are approximately 5,600 water systems in this category, serving more than 130 million people. While this category represents only about 8 percent of all community and non-transient non-community water systems, at the time of proposal this category

was projected to incur about 50 percent of total capital costs. In addition, this category represents about 80 percent of the total population served by surface water systems.

The preliminary analysis focused on two options, Option 1 and Option A. Option 1 proposed a total trihalomethane (TTHM) maximum contaminant level (MCL) of 80 and a total haloacetic acid (HAA) MCL of 60 for large water systems (and a simple TTHM standard of 100 for small systems). Option A called for the use of precursor removal technology to reduce the level of total organic carbon (TOC). Alternative levels of TOC were considered, ranging from 4.0 to 0.5. The presumption behind Option A was that DBP MCLs would be established in a manner that would be consistent with meeting the TOC target; i.e., the TOC target would be the driving force and would drive compliance towards precursor removal technology. Potential adverse health risks associated with alternative disinfectants would thus be avoided.

After additional analysis by the RegNeg Committee, two additional options, or hybrids (Option A), were added to the mix: the 80/60/4 and 80/60/5 options represented an attempt to merge concepts of TOC removal and MCLs of 80 for TTHM and 60 for five HAAs (HAA5). These also represented the first detailed considerations of a staged approach to DBP regulation.

Option 1 (100/80/60) and the two hybrids under Option A (80/60/4 and 80/60/5) were carried forward after a review of the reductions in exposure and a comparison of national costs arising from the options. Option 1 would have required treatment changes in 45 percent of plants, whereas the 80/60/4 option would have required changes in 56 percent of plants and the 80/60/5 option would require changes in 43 percent of plants.

National cost estimates developed at the time indicated that total capital cost of the three Stage 1 options ranged from $3.7 billion for Option 1 to $8 to $9 billion for Option A. The small (serving populations of less than 10,000) systems' share of the national capital cost of the Stage 1 options ranged from $0.8 billion for Option 1 to $3.1 to $3.2 billion for Option A (i.e., the 80/60/4 suboption). Reduced exposure to TOC was considerable under Option A hybrids. Option 1, however, does not reduce TOC levels. The major cost difference between Option 1 and the Option A hybrids stems from the requirement to reduce TOC.

The discussion on alternatives began to center on the evaluation of the two-stage approach to DBP regulation, according to consensus reached by the RegNeg Committee. The Stage 1 proposal represented a compromise between the 100/80/60 (Option 1) concept and the 80/60/4 (Option A hybrids) concept. A treatment technique requirement for "enhanced coagulation" would apply to all systems with effluent TOC above 2.0 mg/L to reduce overall TOCs, and this would be coupled with Stage 1 MCLs of 80 and 60, for TTHMs and HAA5, respectively.

The total cost and compliance forecasts presented to the RegNeg Committee at the end of the process included $4.4 billion for Stage 1 and $10.5 to $11.2 billion for a possible Stage 2. At the time, total annualized costs were estimated at $1.1 billion for Stage 1 and $2.43 to $2.6 billion for the Stage 2 option (i.e., the cumulative costs from Stage 1 through Stage 2). These costs and compliance forecasts served as the starting point for the M-DBP Committee three years later.

The M-DBP Committee convened in 1997 to review assumptions and new data and to lay the groundwork for the promulgation of the final rule in November of 1998. As described in Chapter 5, costs

were modified based on new unit cost estimates and revised assumptions about the compliance treatment forecast.

One topic of discussion of the M-DBP Committee was a change to the enhanced coagulation model. The rule requires systems treating surface water (or ground water under the direct influence of surface water) and using conventional treatment or precipative softening to remove DBP precursors by enhanced coagulation or enhanced softening. The removal of TOC is to be used as a performance indicator for DBP precursor removal. Removal targets for subject systems are described in the rule by a matrix of influent raw TOC and alkalinity levels (the "3-X-3 matrix," Exhibits 4.5a, 4.5b, 4.5c).

Extensive research on key elements of the proposed enhanced coagulation requirements in recent years led the M-DBP Committee to recommend additional exceptions, the primary on being if utilities had raw-water Specific Ultraviolet Light Absorbence (SUVA—an indicator of the humic content of the water) of equal or less than 2.0 L/mg-m. This exception, among others, was intended to limit enhanced coagulation requirements to only those waters where DBP precursors would be effecting removal, and thereby also to limit costs for the utilities and their primary agencies.

Based on recent research on enhanced softening (removal of certain levels of TOC or of 10 mg/L magnesium hardness), the M-DBP Committee recommended changes to the 1994 proposal. In particular, proposed TOC removals were modified at systems with high alkalinity, and lime softening plants would not be required to perform lime soda softening or to lower alkalinity below 40 mg/L.

Additionally, the M-DBP Committee reviewed the significance of predisinfection on treatment. The Stage 1 DBPR as proposed originally would not have allowed utilities required to use enhanced coagulation or enhanced softening to take credit for compliance with disinfection requirements in the 1989 Surface Water Treatment Rule (SWTR) or the IESWTR prior to removing required levels of precursors, unless they met specified criteria. Analysis by the M-DBP Committee indicated that most utilities using enhanced coagulation, as required by the treatment technique provision, would be able to meet the MCLs for TTHM and HAA5 while maintaining their existing disinfection practice. This analysis also indicated that significant precursor removal and DBP reduction could still be achieved with predisinfection left in place. Also, systems would incur large capital costs to remain in compliance with disinfection requirements if predisinfection credits were disallowed. The Committee, therefore, recommended that EPA continue to allow credit for compliance with applicable disinfection requirements for disinfectants applied at any point prior to the first customer, consistent with the existing provisions of the 1989 SWTR.

## 2.2 Options with Complete Cost and Benefit Analyses

National compliance costs and projected benefits were estimated for all elements of the final rule with cost implications. These cost and benefit projections follow in Chapters 4, 5, and 6.

# 3: Baseline Conditions

## 3.1 Introduction

To develop forecasts of the economic and financial impacts of regulatory alternatives on the water supply industry, and ultimately on customers, for the Stage 1 Disinfectants/Disinfection Byproducts Rule (Stage 1 DBPR), it is necessary to develop a baseline—a characterization of the industry and its operations—before considering the effect of any regulatory option. This chapter reviews this baseline in three sections:

- Industry Profile—describing the water supply industry that is subject to the rule;
- Influent Water Quality Characterization—describing the quality of the water the industry has to work with; and,
- Existing Treatment Characterization—describing what the industry currently does with the water.

The baseline is not an encyclopedic review of the industry, source waters, and practices. Instead, the baseline is at a level of detail and precision appropriate to the needs of subsequent analyses and the decisions that were under consideration. Characteristics that were important to the decisions being made were given careful treatment; those distinctions that were unlikely to result in significant differences or affect decisions about the proposed rule were considered, though not in great detail.

This baseline derives from analyses that accompanied the 1994 Stage 1 DBPR package and considers new data, where available. The process involved knowledgeable stakeholders and incorporated the latest research; therefore, the data used in the analyses is accepted as the best available. Further, although new data sources will eventually permit a more refined understanding of the industry, differences that would significantly affect the results of this regulatory impact analysis are not anticipated.

EPA is presently developing a standardized set of baseline information for use in regulatory impact analyses under a separate effort. However, for purposes of the final Stage 1 DBPR and Interim Enhanced Surface Water Treatment Rule (IESWTR) packages, these estimates were not yet available to the Microbial-Disinfectants/Disinfection Byproducts (M-DBP) Committee (and are not yet available). Therefore, the baseline does not draw on this project.

## 3.2 Industry Profile

Data on utilities and their capacity to achieve treatment levels were analyzed to develop the national compliance cost model. Data inputs include the total number of systems to which the provisions would apply, households and populations served by these systems, average and maximum system flow rates, and applicable costs of capital, labor, and operations and maintenance. Utilities are characterized by whether or not they are able to achieve compliance with the rule and, if not, which practices they will need to modify in order to comply.

### 3.2.1 Total Number of Systems and System Size

The two features that most distinguish water suppliers are the source of their water (ground or surface) and size of their systems (as measured by the number of people served). In general, there are about 10 ground water systems for every surface water system, and many more small systems than large systems. Ground water systems primarily serve populations fewer than 10,000 people. For example, about three-quarters of surface water systems serve populations fewer than 10,000, whereas over three-quarters of ground water systems serve fewer than 500 people. These characteristics are summarized in Exhibit 3.1.

A total of 6,561 surface water systems and 69,491 groundwater systems are estimated to be affected by this rule. The total of 76,052 systems are a mixture of publicly and privately operated systems. Analysis of the Federal water system database, the Safe Drinking Water Information System (SDWIS), in 1991 as well as a number of other data sets, established the base number of systems for the regulatory impact analysis. Since the number of small systems is decreasing due to consolidation with larger systems, data on water systems changes frequently, and is difficult to establish with specificity at any time.

**Exhibit 3.1**
**Number of Systems that Disinfect by Source and Size**

| System Size (population served) | Number of Systems | |
|---|---|---|
| | Surface Water | Ground Water |
| 25-100 | 1,046 | 30,476 |
| 100-500 | 1,010 | 22,934 |
| 500-1,000 | 845 | 6,508 |
| 1,000-3,300 | 1,103 | 5,882 |
| 3,300-10,000 | 1,161 | 2,371 |
| 10,000-25,000 | 569 | 866 |
| 25,000-50,000 | 328 | 288 |
| 50,000-75,000 | 157 | 78 |
| 75,000-100,000 | 108 | 29 |
| 100,000-500,000 | 175 | 53 |
| 500,000-1,000,000 | 43 | 5 |
| 1,000,000 or more | 15 | 1 |
| **Total** | **6,560** | **69,491** |

Source: 1994 Stage 1 DBPR RIA

Larger systems, obviously, serve more households and deliver more water (Exhibit 3.2). The largest 292 systems (fewer than one half of one percent of all systems) serve fully half of the households in the country. Because the variability in system size is so important for cost and operational considerations, the baseline includes 12 size categories.

### 3.2.2 Average System Flow Rates

Average system flow rates are integrated into the national compliance cost model in determining household costs. Average and maximum system flows, expressed in millions of gallons per day (MGD), were developed separately from the cost model, but are key components in generating unit costs (EPA, June 24, 1998). The 1996 Water Industry Database (WIDB) contains a higher value for the largest (1,000,000 people or more) system size category (127.8 million gallons per year versus 98.6 million gallons per year) than the data sources used for the bulk of the cost estimation in this analysis. Cost summaries presented in Chapter 5 reflect the lower flow rate. For purposes of comparison, the higher flow rate is used to calculate costs at the 7 percent cost of capital and is displayed at the end of Appendix C.

**Exhibit 3.2**
**Number of Households**

| System Size (Population Served) | Number of Systems | Average Flow/System (000 gallons/year) | Number of Households |
|---|---|---|---|
| 25-100 | 31,522 | 2,044 | 644,000 |
| 100-500 | 23,944 | 8,760 | 2,097,000 |
| 500-1,000 | 7,354 | 31,390 | 2,308,000 |
| 1,000-3,300 | 6,985 | 83,950 | 5,864,000 |
| 3,300-10,000 | 3,532 | 255,500 | 9,024,000 |
| 10,000-25,000 | 1,435 | 766,500 | 10,999,000 |
| 25,000-50,000 | 616 | 1,825,000 | 11,242,000 |
| 50,000-75,000 | 235 | 3,212,000 | 7,548,000 |
| 75,000-100,000 | 137 | 4,745,000 | 6,501,000 |
| 100,000-500,000 | 228 | 9,855,000 | 22,469,000 |
| 500,000-1,000,000 | 48 | 43,800,000 | 21,024,000 |
| 1,000,000 or more | 16 | 98,550,000 | 15,769,000 |
| **Total** | **76,052** | | **115,489,000** |

Note: Detail may not sum due to independent rounding.

### 3.2.3 Cost of Capital

A cost of capital rate of 7 percent was used to calculate the unit costs for the national compliance cost model. This rate represents the standard discount rate preferred by the Office of Management and Budget (OMB) for benefit/cost analyses of government programs and regulations.

In addition to the 7 percent rate, unit costs were generated using both a 10 percent and 3 percent rate and evaluated using the national cost model. The 10 percent cost of capital rate provides a link to the 1994 Stage 1 DBPR cost analyses and is assumed to be a reasonable estimate of the cost to utilities to finance capital purchases that may be called for under the rule.

The exhibits of cost estimates presented in Chapter 5 reflect the 7 percent rate. The 10 and 3 percent rates are presented in the cost summary exhibit (Exhibit 5.5) for purposes of comparison. Costs presented in the analysis are expressed in 1998 constant dollars.

### 3.2.4 Unit Costs

Unit cost estimates are an integral part of the calculation of national compliance costs for the Stage 1 DBPR. They are an estimation of the marginal cost of complying with the rule based on a dollar amount per 1,000 gallons of water. Both capital and operating and maintenance costs for each treatment option have been estimated (EPA, June 24, 1998). These costs were estimated by engineers and economists familiar with equipment, process, and labor costs using available data and expert judgment. Unit costs were calculated at 3, 7, and 10 percent costs of capital. Unit costs estimates are included in Appendices B through D. For detail of the assumptions on deriving the unit costs for this RIA, refer to the July 1998 *Cost and Technologies* document.

### 3.2.5 Costs of Labor

Labor rates in the national compliance cost model are used primarily to estimate costs to utilities and States for DBP monitoring and reporting. A labor load rate, representing fringe payments, indirect costs, and general and administrative costs, was multiplied by the direct labor rate. This rate was originally estimated at 150 percent of the direct labor rate (1.5 load), but current Department of Labor statistics indicate that a lower, 140 percent, rate (1.4 load) is more accurate. The 1.4 load rate was used in the final calculations.

## 3.3 Influent Water Quality

Part of the regulatory baseline is the nature of the source waters that the industry uses. The quality of the source waters, and perhaps more important, the variation in the source waters, determines what is needed and practical to consider as treatment alternatives. An encyclopedic review of characteristics is not needed, but just those parameters key to subsequent analyses.

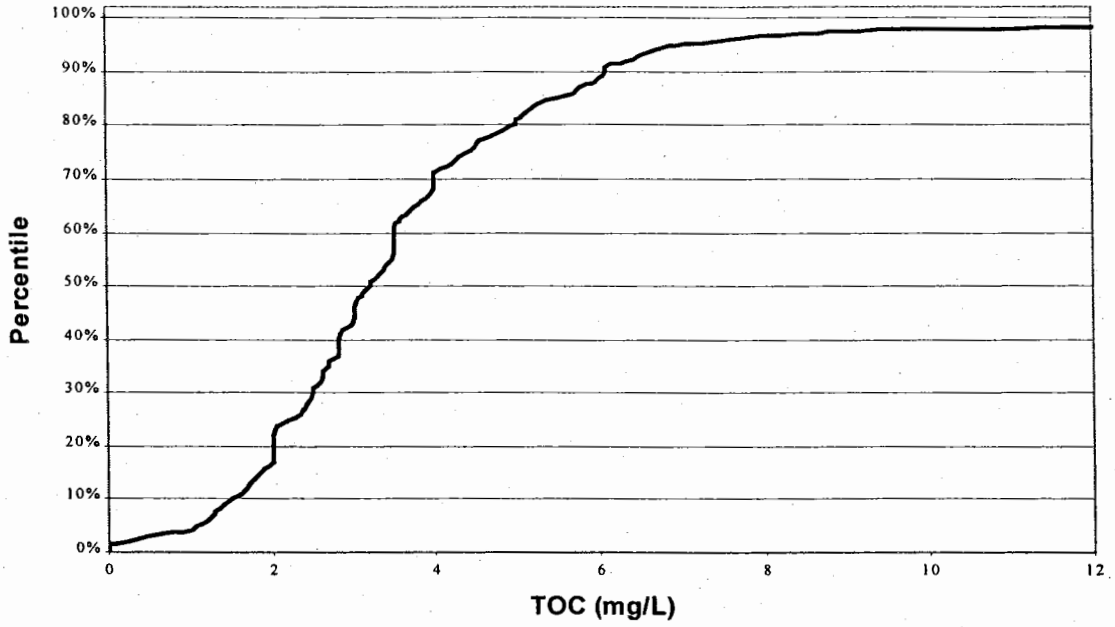
The rule requires surface water systems using conventional treatment processes (and ground water systems under the direct influence of surface water and ground water systems that disinfect) to modify these processes if current DBP formation exceeds the Maximum Contaminant Levels (MCLs) established in the rule, as well as implement enhanced coagulation if influent organic content exceeds a threshold. The 1996 Water Industry Database (WIDB) served as the source of influent water quality characterization, including system process information, influent total organic carbon (TOC), alkalinity, effluent TOC, and DBPs.

The enhanced coagulation treatment technique uses system TOC data to determine whether and how systems must comply with the technique. TOC removal, an indicator of the effectiveness of enhanced coagulation, is measured as the difference between influent TOC and effluent TOC as a percentage of total influent TOC. There are two parameters of influent water quality that drive the analysis—TOC and alkalinity. TOC removal targets are based primarily on the perceived feasibility of the treatment technology to consistently remove TOC without prohibitive cost or level of effort. These measures are used to categorize systems into levels of the needed percent removal of TOC. Available data on these parameters derive from surveys of large surface water systems, but the data are presumed to be representative of all the surface water systems affected by the rule. The reduction of TOC is used as one

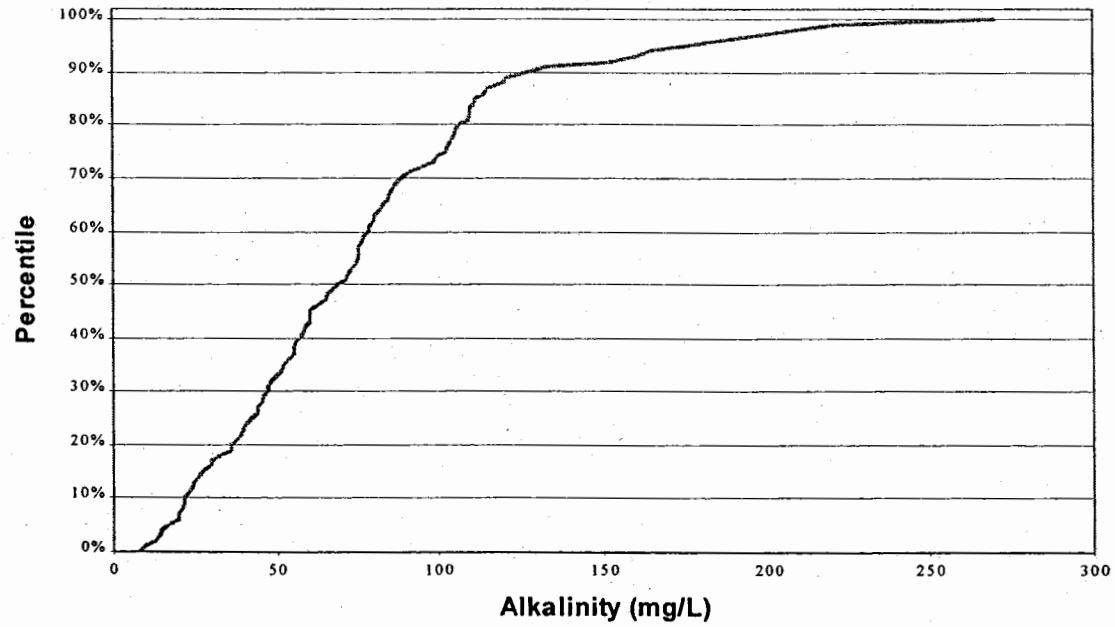
measure for eventual byproduct reduction and so is important for the analysis of benefits, as well as establishing the degree of needed treatment.

Systems are not required to comply with the enhanced coagulation technique if influent TOC values are below 1.7 mg/L (2.0 mg/L with an assumed 15 percent buffer). Above 1.7 mg/L, measurements of influent TOC concentrations in the 221 systems used as a baseline extend to as high as 26 mg/L, although few samples had levels above 6.8 mg/L (Exhibit 3.3). Alkalinity has a less concentrated distribution (Exhibit 3.4).

## Exhibit 3.3
## Cumulative Distribution of TOC Concentration in Source Waters
**(Based on Data for Large Surface Water Systems)**




## Exhibit 3.4
## Cumulative Distribution of Alkalinity in Source Waters
**(Based on Data for Large Surface Water Systems)**



The percent removal targets of TOC required under the Stage 1 DBPR are presented in Exhibit 3.5a. These targets are based on the feasibility of TOC removal given the removal technology within the specified TOC and alkalinity parameters (mg/L). Subsequent analyses categorize systems into nine groups in the form of a "3-X-3 matrix" (Exhibit 3.5b and 3.5c) using the relationship of systems' TOC and alkalinity. The systems are not evenly divided among the nine groupings; most systems are in the lower range of both TOC and alkalinity. The scatterplot of TOC and alkalinity for each of the systems shows the variability across both parameters and, for reference, shows the divisions used in subsequent analyses (Exhibit 3.6). Those systems not currently meeting the TOC removal target are presented in Exhibit 3.7. The cumulative distributions for each cell of the 3-X-3 matrix are presented in Exhibit 3.8. These distributions show the removal targets for TOC, the percent reduction in TOC removal for the systems in the specific cell, and the systems meeting and not meeting the TOC removal target.

**Exhibit 3.5a**
**Percentage of TOC Removal Required under the Stage 1 DBPR***

| | If plant alkalinity (mg/L) is... | | |
|---|---|---|---|
| **and influent TOC (mg/L) is...** | **≤ 60** | **60 to 120** | **> 120** |
| **> 1.7 to ≤ 3.4** | ❶ 35% | ❷ 25% | ❸ 15% |
| **3.4 to 6.8** | ❹ 45% | ❺ 35% | ❻ 25% |
| **> 6.8** | ❼ 50% | ❽ 40% | ❾ 30% |
| | **...then plants must remove this percentage of TOC**** | | |

* Removal targets are based on the feasibility of TOC removal in each category.
** Percent TOC Removal = [(Influent TOC – Effluent TOC)/Influent TOC]

## Exhibit 3.5b
## Systems within TOC and Alkalinity Parameters as a Percentage of Total Systems

| Total Systems: 221 (100%) | | Alkalinity (mg/L) | | |
|---|---|---|---|---|
| | | ≤ 60 | 60 to 120 | > 120 |
| Influent TOC (mg/L) | > 1.7 to ≤ 3.4 | ❶ Systems: 31 Percent of Total: 14.0% | ❷ Systems: 46 Percent of Total: 20.8% | ❸ Systems: 22 Percent of Total: 10.0% |
| | 3.4 to 6.8 | ❹ Systems: 33 Percent of Total: 14.9% | ❺ Systems: 43 Percent of Total: 19.5% | ❻ Systems: 29 Percent of Total: 13.1% |
| | > 6.8 | ❼ Systems: 2 Percent of Total: 0.9% | ❽ Systems: 5 Percent of Total: 2.3% | ❾ Systems: 10 Percent of Total: 4.5% |

Source: Calculated from 1996 WIDB Data

## Exhibit 3.5c
## Systems Meeting and Not Meeting Removal Targets within TOC and Alkalinity Parameters

| Total Systems: 221 | | Alkalinity (mg/L) | | |
|---|---|---|---|---|
| | | ≤ 60 | 60 to 120 | > 120 |
| Influent TOC (mg/L) | > 1.7 to ≤ 3.4 | ❶ Systems: 31 meeting target: 14 not meeting target: 17 | ❷ Systems: 46 meeting target: 20 not meeting target: 26 | ❸ Systems: 22 meeting target: 10 not meeting target: 12 |
| | 3.4 to 6.8 | ❹ Systems: 33 meeting target: 18 not meeting target: 15 | ❺ Systems: 43 meeting target: 9 not meeting target: 34 | ❻ Systems: 29 meeting target: 17 not meeting target: 12 |
| | > 6.8 | ❼ Systems: 2 meeting target: 2 not meeting target: 0 | ❽ Systems: 5 meeting target: 2 not meeting target: 3 | ❾ Systems: 10 meeting target: 10 not meeting target: 0 |

Source: 1996 WIDB Data

**Exhibit 3.6**
**Systems Meeting and Not Meeting TOC Removal Targets (Based on Data for Large Surface Water Systems)**
**(Does not include systems with TOC < 1.7 mg/L)**

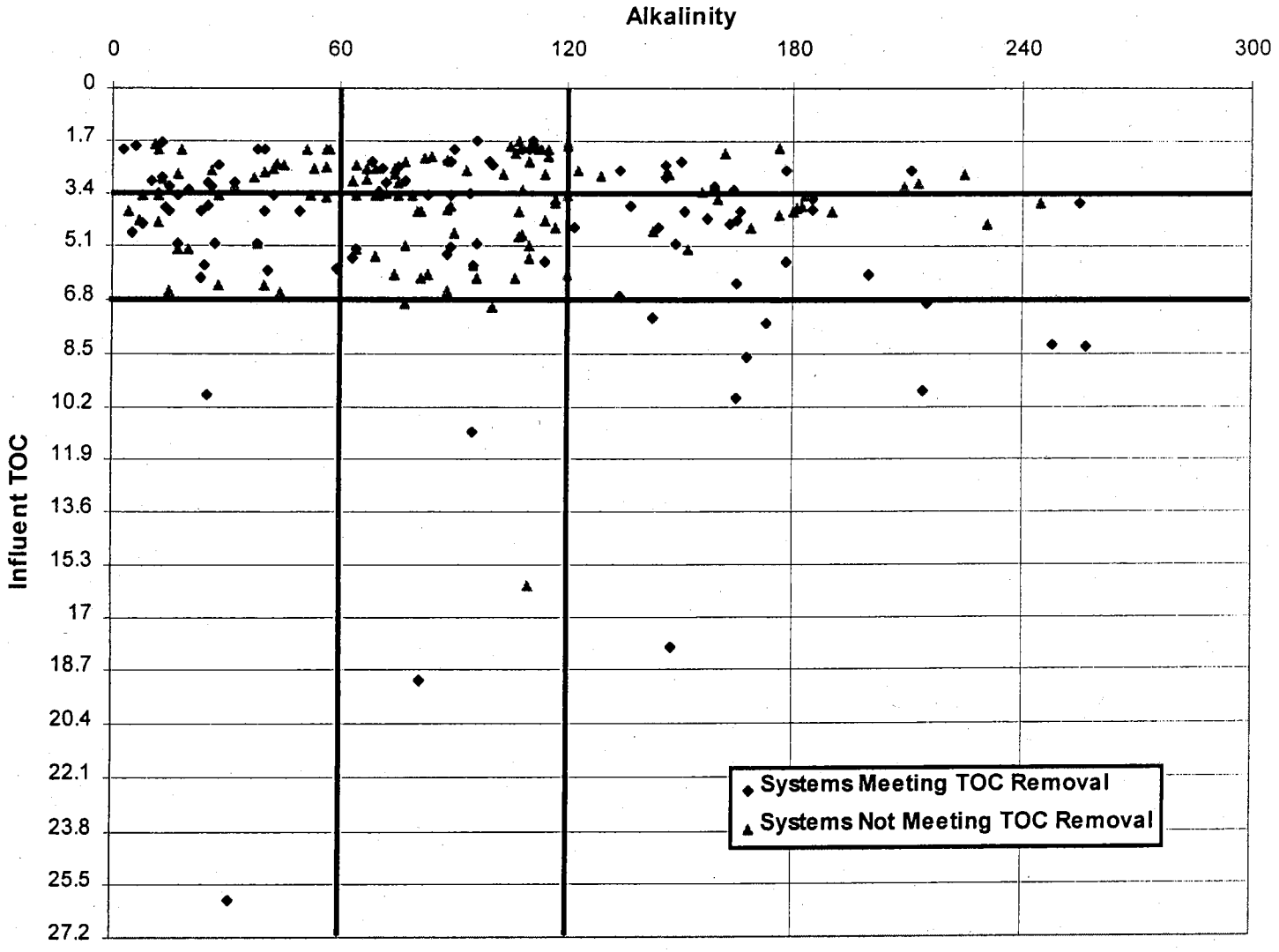
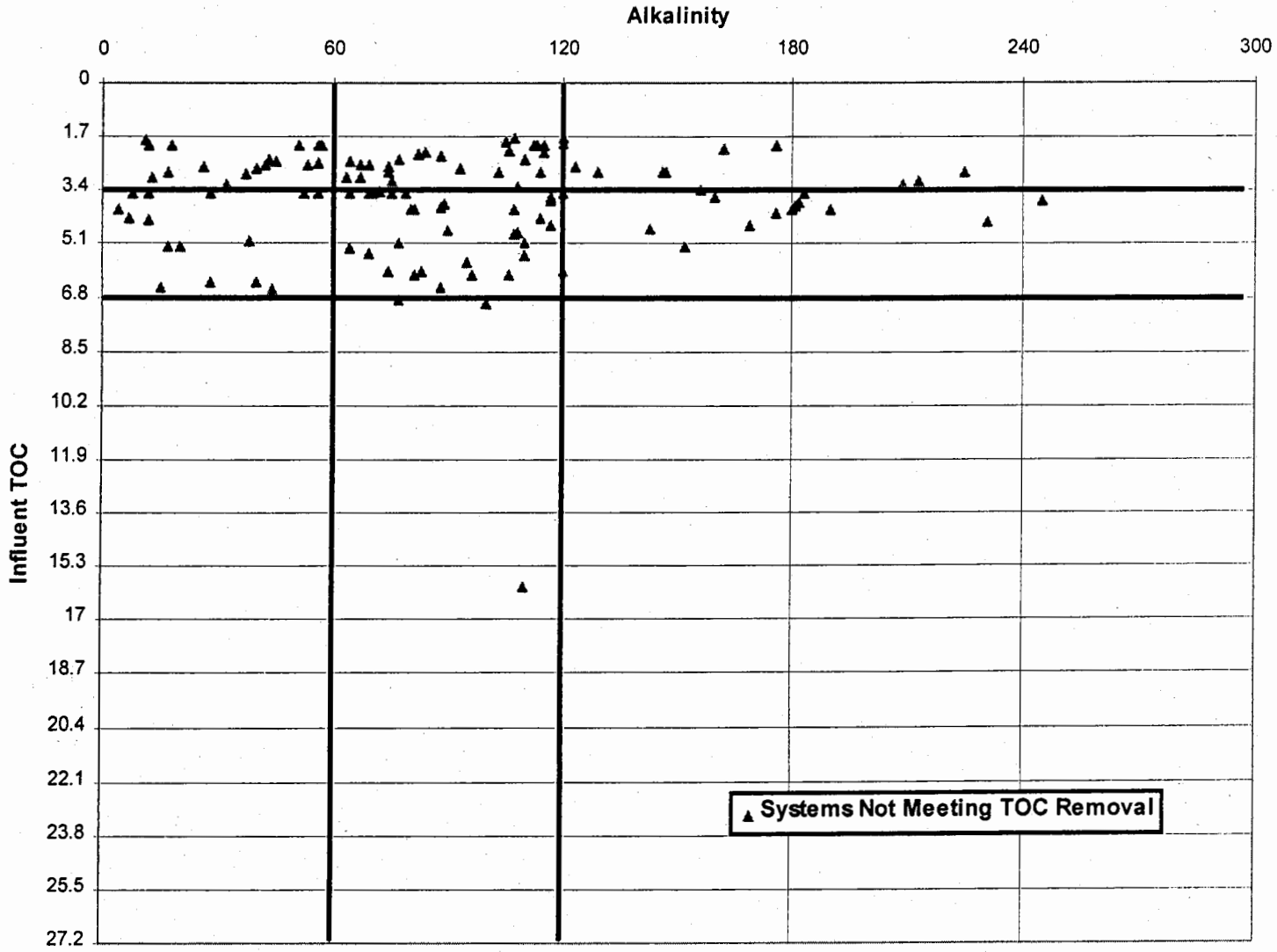
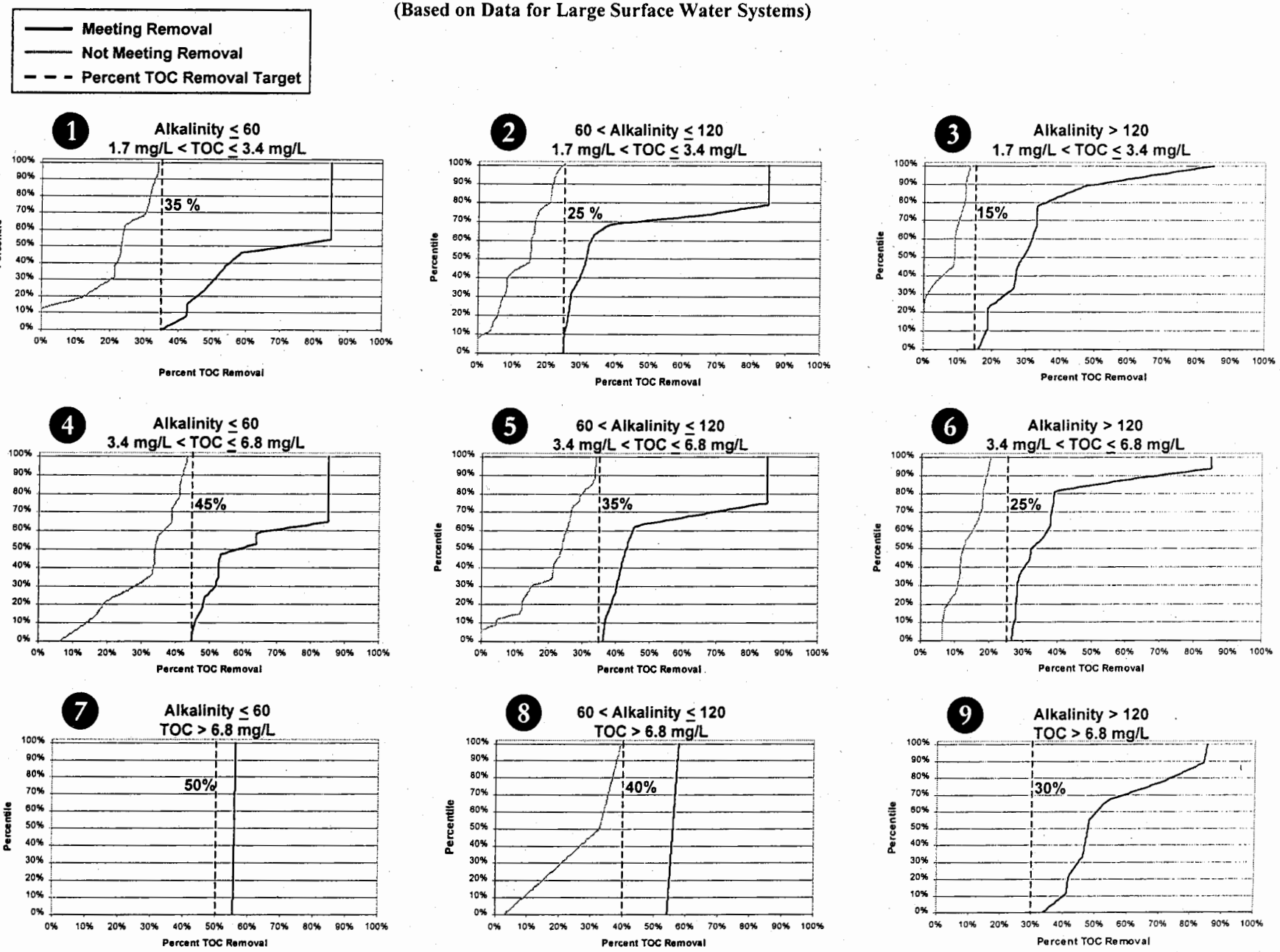


**Exhibit 3.7**
**Systems Not Meeting TOC Removal Targets (Based on Data for Large Surface Water Systems (Does not include systems with TOC < 1.7 mg/L)**



# Exhibit 3.8
## Enhanced Coagulation Matrix Distribution of TOC Removal
(Based on Data for Large Surface Water Systems)



## 3.4 Existing Treatment Characterization

Two parameters—TTHMs and HAA5—are important byproducts of treatment that the Stage 1 DBPR aims at reducing. Establishing a baseline concentration for these parameters is needed to estimate the benefits of reductions in their concentrations. This baseline characteristic is a moving target because both disinfection practices and byproduct control strategies may have changed in the wake of the implementation of the Surface Water Treatment Rule and Total Coliform Rule in the early 1990s. In addition, some systems may have begun to implement changes in anticipation of the IESWTR and Stage 1 DBPR, as these regulatory proposals have been on the table for a number of years.

The WIDB serves as the source for TTHM and HAA5 data for surface water systems for use in this RIA. The distribution of TTHMs is relatively even across the range (Exhibit 3.9). The distribution of HAA5 (a much smaller data set) is shown in Exhibit 3.10. Subsequent analyses distinguish between systems that are above certain levels of either parameter. The scatterplot of TTHMs against HAA5 (Exhibit 3.11) segments those systems that meet the levels 64 $\mu$g/L for TTHMs or 48 $\mu$g/L for HAA5 from those systems that exceed either level. These breakpoint levels are used in subsequent analyses and are set at 20 percent below the Stage 1 DBPR MCLs of 80 $\mu$g/L and 60 $\mu$g/L, respectively. This buffer provides some range for variability taking into account the need for systems to reliably meet compliance targets. The TWG set the assumed buffer for TTHM and HAA5 compliance slightly higher than the buffer for TOC removal (20 percent versus 15 percent) to reflect the greater variability and uncertainty of controlling TTHMs and HAA5.

Within each of the nine TOC/alkalinity categories described for the enhanced coagulation technique, different TOC removal levels apply. Part of the baseline is to characterize the distribution of systems within each of the nine cells of the 3-X-3 matrix and to identify the number that do not meet the required levels (See Exhibits 3.5, 3.6, and 3.7) and by how much (Exhibit 3.8). As noted above, Exhibit 3.8 displays the cumulative distributions of those systems meeting and not meeting the TOC removal levels. The degree to which those not meeting the targets must achieve compliance is shown by the distance between the cumulative distribution and the target level appropriate to each category. Because the TOC removal targets are compliance targets, the analysis treats a measured removal of 25 percent (for example) as though it were actually 21 percent (that is, 25 percent multiplied by 0.85 to allow a 15 percent buffer) in developing compliance forecasts. The levels are shown here for reference.

These data are not a census of affected plants, but the relationships described above are representative of the universe of the surface water industry and are used in subsequent analyses.

## 3.5 Risk Assessment and Benefit Analysis

Assessing the benefits of reducing exposure to disinfection byproducts requires performing a risk assessment to determine the health effects due to exposure to DBPs in drinking water, the reduction in the health effects produced by the Stage 1 DBPR, and then assigning a value to those reductions. Risk assessments require information on the health effects, toxicity, and exposure. Benefits analysis require information on the value of reducing health and other potential damages.

### 3.5.1 Health Effects and Toxicity

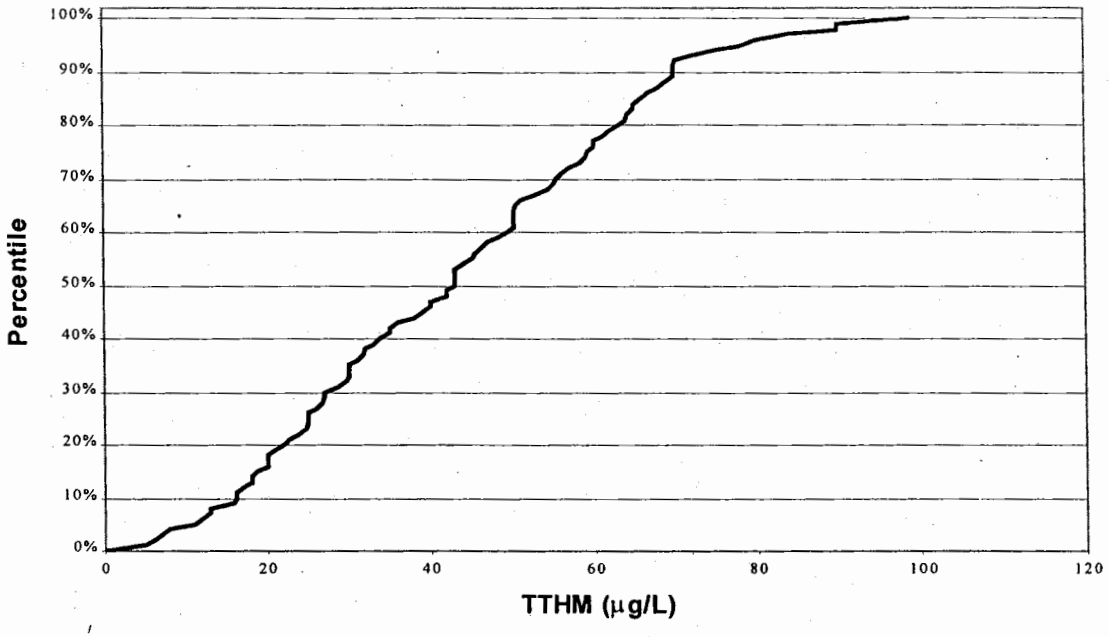
Several sources were used to assess the health effects and hazards posed by DBPs in drinking water. Available baseline toxicological and epidemiological data is discussed in detail in Chapter 4 and is

largely derived from "Summaries of New Health Effects Data" in the EPA drinking water docket (EPA, October 1997), information contained in the *1998 Notice of Data Availability*, and the supporting information to this document. The TTHM occurrence information from WIDB discussed earlier is also used to assess exposure and changes to exposure.

### 3.5.2 Benefits Analysis

To estimate the benefits of reducing the health damage attributable to DBPs, the monetary valuations for two health endpoints—fatal bladder cancer cases and nonfatal bladder cancer cases—were considered. Chapter 4, Section 4.5 discusses fully the source and derivation of the values for fatal and nonfatal bladder cancer used throughout this RIA. In addition, Appendix H also discusses the assumptions about the bladder cancer incidence, fatality rate, and trends in population that might affect the benefits projections.

## Exhibit 3.9
## Cumulative Distribution of TTHM Concentration within Distribution System
**(Based on Data for Large Surface Water Systems)**




## Exhibit 3.10
## Cumulative Distribution of HAA5 Concentration within Distribution System
**(Based on Data for Large Surface Water Systems)**

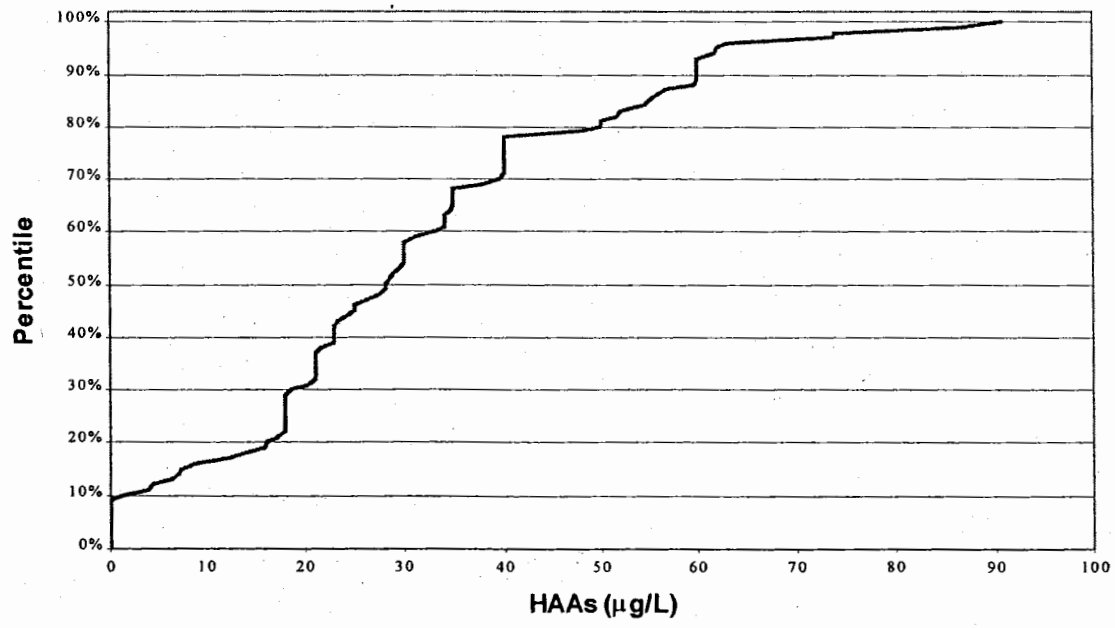
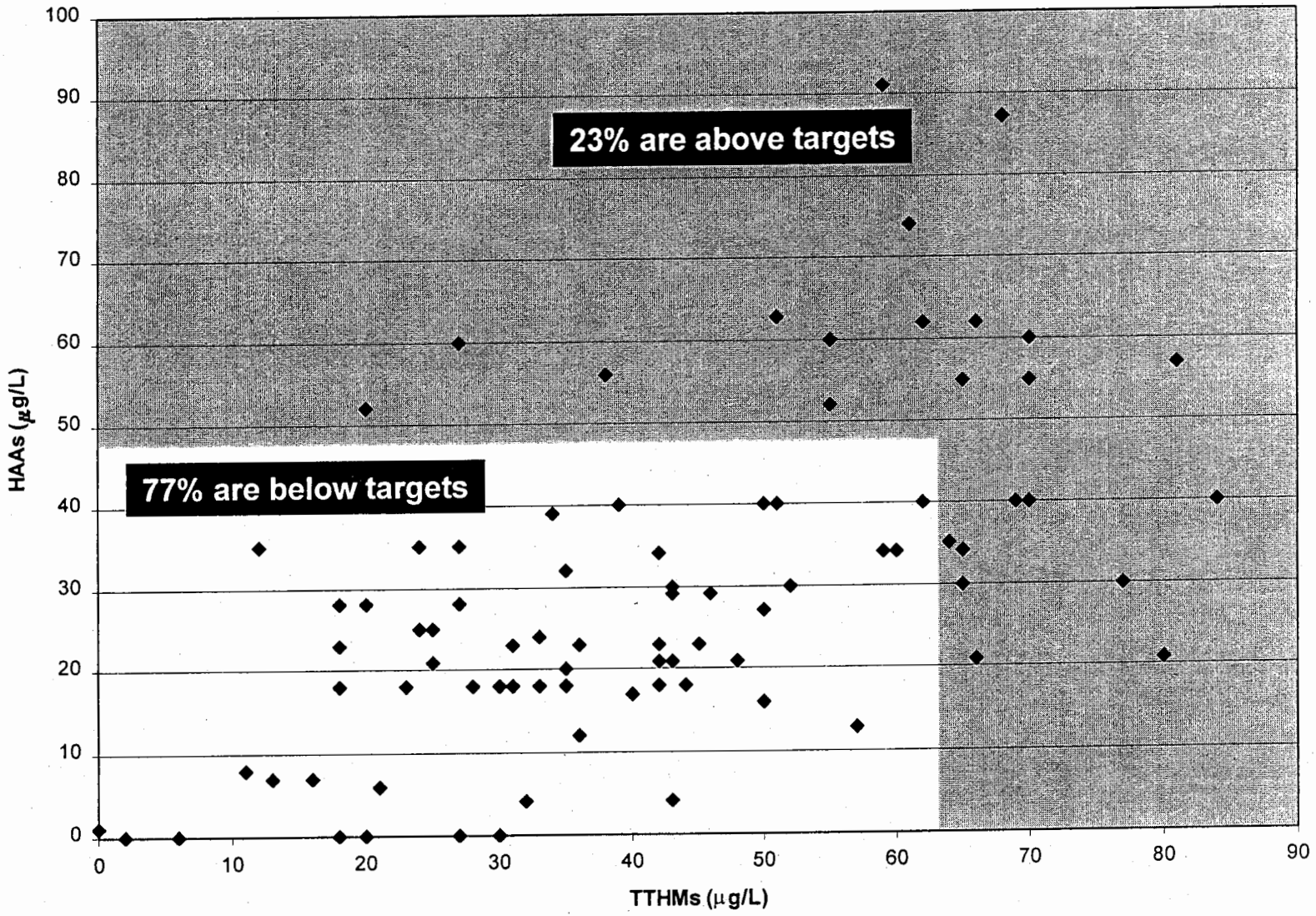


**Exhibit 3.11**
**Plant-Level Concentration of TTHMs and HAA5 within Distribution System**
**(Based on Data for Large Surface Water Systems)**




Source: WIDB Data

# 4: Benefits Analysis

## 4.1 Introduction

The benefit derived from the promulgation of a drinking water standard has often been measured by the health damages (medical costs and productivity losses) that will be avoided as a result of the enforcement of the standard. This is an incomplete concept of the true economic benefit. The complete concept of the economic benefit of drinking water standards consists of the total value to the consumer of the reduced health risk. The total value includes not only the avoidance of health damages, but also the avoidance of the pain and suffering associated with the health endpoint and the disutility associated with risk and uncertainty (i.e., the risk premium). This larger conceptual framework goes beyond valuing out-of-pocket medical costs and lost time to include the value consumers place on avoiding pain and suffering and the disutility associated with risk and uncertainty, captured in the consumer's "willingness-to-pay" for the change (Freeman, 1979). To the extent possible, the analysis in this chapter focuses on quantifying and valuing the willingness-to-pay to avoid health damages, using out-of-pocket costs as a substitute only if the more complete value is unavailable.

The potential economic benefits of the Stage 1 DBPR are derived from the increased level of protection to public health and decreased level of potential health risks such as cancer and adverse reproductive/developmental effects from disinfection byproducts (DBPs). As discussed below, there are significant uncertainties in the available data to assess health risks associated with exposure to DBPs. Because of these uncertainties, this RIA presents five alternative approaches to assess net health benefits or cost effectiveness of the Stage 1 DBPR. The health benefit of a drinking water standard is a reduction in risk—i.e., a decrease in the likelihood of potential health damage that would translate to economic benefits. The analysis of uncertainties that enter into the assessment of health damage is critical, and it is a central theme that is carried through this RIA.

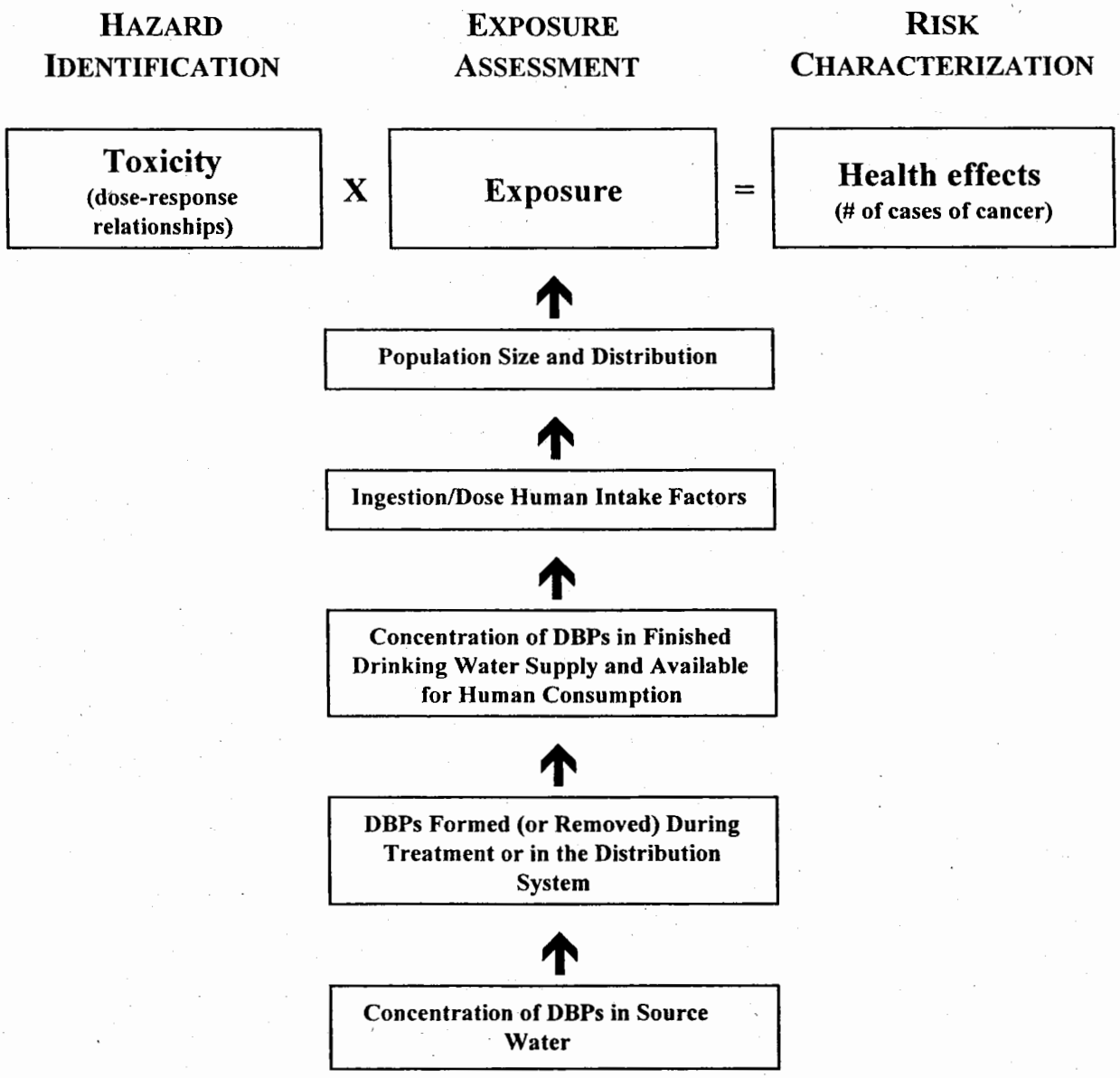
Based on a consideration of the five alternative approaches discussed in Chapter 6, there is a reasonable basis to believe that the Stage 1 DBPR will produce positive net benefits and is superior to the alternatives of no action or stronger intervention. It is also important to stress that the benefits that have been quantified in this chapter are based on human bladder cancer cases only. Other potential benefits from this rule could include other cancers (e.g., colon and rectal) and adverse reproductive and developmental effects. Data were inadequate for quantifying these benefits, however. Since economic benefits inherently derive from a reduction in risk, these qualitative benefits should be considered when evaluating the Stage 1 DBPR.

## 4.2 Health Risks from Exposure to DBPs

Risk assessment is an integral element of benefit/cost analysis and environmental decision making. It is used to characterize and estimate the potentially adverse health effects associated with exposure to environmental agents and to understand potential benefits. It follows a standard methodology employed within EPA and the Federal government and is generally organized by the paradigm put forward by the National Academy of Sciences/National Research Council (1983; 1994). Risk assessment is based on analysis of scientific data to determine the likelihood, nature, and magnitude of harm to public health associated with particular agents, and involves four types of analysis: hazard identification, dose-response assessment, exposure assessment, and risk characterization. In the case of DBPs, the RIA

focuses on the potential bladder cancer hazard associated with exposure to DBPs. Exhibit 4.1 illustrates the steps in a traditional risk assessment process for characterizing the potential human cancer associated with DBPs in drinking water.

**Exhibit 4.1 Steps in the Risk Assessment Process for Cancer**




In the case of Stage 1 DBPR, it is only possible to perform dose response assessments for a few individual DBPs—chloroform, BDCM, bromoform, and DBCM—based on laboratory animal studies. Health research of other DBPs and mixtures of DBPs is continuing but not yet sufficient to perform a dose-response assessment.

EPA's main mission is the protection of human health and the environment. When carrying out this mission, EPA must often make regulatory decisions with less than complete information and with uncertainties in the available information. EPA believes it is appropriate and prudent to err on the side of public health protection when there are indications that exposure to a contaminant could present risks to public health.

The National Research Council (NRC) noted in 1983, and in 1994, that uncertainties are inherent in risk assessment because scientific knowledge is not typically complete regarding the health risks of particular agents, and thus, default assumptions must be made in risk assessment. This is the case with potential health risks associated with exposure to DBPs in disinfected drinking water. In its 1994 report, the NRC supported the continued use of default assumptions as a reasonable way to deal with uncertainty and recommended that EPA explain the science and policy considerations underlying the appropriate default assumptions in a risk assessment.

In regard to the Stage 1 DBPR, EPA acknowledges that the assessment of public health risks from disinfection of drinking water currently relies on inherently difficult and incomplete empirical analysis. On one hand, epidemiologic studies of the various populations are hampered by difficulties of design, scope, and sensitivity. On the other hand, uncertainty is involved in using the results of high-dose animal toxicological studies of a few of the numerous byproducts that occur in disinfected drinking water to estimate the risk to humans from chronic exposure to low doses of these and other byproducts. Such studies of individual byproducts cannot characterize the entire mixture of DBPs in drinking water. While recognizing these uncertainties, EPA continues to believe that the Stage 1 DBPR is needed for protection of public health from exposure to potentially harmful DBPs. There was agreement among the members of the regulatory negotiating committee on the need to take steps to reduce exposure to DBPs. There is also general agreement among the scientific community that the risk associated with disinfected drinking water and DBPs can not be reliably quantified at this time. Under the Executive Order 12866, EPA must conduct an RIA. It should be understood that the quantitative analyses presented in this chapter are done so in support of the RIA Executive Order and to provide some reasonable basis for projecting potential health risks.

### 4.2.1 Hazard and Dose-Response Assessment: Toxicology

Since the discovery of chlorination byproducts in drinking water in 1974, a number of studies in laboratory animals have been conducted. As depicted in Exhibit 4.2, several key DBPs, including trihalomethanes (THMs), such as chloroform, bromodichloromethane (BDCM), and bromoform, have been shown to produce cancer in 2-year rodent bioassays. Certain haloacetic acids (HAAs), such as dichloroacetic acid, also have been reported to cause cancer in animal studies. Several DBPs, including chlorite, DCA, trichloroacetic acid (TCA), and BDCM, have been shown to cause reproductive or developmental effects in laboratory animals. A few DBPs have been identified as potentially causing other health problems such as nervous system effects in laboratory animals (e.g., DCA). EPA thus believes that these toxicological studies provide supporting evidence that DBPs present a potential public health problem that must be addressed.

## Exhibit 4.2
## Potential Health Effects from Disinfectants and Disinfection Byproducts from Laboratory Animal Studies

| Contaminants | Health Effects [1] |
|---|---|
| **Disinfectants** | |
| Chlorine dioxide | neurodevelopmental, hemolytic, reproductive |
| **Trihalomethanes** | |
| Chloroform | cancer, liver and kidney toxicity, developmental |
| Bromodichloromethane | cancer, liver and kidney toxicity, developmental |
| Chlorodibromomethane | cancer, liver and kidney toxicity |
| Bromoform | cancer, liver and kidney toxicity, reproductive, developmental |
| **Haloacetic Acids** | |
| Dichloroacetic acid | cancer, liver toxicity, developmental, reproductive, neurotoxicity |
| Trichloroacetic acid | cancer, liver toxicity, developmental |
| Dibromoacetic acid | reproductive, developmental |
| Bromochloroacetic acid | reproductive, developmental |
| Bromoacetic acid | developmental |
| **Inorganic DBPs in Stage 1 DBPR** | |
| Bromate | cancer, kidney toxicity, reproductive |
| Chlorite | neurodevelopmental, reproductive, hemolytic |
| **Aldehydes** | |
| Formaldehyde | cancer, developmental [2] |
| Acetaldehyde | cancer, developmental [2] |
| **Other** | |
| MX | cancer [3] |

[1] Health effects summarized in: 1) preamble to the 1994 proposed Stage 1 DBPR (59 FR 38668) and the criteria documents accompanying the proposed rule (USEPA, 1993; 1994a; 1994b; 1994c; 1994d; 1994e; 2) preamble to the 1997 Notice of Data Availability (62 FR 59388) and in "Summaries of New Health Effects Data" (USEPA, 1997); and in the preamble to a 1998 Notice of Data Availability (63 FR 15674) and in several assessment documents that accompanied the Notice (USEPA, 1998a; 1998b; 1998c.
[2] Integrated Risk Assessment System (IRIS).
[3] Komulainen, et al., 1997.

To date, EPA has established cancer assessments for seven DBPs, as reported in the 1994 Proposed Stage 1 DBPR, the 1997 and 1998 NODAs, and the Integrated Risk Information System (IRIS). A health assessment on a given chemical is included in IRIS after a comprehensive review of all available health data by U.S. EPA scientists from several Agency program offices, including the Office of Research and

Development. The information in IRIS includes a weight-of-evidence evaluation of whether the chemical has the potential to be a human carcinogen and, generally, a dose-response assessment. An RfD and RfC may also be available for noncancer toxicities. The dose-response assessment involves describing how the frequency of an adverse effect changes with the amount of exposure to a substance. The sidebar summarizes the DBP animal cancer information contained in the DBP proposed rule, the NODAs, and IRIS.

The cancer assessments presented in Exhibit 4.2 rely on animal studies conducted at DBP exposures much higher than those found in drinking water. Some studies (e.g., for BDCM, bromoform, and DBCM) did not use the most relevant route of human exposure (i.e., drinking water) but rather delivered the DBP to the animals via corn oil gavage. Thus, several extrapolations are required to project human risk (e.g., from high to low doses, from nonhuman species to human beings, from one route to another route of exposure). Each extrapolation may introduce uncertainty into the assessment.

**Summary of DBP Cancer Risk Assessments**

| Chemical | Human Carcinogen Assessment[1] | Dose Response Assessment[2] |
|---|---|---|
| Bromoform | Probable | $2.3 \times 10^{-7}$ (IRIS, 1994) |
| Bromodichloromethane | Probable | $1.8 \times 10^{-6}$ (IRIS, 1994) |
| Chloroform[3] | Probable | $1.7 \times 10^{-7}$ (IRIS, 1994) |
| Dibromochloromethane | Possible | $2.4 \times 10^{-6}$ (IRIS, 1994) |
| Dichloroacetic Acid | Probable | Not available (1998 NODA) |
| Trichloroacetic Acid | Possible | Not available (IRIS, 1994) |
| Bromate | Probable | $2 \times 10^{-5}$ (1998 NODA) |

[1] Classified under EPA 1986 Cancer Risk Assessment Guidelines

[2] Dose Response information is the Drinking Water Lifetime Unit Risk (risk per $\mu$g/liter)

[3] Under Agency review

These assessments also use the Agency's default assumption of low-dose risk (i.e., linear extrapolation) to extrapolate from the high doses used in animal studies to the anticipated low environmental human exposures because the mode of carcinogenic action is not understood for most DBPs at this time. EPA continues to believe, as discussed in the 1998 NODA, that the issues underlying a nonlinear approach for estimating the carcinogenic risk associated with lifetime exposure to chloroform via drinking water is well founded. However, based on several policy and scientific issues raised in public comments from the 1998 NODA, EPA believes it is important that additional deliberations with EPA's Science Advisory Board be completed on the questions of a nonlinear approach. Therefore, the low-dose, linear-dose response assessment for chloroform will be used in this RIA. Although cancer assessments are available for several key DBPs, it is important to note that cancer data are lacking for the majority of DBPs. Thus, a comprehensive assessment of DBP cancer risks is not possible.

Research into cancer effects of other DBPs and health effects is ongoing. The Stage 1 DBPR is expected to reduce health effects associated with Total Trihalomethanes (TTHMs), five Haloacetic Acids (HAA5), chlorite, and bromate through the setting of maximum contaminant levels (MCLs). Other DBPs will be controlled by these MCLs, as well as the enhanced coagulation treatment technique. Health damages that may be reduced include cancer, reproductive and developmental effects, and neurotoxicity.

### 4.2.2 Hazard Assessment: Epidemiology

Cancer epidemiological data provides valuable information that contributes to the overall weight-of-evidence evaluation on the potential human health hazards from exposure to chlorinated drinking water. Approximately 30 cancer epidemiological studies have been conducted over the past 20 years to examine the association between exposure to chlorinated water and cancer, including several new studies published since the 1994 proposal (EPA, 1994b, 1997; 1998). These studies have reported small relative risks for bladder, rectal, and colon cancer incidence for populations consuming chlorinated drinking water for long periods of time (EPA 1994, 1997, 1998).

Several epidemiology studies have been completed evaluating the association between exposure to chlorinated drinking water and reproductive and developmental outcomes (EPA, 1994; 1997; 1998). While there are fewer studies than for cancer, more-recent, better-designed studies have suggested an association between exposure to drinking water with elevated THMs and adverse reproductive and developmental outcomes. In particular, a study by Waller, et al., (1998) suggests an association between consumption of drinking water containing high concentrations of THMs with an increased risk of early term miscarriage. Another recent report by Klotz and Pyrch (1998) in New Jersey, reported a small increased risk of neural tube defects associated with consumption of drinking water containing high levels of TTHMs. However, no significant associations were observed with individual THMs, HAAs, and haloacetonitriles.

### 4.2.3 Hazard/Risk Characterization

As conveyed in the 1994 proposal, the interpretation of the epidemiological studies on chlorinated drinking water remains controversial. EPA believes that causality has not been established between exposure to chlorinated drinking water and adverse health effects based on epidemiological studies. As discussed later, EPA acknowledges that the epidemiological and toxicological data are limited for making quantitative inferences regarding exposure to DBPs and disease. Nevertheless, EPA believes that the overall weight-of-evidence (i.e., epidemiological findings plus toxicological results) have sufficient merit to support a public health concern and thus the need to reduce exposure to DBPs in drinking water.

## 4.3 Exposure Assessment

A large portion of the U.S. population is potentially exposed to DBPs via drinking water. Over 200 million people in the U.S. are served by PWSs that apply a disinfectant (e.g., chlorine) to water in order to provide protection against microbial contaminants. While these disinfectants are effective in controlling many harmful microorganisms, they combine with organic and inorganic matter in the water and form DBPs, some of which may pose health risks. One of the most complex questions facing water supply professionals is how to minimize the risks from these DBPs and still control for microbial contaminants. Because of the large number of people potentially exposed to DBPs, there is a substantial concern for any health risks that may be associated with exposure to DBPs.

Several factors are necessary to assess the exposure to DBPs: the size of the population potentially at risk; the method and rate of ingestion; and the concentration of DBPs in drinking water. Because DBPs are formed in drinking water by the combination of disinfectants with organic compounds, the population at risk is identified as the population served by drinking water systems that disinfect. Based on recent Safe Drinking Water Act Information System (SDWIS) data, Exhibit 4.3 contains the estimated population served by each of the four system categories. Based on recent information, it was assumed

that all surface water systems disinfect and a portion of ground water systems disinfect (95 percent by population for large systems and 83 percent by population for small systems). Approximately 239 million persons are estimated to be served by water systems that disinfect and are potentially exposed to DBPs. This widespread exposure represents over 88 percent of the total U.S. population (270 million). The route of exposure is through drinking disinfected tap water. The general adult population is assumed to consume nearly 2 liters of water per day (which represents the 84$^{th}$ percentile) (Haas and Rose, 1995).

**Exhibit 4.3 Population Potentially Exposed to DBPs**

| | Population Served | Percent of Population Receiving Disinfected Water | Population Receiving Disinfected Water |
|---|---|---|---|
| **Large Surface Water (≥ 10,000 population)** | 141,297,000 | 100% | 141,297,000 |
| **Small Surface Water (< 10,000 population)** | 17,232,000 | 100% | 17,232,000 |
| **Large Ground Water (≥ 10,000 population)** | 56,074,000 | 95% | 53,270,300 |
| **Small Ground Water (< 10,000 population)** | 32,937,000 | 83% | 27,337,710 |
| **TOTAL** | | | **239,137,010** |

In general, little data are available on the occurrence of DBPs on a national basis. Although there is sufficient occurrence data available for key THMs in large water systems to develop a national occurrence distribution for that subset of systems, data are limited for small water systems. Similarly, some occurrence data for HAA5 are available for large surface water systems but not small surface water and ground water systems. Thus, the development of a national distribution capturing all system sizes and types is problematic. Data are also lacking on the co-occurrence of the mix of DBPs found in drinking water.

## 4.4 Baseline Risk Assessment Based on TTHM Toxicological Data

As shown in Exhibit 4.4, a quantitative risk assessment based on laboratory animal studies can be performed using the dose-response information on certain THMs (found in IRIS and the supporting EPA assessment documents 1994, 1997, 1998). These assessments, however, capture only a portion of the potential risk associated with DBPs in drinking water. It is not possible, given existing toxicological and exposure data, to gauge how much of the total cancer risk associated with the consumption of chlorinated drinking water is posed by TTHMs alone. An assessment of certain key THMs, however, should provide some estimation of the potential human risk, albeit limited.

As discussed in Section 4.2.1, performing the risk assessment based on TTHM toxicological data requires making several assumptions and extrapolations (from a nonhuman species to humans, from high doses in the laboratory study to lower environmental exposures, and from a nondrinking water route to the relevant route of human exposure). Assumptions are also made about the occurrence of TTHMs and the individual DBPs. EPA has derived a weighted average TTHM baseline concentration for use in the

exposure assessment (described in detail in Appendix G). The mean weighted average baseline TTHM concentration is estimated at 43.55 $\mu$g/L, with a 25$^{th}$ percentile of 41.2 $\mu$g/L and a 75$^{th}$ percentile of 45.9 $\mu$g/L, as modeled using a Monte Carlo simulation. It should be noted that this range does not capture the full variability of TTHMs in all systems. Instead, it captures the distribution around the weighted average (central tendency), which is an adequate value for risk assessment.

Occurrence data from an EPA DBP field study indicate that chloroform is the most common THM (in general, about 70 percent of total THMs), with bromoform being the least common (1 percent). Bromodichloromethane has an occurrence of approximately 20 percent, with dibromochloromethane comprising the final 8 percent. These proportions are used to divide the average TTHM concentration into the concentration for the four individual compounds. It is important to understand that this study was biased towards systems with potentially high DBP levels and towards systems that were low in bromide. In systems with higher bromide levels, the relative percentages of the different THMs would shift to the more brominated species.

Two estimates of risk factors are used to estimate the cancer incidence. The first set of lifetime unit risk factors is from EPA's IRIS system and EPA (1998) and represents the upper 95 percent confidence limit of the dose-response function. The second estimate of lifetime unit risk is the maximum likelihood estimate used in the 1994 analysis that represents the central tendency of the dose-response function (Bull, 1991). The annual unit risk is calculated by dividing the lifetime risk by a standard assumption of 70 years per lifetime.

To calculate the annual incidence of cancer due to consumption of TTHMs in drinking water, the annual drinking water unit risk is multiplied by the number of units, in this case the concentration of TTHMs in $\mu$g/L, broken out into individual THMs based on the proportions presented above. Exhibit 4.4 contains the resulting estimated annual cancer cases due to TTHMs in drinking water.

Based on these cancer risk estimates derived from laboratory animal studies, the annual number of cancer cases attributable to TTHMs is approximately 100. Using the maximum likelihood estimates, the number of cancer cases is about 2. For the purposes of the analyses that follow, a range of zero to 1 - 100 possible baseline cancer cases is assumed to be attributable to TTHMs based on existing toxicological data.

## Exhibit 4.4
## Baseline Cancer Incidence
## Based on Modeled TTHM Concentration and Toxicological Data

**Annual Cases = Population Exposed (persons) X DBP Concentration ( $\mu$g/L) X Annual Risk Factor (cases/persons/year/$\mu$g/L)**

**Total Population (served by systems that disinfect)** (Appendix G) 239,137,010

| **Pre-Stage 1 Population-Weighted Average Concentration** (See Appendix G) | | |
|---|---|---|
| | Percent | $\mu$g/L |
| TTHMs | 100% | 43.55 |
| Chloroform | 70% | 30.49 |
| Bromodichloromethane | 21% | 9.15 |
| Dibromochloromethane | 8% | 3.48 |
| Bromoform | 1% | 0.44 |

| **Drinking Water Unit Risk Factors** (from IRIS system and central tendency of dose-response) | | | | |
|---|---|---|---|---|
| | **IRIS (Upper 95% Confidence Interval)** | | **Maximum Likelihood Estimate (from Bull, 1991)** | |
| | Lifetime (unit risk $\mu$g/L) | Annual Risk | Lifetime (unit risk $\mu$g/L) | Annual Risk |
| Chloroform | 1.70E-07 | 2.4E-09 | n/a | 1.4E-10 |
| Bromodichloromethane | 1.80E-06 | 2.6E-08 | n/a | 3.3E-10 |
| Dibromochloromethane | 2.40E-06 | 3.4E-09 | n/a | 3.3E-10 |
| Bromoform | 2.30E-07 | 3.3E-09 | n/a | 1.8E-10 |

| **Annual Cancer Incidence Based on Toxicological Data (cases/year)** | | |
|---|---|---|
| | **IRIS (Upper 95% Confidence Interval)** | **Maximum Likelihood Estimate** |
| Chloroform | 17.7 | 1.0 |
| Bromodichloromethane | 56.2 | 0.7 |
| Dibromochloromethane | 28.6 | 0.3 |
| Bromoform | 0.3 | 0.0 |
| **Total** | **102.8** | **2.0** |

## 4.5 Baseline Risk Assessment for Bladder Cancer Based on Epidemiological Data

Epidemiological studies can be used to assess the overall population risk associated with a particular exposure. Since the late 1970s, epidemiological investigations have attempted to assess whether chlorinated drinking water contributes to the incidence of bladder, colon, rectal, and other cancers. Several studies have reported a weak association between bladder cancer and exposure to chlorinated drinking water but a causal relationship has not been confirmed (Freedman, et al., 1997).

A 1992 analysis presented an aggregate meta-analysis of the published epidemiology literature relating to water chlorination and cancer (Morris, et al., 1992). The analysis identified ten articles published between 1966 and 1991 that evaluated exposure to chlorinated water and cancer at the level of the individual (called case-control studies). The analysis evaluated various cancer sites, the most frequent being bladder and colon (seven articles each), followed by stomach, rectum, and pancreas (six articles each). The study found that there were elevated risks associated with bladder and rectal cancer (odds ratio of 1.21 for bladder and 1.38 for rectal). These summary odds ratios were used to generate estimates of the number of cases of cancer within the general population that could be prevented by eliminating exposure to chlorinated drinking water (i.e., 10,000 cases per year).

During the regulatory negotiation, some negotiators supported using an estimate of over 10,000 cancer cases per year linked to exposure to chlorinated water and its associated byproducts based on the meta-analysis and supporting evidence of carcinogenicity from toxicological studies. Others argued that the national baseline incidence of cancer attributed to DBPs may be less than 1 case per year, based on maximum likelihood estimates of toxicological risk associated with the THMs. Deriving toxicological risk estimates for the other DBPs is not possible because of the lack of occurrence and dose-response data. The 1994 regulatory negotiation and draft Regulatory Impact Analysis determined that until more extensive epidemiological and toxicological studies have been completed, it is not possible to draw definitive quantitative conclusions regarding the extent of cancer and non-cancer health effects from exposure to DBPs beyond the broad range of less than 1 to 10,000 cancer cases.

Subsequent review of the meta-analysis indicated that the estimate of cancer cases had limited utility for risk assessment purposes for several methodological reasons. Problems included sensitivity to reasonable changes in analytical methods and the addition or deletion of one study and evidence of publication bias within the body of literature. Based on these issues, EPA has decided not to use the Morris, et al., meta-analysis to estimate the potential benefits from the Stage 1 DBPR.

Several cancer epidemiological studies examining the association between exposure to chlorinated surface water and cancer were published subsequent to the 1994 proposed rule and the 1992 meta-analysis. In general, these new studies are better designed than the studies published prior to the 1994 proposal. The new studies include incidence of disease, interviews with the study subjects, and better exposure assessments. More evidence is available on bladder cancer for a possible association to exposure to chlorinated surface water than other cancer sites.

Based on the better-designed studies, a range of potential risks was developed through the use of the population attributable risk (PAR) concept. Epidemiologists use PAR (also referred to as attributable fraction, attributable portion, or etiologic fraction) to quantify the fraction of disease burden in a population (e.g., bladder cancer) that could be eliminated if the exposure (e.g., chlorinated drinking water) were absent. PAR provides a perspective on the potential magnitude of risks associated with various exposures under the assumption of causality. For example, the National Cancer Institute

estimates that there will be 54,500 new cases of bladder cancer in 1997. If data from an epidemiological study analyzing the impact of consuming chlorinated drinking water reports a PAR of 1 percent, it can be estimated that 545 (54,500 X 0.01) bladder cancer cases in 1997 may be attributable to chlorinated drinking water.

For the purposes of this RIA, EPA has chosen to estimate cancer risk for chlorinated drinking water using PAR to provide a basis for the benefit/cost analysis. While EPA recognizes the limitations of the current epidemiological data base for quantitative risk assessment, EPA considers the data base reasonable for performing an RIA, as it does not require proof of causality before the determination of regulatory benefits. To that end, EPA selected studies for inclusion in the quantitative analysis if they contained the pertinent data to perform a PAR calculation and met all three of the following criteria:

1. The study was a population-based, case-control, or cohort study conducted to evaluate the relationship between exposure to chlorinated drinking water and incidence of cancer cases, based on personal interviews;

2. The study was of high quality and well designed (e.g., adequate sample size, high response rate, adjusted for known confounding factors); and,

3. The study had adequate exposure assessments (e.g., residential histories, actual THM data).

Using the above criteria, five bladder cancer studies were selected for estimating the range of PARs.

- Cantor, et al., 1985;
- McGeehin, et al., 1993;
- King and Marrett, 1996;
- Freedman, et al., 1997; and
- Cantor, et al., 1998.

Exhibit 4.5 contains a summary of these five bladder cancer studies.

The PARs from the five bladder cancer studies ranged from 2 percent to 17 percent. These values were derived from measured risks (odds ratios) based on the number of years exposed to chlorinated surface water. Because of the uncertainty in these estimates, it is possible that the PAR could also include zero. The uncertainties associated with these PAR estimates are likely to be large due to the common prevalence of both the disease (bladder cancer) and exposure (chlorinated drinking water).

This PAR range would pertain to the U.S. population of bladder cancer cases if the study populations selected for each of the cancer epidemiology studies were reflective of the entire population that develops bladder cancer; if the percentage of those cancer cases in the studies exposed to chlorinated drinking water were reflective of the bladder cancer cases in the U.S.; if DBPs were the only carcinogens in these chlorinated surface waters; and if the relationship between DBPs in chlorinated drinking water and bladder cancer were assumed to be causal.

## Exhibit 4.5 Summary of Epidemiology Studies for Bladder Cancer

| Study | Description | Summary of Results | Interpretation |
|---|---|---|---|
| Cantor, et al. (1998) | Case-control study of association between bladder cancer and consumption of chlorinated surface water | - Little overall association between bladder cancer risk and exposure to chlorination byproducts<br>- Bladder cancer risk increased with exposure duration | Opposite trends were found in males and females. Total lifetime and average lifetime TTHM levels show all risk increases are apparently restricted to male smokers. |
| Cantor, et al. (1987) | Case-control study of association between bladder cancer and consumption of chlorinated surface water | - Odds ratio for all Whites with over 59 years of exposure is 1.1 (Confidence Interval: 0.8-1.5)<br>- Odds ratio for nonsmokers is 2.3 (Confidence Interval: 1.3-4.2)<br>- Odds ratio for current smokers is 0.6 (Confidence Interval: 0.3-1.2) | Majority of water systems contained less than 20 $\mu$g/L THMs. |
| McGeehin, et al. (1993) | Case-control study of association between bladder cancer and consumption of chlorinated surface water | - Odds ratio for bladder cancer with over 30 years of exposure is 1.8 (Confidence Interval: 1.1-2.9)<br>- Odds ratio for cases consuming over 5 glasses of tap water per day is 2.0 (Confidence Interval: 1.1-2.8) | Level of total THMs, residual chlorine, or nitrates not associated with bladder cancer risk controlling for years of exposure. |
| Freedman, et al. (1997) | Nested case-control study of association between bladder cancer and consumption of chlorinated drinking water | - Odds ratio for bladder cancer using 1975 measure of exposure is 1.2 (Confidence Interval: 0.9-1.6)<br>- Slight gradient of increasing risk with increasing duration noted only among smokers | Further stratification by gender showed elevated odds ratios to be restricted to male smokers. |
| King and Marrett (1996) | Case-control study of association between bladder cancer and consumption of chlorinated surface water | - Bladder cancer risk increased with years of exposure<br>- Odds ratio for bladder cancer for 30 years of exposure compared to 10 years is 1.41 (Confidence Interval: 1.09-1.81)<br>- Bladder cancer risk increased with years of exposure<br>- Risk increases by 11 percent with each 1,000 $\mu$g/L THMs-years | Statistically signficant only for lengthy exposures. Results provide no support for an interaction between volume of water consumed and years of exposure to THMs level > 49 $\mu$g/L. |

Based on the estimate of 54,500 new bladder cancer cases per year nationally, as projected by the National Cancer Institute for 1997, the number of possible bladder cancer cases per year potentially associated with exposure to DBPs in chlorinated drinking water is estimated to range from zero to 1,100 (0.02 X 54,500) to 9,300 (0.17 X 54,500) cases. In making these estimates it is necessary to assume that these bladder cancer cases are attributable to DBPs in chlorinated surface water, even though the studies examined the relationship between chlorinated surface water and bladder cancer. This derived range is not accompanied by confidence intervals, but the confidence intervals are likely to be very wide. EPA

believes that the central tendency (i.e., mean) is a reasonable estimate of the potential range of risk suggested by the selected epidemiological studies. Exhibit 4.6 contains a summary of the risk estimates from the 1994 draft RIA and the estimates derived from the more recent analysis.

It should be noted that an alternative analysis based on odds ratios was conducted to derive a range of plausible estimates for cancer epidemiologic studies. This analysis was also based on bladder cancer studies (the five studies cited above in addition to Doyle, et al., 1997). For the purpose of this exercise, the annual U.S. expected number of 47,000 bladder cancers cited by Morris, et al., (1992) was used to calculate estimates of the cancers prevented. The number of cancers attributable to DBP exposure was estimated not to exceed 2,200-9,900 per year. Given the uncertainty in the epidemiology studies, EPA believes that this range is similar to the 1,100 - 9300 PAR range and used the PAR range for this RIA.

**Exhibit 4.6**
**Bladder Cancer Epidemiology and Toxicology:**
**Comparison of Estimates Made in 1994 & 1998**

| | 1994 Estimates | 1998 Estimates |
|---|---|---|
| Number of New Bladder Cancer Cases/Year | approx. 50,000 | 54,500 |
| Number of Estimated Deaths Due to Bladder Cancer/Year | did not state | 12,500 |
| **Attributable to DBPs in Drinking Water** | | |
| Data Source | > 15 studies | 5 studies that meet specific criteria |
| Causality | No | No |
| Percent Attributable to DBPs | did not state | 2% to 17% |
| Number of Cancer Cases Attributable to DBPs | | |
| Estimated Using Toxicological Data | less than 1* | 1* to 100** |
| Estimated Using Epidemiological Data | over 10,000 | Zero to 1,100-9,300 |

* Based on maximum likelihood estimates of risk from THMs
** Based on IRIS 95$^{th}$ percent Confidence Interval estimates of risk from THMs

## Interpreting the Risk Results

The current benefits analysis is structured in roughly the same manner as that presented in the 1994 RIA—the baseline cancer risks could lie anywhere from 0 to 1-100 cases per year based on toxicological data; and 0 to 1,100-9,300 cases per year based on epidemiological data. Consequently, the task is to assess the economic benefit of the final Stage 1 DBPR in the face of this broad range of possible risk.

## 4.6 Baseline Risk Assessment for Other Cancers Based on Epidemiological Data

The scientific literature indicates that exposure to DBPs may be related to other health effects besides the bladder cancer quantified in the above analyses. Some epidemiology studies have indicated a weak association (Odds ratio: 1.5-2.0) between consumption of chlorinated drinking water and cancer of other sites besides the bladder, namely colon and rectal cancer, while other studies have shown no association. Several population-based, case-control studies have been published that evaluate the association between consumption of chlorinated drinking water and colon or rectal cancer. Exhibit 4.7 summarizes key epidemiology studies for colon and rectal cancer.

**Exhibit 4.7 Summary of Epidemiology Studies for Colon and Rectal Cancer**

| Study | Description | Summary of Results | Interpretation |
|---|---|---|---|
| Cragle, et al. (1985) | Hospital-based, case-control study of association between colon and rectal cancer and exposure to THMs | - Increased risk in those persons 60 years and older with greater than 15 years of exposure to chlorinated water<br>- Increased risk in those persons greater than 70 years with any duration of exposure | Results could be misinterpreted because of common disease and common low exposure prevalence. |
| Young, et al. (1987) | Case-control, interview study of association between colon and rectal cancer and exposure to THMs | - Odds ratio for all variables uniformly close to 1.0 | Majority of water systems contained less than 20 $\mu$g/L THMs. |
| Doyle, et al. (1997) | Prospective cohort study to evaluate the association between cancer incidence and drinking water source and chlorinated byproducts. | - Increased risk of colon cancer in women who used municipal surface water sources in comparison with women who used municipal ground water sources. | |
| Hildesheim, et al. (1997) | Population-based, case-control study of the association between chlorination byproducts and colon and rectal cancer | - A significant increase in risk associated with durations of chlorinated surface water and colon cancer was not reported.<br>- Indicated an association between rectal cancer and chlorinated surface water. | |

EPA believes that the association between exposure to chlorinated drinking water and colon and rectal cancer, while possibly significant, cannot be determined at this time because of the limited data for these cancer sites (EPA, March 31, 1998).

## 4.7 Baseline Risk Assessment for Reproductive and Developmental Health Effects Based on Epidemiological Data

Epidemiological studies have also indicated that consumption of chlorinated drinking water could be linked to various reproductive and developmental adverse health effects. Epidemiology studies have evaluated the impacts of chlorinated drinking water on somatic parameters (e.g., birthweight, body length, cranial circumference, and neonatal jaundice), premature births, intrauterine growth retardation,

increased risk of miscarriage, and neural tube defects (EPA, March 31, 1998). One recent study reported an elevated odds ratio, generally between 1.5 to 2.1, for the association of neural tube defects with TTHMs (Klotz and Pyrch, 1998). Another study reports that consumption of tap water containing high concentrations of THMs, specifically BDCM, is associated with an increased risk of early term miscarriage (Waller, et al., 1998). Exhibit 4.8 summarizes some of the epidemiological studies on the potential reproductive and developmental health effects possibly associated with chlorinated drinking water and DBPs.

**Exhibit 4.8 Summary of Epidemiology Studies for Reproductive and Developmental Effects**

| Study | Description | Summary of Results | Interpretation |
|---|---|---|---|
| Kramer, et al. (1992) | Population-based case-control study to determine if high levels of chloroform and other THMs are associated with low birthweight, prematurity, and intrauterine growth retardation | - Increased risk of intrauterine growth retardation (Odds ratio: 1.8; 95% Confidence Interval: 1.1-2.9) at THM > 10$\mu$g/L<br>- Slightly increased risk of low birth weight (Odds ratio: 1.3; 95% Confidence Interval: 0.8-2.2) | Authors indicate results are preliminary and should be interpreted with caution. |
| Aschengrau, et al. (1993) | Case-control study of the association between drinking water quality and a variety of birth defects | - Higher frequency of stillbirths correlated with chlorination and lead levels | Results are preliminary. |
| Bove, et al. (1992 a and b) | Cross sectional and case-control study by the New Jersey Department of Health of the association between drinking water contaminants and birth weight and birth defects | - Elevated risk for low-term birth weight (Odds ratio: 1.29; 95% Confidence Interval: 1.08-1.5)<br>- Increased risk of central nervous system defects (Odds ratio: 2.6; 95% Confidence Interval: 1.48-4.6)<br>- Increased risk of central neural tube defects (Odds ratio: 2.98; 95% Confidence Interval: 1.25-7.1)<br>- Increased risk of cardiac defects (OR 1.44, 95% CI: .97-2.1) | Results are useful for hypothesis generation; should be interpreted with caution and may be subject to confounding factors. |
| Savitz, et al. (1995) | Population-based, case-control study of potential risk of miscarriage, preterm delivery, and low birth weight based on water source, amount of water consumed, and TTHM concentration | | "These data do not indicate a strong association between chlorinated byproducts and adverse pregnancy outcome, but given the limited quality of the exposure assessment and the increased miscarriage risk in the higher exposure group, more refined evaluation is warranted." |

| Study | Description | Summary of Results | Interpretation |
|---|---|---|---|
| Klotz and Pyrch (1998) | Case-control study of neural tube defects and TTHM exposure | - Increased risk levels, generally between 1.5 and 2.1, for the association between neural tube defects with TTHMs<br>- Statistically significant results at highest THM exposures (> 40 ppb) and limited to those subjects in which there was no other malformation (Odds ratio: 2.1; 95% Confidence Interval 1.1-4.0)<br>- No clear relationship for HAAs or HANs | Study adds to weight-of-evidence concerning the potential adverse reproductive health effects from DBPs. |
| Waller, et al. (1998) | Population-based study of early term miscarriage and exposure to THMs. | - Increased risk of early term miscarriage associated with high TTHM exposure in home tap water (drinking 5 or more glasses per day of cold home tap water or drinking any amount of tap water containing at least 75 $\mu$g/L) (Odds ration: 1.8; 95% Confidence Interval: 1.1-3.0)<br>- Increased risk from BDCM exposure (Odds ratio: 3.0; 95% Confidence Interval 1.4-6.6) | Study adds to weight-of-evidence concerning the potential adverse health effects from DBPs, but does not prove that exposure to TTHMs and BDCM causes early term miscarriages. |

As with the other reported adverse outcomes from the epidemiology studies, there is considerable debate in the scientific community on the significance of these and earlier findings. While the new epidemiology studies add to the database on the potential reproductive and developmental effects from DBPs, the results are inconclusive and do not support quantification of benefits at this time. These uncertainties, however, need to be considered when evaluating regulatory alternatives from a public health standpoint.

## 4.8 Exposure Reduction Analysis

During the 1994 RegNeg, the DBPRAM model (Appendix K) was used to estimate the changes in exposure due to the provisions of the proposed Stage 1 DBPR. The DBPRAM was a Monte Carlo simulation model of influent variability combined with a treatment model to predict treatment performance. The DBPRAM used the Water Treatment Plant model and its chemical equations to estimate the formation of DBPs given a range of influent waters and various compliance choices. The DBPRAM estimated that in the average (median) system the proposed Stage 1 DBPR would result in a reduction in TTHMs of 33 percent, in HAA5s of 29 percent, and TOC of 12 percent in large surface water systems.

As discussed in Chapter 3, review of new data available from the 1996 replication of the WIDB survey indicated that some of the assumptions underlying the DBPRAM modeling work, drawn from the 1988-90 WIDB survey, no longer reflect existing baseline conditions. In addition, some of the provisions of the rule have changed. These changes are outside the sensitivity of the DBPRAM modeling apparatus.

Considering this new data, EPA undertook an alternative "desktop" analysis to predict exposure reductions due to the current Stage 1 DBPR based on present baseline conditions. This analysis consists of a sequence of data and assumptions that lead to quantitative assessment of exposure reduction. While it is considered the best assessment that can be made at this time, it is necessary to recognize the substantial uncertainties inherent in such analysis. Appendix G contains a full description of the methodology and assumptions used to assess the change in exposure resulting from the Stage 1 DBPR.

EPA used the current concentration of TTHMs as a marker to measure the exposure to the range of DBPs because data are available on the baseline occurrence and formation of TTHMs. There are limited data on the total mix of byproducts in drinking water. Therefore, the reduction in TTHMs is assumed to reflect the reduction in exposure to all DBPs. To determine the change in exposure, it is necessary to estimate the Pre-Stage 1 baseline TTHM concentration and the Post-Stage 1 TTHM concentration. The difference in the Pre- and Post-Stage 1 TTHM concentrations reflect the potential reduction in TTHMs and thus in DBPs.

EPA calculated the Pre-Stage 1 TTHM concentration for the four system categories (large and small surface water, and large and small ground water) and then derived a weighted-average concentration based on the population served by systems that disinfect within each system category. The Pre-Stage 1 TTHM weighted-average concentration is 43.55 $\mu$g/L, with a modeled 25$^{th}$ percentile of 41.2 $\mu$g/L and a modeled 75$^{th}$ percentile of 45.9 $\mu$g/L. This distribution represents the variability around the calculated weighted average, not the full variability of possible TTHM measurements in all systems.

The Post-Stage 1 TTHM weighted average concentration is estimated at 32.9 $\mu$g/L, with a modeled 25$^{th}$ percentile of 30.9 $\mu$g/L and a modeled 75$^{th}$ percentile of 34.9 $\mu$g/L. Again, this distribution represents the variability around the weighted average, not the full variability of the underlying TTHM values.

The resulting reduction in exposure as modeled by the Monte Carlo simulation is 24 percent at the mean with a 25$^{th}$ percentile of 18 percent and a 75$^{th}$ percentile of 30 percent. Please refer to Appendix G for a full explanation and presentation of results.

## 4.9 Expected Benefits from Reduction in Exposure to DBPs

The economic benefit of a drinking water standard is a reduction in risk—i.e., a decrease in the likelihood of health damage. The Stage 1 DBPR is expected to reduce exposure to DBPs by approximately 24 percent, thereby reducing the likelihood of the health damages described previously, including the potential risk of bladder cancer, colon cancer, rectal cancer, and developmental and reproductive effects. Sufficient data, however, is available to quantify and monetize only the benefits associated with the reduction in bladder cancer. The discussion of monetization of health effects and net benefits that follows includes only those benefits associated with reducing the risk of bladder cancer. In deciding whether and how to regulate, it is essential to consider all potential benefits in the protection of public health and safety, including both the quantifiable benefits and qualitative benefits (Exhibit 4.9).

| Exhibit 4.9 Summary of Stage 1 DBPR Benefits | |
|---|---|
| **Category** | **Analytical Approach** |
| Bladder Cancer Benefits | |
| Fatal Bladder Cancer | Monetized |
| Nonfatal Bladder Cancer | Monetized |
| Other Cancer Sites | Qualitative |
| Reproductive Effects | Qualitative |
| Developmental Effects | Qualitative |
| Total Benefits | ? |

## 4.10 Monetization of Bladder Cancer Health Endpoints

Monetary valuations were derived for two health endpoints: fatal bladder cancer cases and nonfatal bladder cancer cases. The following discusses the source and derivation of the values for fatal and nonfatal cancer used throughout the regulatory impact analysis.

Bladder cancer is a disease in which cancer (malignant) cells are found in the bladder. Bladder cancer affects approximately 50,000 individuals in the United States each year. An estimated 54,500 new cases were expected in 1997. Of these, approximately 11,700 were expected to result in death. Bladder cancer risk increases with age (over 65) and is much more prevalent in men than women.

Four types of treatment are used for bladder cancer:

- Surgery (taking out the cancer or removing the bladder in an operation. If the bladder is removed, a new way for the patient to store and pass urine must be made);
- Radiation therapy (using high-dose x-rays or other high-energy rays to kill cancer cells and shrink tumors);
- Chemotherapy (using drugs to kill cancer cells); and
- Biological therapy (using the body's immune system to fight cancer).

Bladder cancer is one of the first cancers associated with industrialization, due most likely to organic chemical, solvent, and dye exposure. There is also evidence that bladder cancer risk increases with increases of fluid intake. However, the largest risk factor in the development of bladder cancer, responsible for as many as 60 percent of the cases, is cigarette smoking.

### 4.10.1 Willingness-to-Pay to Avoid a Fatal Bladder Cancer Case

In regulatory impact analyses, it is common to use an average willingness-to-pay (WTP) (or willingness-to-accept) value—derived from either revealed preference or stated preference approaches—as the basis for monetizing small changes in risk, known as the "value of statistical life (VSL)" (Chestnut and Alberini, 1997). One recent study, The Benefits and Costs of the Clean Air Act, 1970 to 1990, derived a distribution of VSL estimates based on 26 individual studies selected as appropriate for policy use (Chestnut and Alberini, 1997). The distribution was lognormally distributed with a mean of $4.8 million and standard deviation of $3.2 million at a 1990 price level, truncated at an upper value of $13.5 million (Chestnut and Alberini, 1997). For the purposes of the benefit evaluations in the Stage 1 DBPR RIA, the distribution of values was updated to a June 1998 price level by multiplying the distribution by an update factor of 1.25 through a Monte Carlo simulation.[1] The resulting distribution has a mean of $5.6 million and a standard deviation of $3.16 million. The actual distribution generated by the Monte Carlo simulation, capped at $16.87 million ($13.5 million X 1.25), is used consistently throughout the DBP benefits analysis. The results of the updated VSL simulation appear in Appendix H-2.

### 4.10.2 Valuation of Nonfatal Bladder Cancer Case

The complete valuation of the nonfatal cancer case measures the WTP to avoid a nonfatal case of bladder cancer. Presumably, the WTP would exceed the medical costs of the illness to include the premium for risk aversion and the value of avoiding the pain and suffering associated with the treatment of bladder cancer, including chemotherapy, radiation, and removal of the bladder. A review of the available WTP literature did not reveal any studies that measured the WTP to avoid bladder cancer, specifically. A distribution of values derived through a contingent valuation study of the WTP to avoid chronic bronchitis is used a substitute for the WTP to avoid nonfatal bladder cancer. As an alternative, a cost-of-illness (COI) value derived directly from medical costs and lost productivity is also estimated and used in the benefits analysis to compare the results. It is important to note that either the substitute WTP measure *or* the COI measure is used to value nonfatal bladder cancer, not both.

#### Derivation of Cost-of-Illness for Nonfatal Bladder Cancer

The COI estimate for nonfatal bladder cancer cases consists of two costs: the costs of medical treatment and the cost of lost productivity. The treatment for bladder cancer usually involves surgery, alone or in combination with other treatments, in 90 percent of the cases. Preoperative chemotherapy alone or with radiation before cystectomy (bladder removal) has improved some treatment results (American Cancer Society, 1998).

The treatment costs for bladder cancer were derived from a study of Medicare payments for patients with bladder cancer. The study found that average payments for bladder cancer were $57,629 in 1990 dollars (Riley, et al., 1995). Medicare payments cover only part of medical treatment costs. One article reports that an additional 4.1 percent of medical costs are paid by private insurance companies and an additional 3 percent are paid as out-of-pocket expenses by the patient (Bried and Scheffler, 1992). The total treatment costs are estimated by multiplying the Medicare costs by 1.071 to take into account out-of-pocket costs (3 percent) and private insurance costs (4.1 percent) for a total treatment cost of

[1] Consumer Price Index, all items, all consumers, June 1998/1990 average = 163.0/130.7 = 1.25. Assumed to reflect 1998 price levels.

$61,721 in 1990 dollars. This value is then updated to a current value of $91,964.[2] This value is in the same range as values for comparable cancer sites calculated and used to estimate benefits of the Superfund program (EPA, June 1994).

The same Superfund report is the source of the estimate for productivity losses. Using rectal cancer as a substitute for bladder cancer, the report estimates that the average expected number of productivity loss days over the first 2 years of treatment is 283 days (EPA, June 1994). Assuming a value-per-day loss of $101.92, the total value of productivity losses is estimated at $28,843 (Bureau of Labor Statistics, 1998). The resulting total COI used in the benefits analysis is the treatment cost ($91,964) plus the productivity loss ($28,843) for a total of $121,000. The calculations, assumptions, and estimates for the COI value appear in Appendix H-3.

### Derivation of Willingness-to-Pay for Nonfatal Bladder Cancer

As stated previously, there is no reported value in the literature for the WTP to avoid a nonfatal bladder cancer case. One study, however, derived WTP to avoid a case of chronic bronchitis through a contingent valuation survey that measured risk-risk tradeoff (Viscusi, et al., 1991). The study asked participants to compare the risk of chronic bronchitis with the risk of a fatal auto accident to produce a relative valuation. The results "...suggest that the risk of a chronic bronchitis case is worth 32 percent of the comparable risk of death, as measured by the median tradeoff rate" (Viscusi, et al., 1991). The study also measured a risk-dollar tradeoff by comparing the risk reduction for chronic bronchitis or an auto accident fatality against a cost-of-living increase. The result is a distribution of values representing the WTP to avoid a case of chronic bronchitis with a median of $457,000 in 1990 dollars. The value derived for the auto fatality was $2.29 million in 1990 dollars, which is well within the value of statistical life distribution, although at the lower end.

The distribution of values for the WTP to avoid chronic bronchitis reported in the study is updated through a Monte Carlo simulation by multiplying by a Consumer Price Index factor of 1.25. The resulting distribution, with a median value of $535,600, a mean value of $587,500, and truncated at $1.5 million, is used throughout subsequent analyses. The results of the Monte Carlo simulation are presented in Appendix H-4.

The WTP to avoid chronic bronchitis is not a perfect substitute for the WTP to avoid a case of bladder cancer, though it appears to be a reasonable approximation for the purposes of benefit assessment (see sidebar). Some of the attributes of chronic

**Applicability of Using WTP to Avoid Chronic Bronchitis for WTP to Avoid Bladder Cancer**

1. Both have similar long-term quality of life health implications, including:
- Using medical equipment for the rest of life (for chronic bronchitis, wearing small portable oxygen tank; for bladder cancer, wearing a bag to store and pass urine),
- Limiting recreational and job-related activities,
- Visiting doctors regularly and taking medication, and
- Experiencing periods of depression.

*Net Impact on WTP: About the same*

2. Chronic bronchitis is associated with more obvious lingering implications, such as shortness of breath and more frequent chest infections.

*Net Impact on WTP: Chronic bronchitis higher*

3. Bladder cancer has more severe acute health effects, including major surgery and undergoing radiation or chemotherapy treatments (with attendant side effects).

*Net Impact on WTP: Bladder cancer higher*

[2] Consumer Price Index, medical care, all consumers, June 1998/1990 average = 242.0/162.8 = 1.49. Assumed to reflect 1998 price levels.

bronchitis and bladder cancer are quite similar, such as using a respirator for chronic bronchitis and using a bag to store and pass urine for bladder cancer. Chronic bronchitis may be associated with more severe chronic effects, but bladder cancer is associated with more severe acute effects. In addition, a comparison of the COI for chronic bronchitis and bladder cancer reveals that the COIs are similar: $95,000 for chronic bronchitis and $121,000 for bladder cancer (Cropper and Krupnick, 1989).

## 4.11 Range of Potential Monetized Benefits from Reducing Bladder Cancer

The range of potential benefits from the Stage 1 DBPR can be calculated by applying the monetary values for fatal and nonfatal bladder cancer cases to the estimated number of bladder cancer cases that will be reduced by the rule. The following assumptions are used to estimate the range of potential benefits:

- An estimate of the number of bladder cancer cases attributable to DPBs in drinking water ranges from 0 to 9,300 annually;
- A 24 percent reduction in exposure to DBPs (using reduction in TTHMs as a proxy for reduction for all DBPs) due to the Stage 1 DBPR (75 percent Confidence Interval of 18 to 30 percent) will result in a 24 percent reduction in bladder cancer cases;
- A value per statistical life (VSL) saved for fatal bladder cancer is represented by a distribution with a mean of $5.6 million; and,
- A WTP to avoid a nonfatal case of bladder cancer is represented by a distribution with a mean of $587,500.

Using the low end of the risk range of 0 bladder cancer cases attributable to DBPs results in a benefits estimate of $0. To calculate the high end of the range, the estimated 9,300 attributable cases is multiplied by the percent reduction in exposure to derive the number of bladder cancer cases reduced (9,300 X 0.24 = 2,232 bladder cancer cases reduced). Assuming that 23 percent of the bladder cancer cases end in fatality and 77 percent are nonfatal, the number of fatal bladder cancer cases reduced is 513 (2,232 X 0.23) and the number of nonfatal bladder cancer cases is 1,719 (2,232 X 0.77). Based on the valuation distributions described above, the estimate of benefits at the mean associated with reducing these bladder cancer cases is approximately $4 billion. It should be noted that these estimates do not include potential benefits from reducing other health effects (other cancers; reproductive and developmental effects) that cannot be quantified at this time. While the low end of the range cannot extend below $0, it is possible that the high end of the range could extend beyond $4 billion if the other reductions in risk could be quantified and monetized. No discount factor has been applied to these valuations, although there is likely to be a time lag between compliance with the rule and realization of benefits.

Given this wide range of potential benefits and the uncertainty involved in estimating the risk attributable to DBPs, EPA undertook five different approaches to assessing the net benefits of the Stage 1 DBPR to assist decision-makers in choosing a regulatory alternative for addressing the public health risk of DBPs in drinking water. These approaches are described in Chapter 6 and should be considered both individually and in the aggregate in support of rulemaking to protect the public's health and safety.

# 5: Cost Analysis

## 5.1 Introduction

This chapter estimates the total national costs of complying with the Stage 1 Disinfectants/Disinfection Byproducts Rule. It discusses which elements of the rule incur costs, on what basis those costs are estimated, and how they are aggregated. Chapter 6 compares the cost estimates with the potential benefits of the rule.

The cost estimation for the Stage 1 DBPR combines information from existing data sources with technical assumptions based on expertise developed by the Microbial-Disinfectants/Disinfection Byproducts (M-DBP) Advisory Committee and its Technologies Working Group (TWG). These estimates are the result of an iterative process that was continually updated by new data and modified assumptions. Where necessary, a chronology of the decisions that formed a particular estimate is discussed.

### 5.1.1 How This Chapter Is Organized

This chapter describes how these estimates were derived from previous analyses, changes in the Stage 1 DBPR, and review of recent studies. Section 5.2 presents an overview of the process and available new data. Section 5.3 discusses DBP treatment effectiveness and costs. Section 5.4 more fully describes the national cost estimates. Finally, Section 5.5 addresses the impacts of the rule on small systems, consistent with analytical requirements under the Regulatory Flexibility Act. Additional documentation on the analyses and cost estimates in this chapter are included in Appendices A through E.

## 5.2 The Stage 1 DBPR and New Data

A regulatory impact analysis was developed in 1994 in support of the 1992-1993 Regulatory Negotiation (RegNeg) process that produced the proposed Stage 1 DBPR. The results of the 1992-1993 RegNeg process are summarized in Chapters 1 and 2. Since the rule was proposed, some new sources of data have become available that were used to update the forecasts made in the 1994 RIA. In addition, there have been several revisions incorporated into the final Stage 1 DBPR (and into the companion Interim Enhanced Surface Water Treatment Rule—IESWTR) that have effects on national cost estimates.

The major revisions in the rule that produced changes in the national cost forecast include the following—

- Allowance of credit for disinfection prior to the point of coagulant addition;
- Re-definition of total organic carbon (TOC) removal requirements for enhanced coagulation; and
- Re-specification of minimum disinfection requirements for the IESWTR.

## Exhibit 5.2
## Summary of Costs under the Proposed Stage 1 DBPR in 1998 Dollars (1.129 Inflation Factor), 10 Percent Cost of Capital ($000)

| | Surface Water Systems | | | Ground Water Systems | | | All Systems |
|---|---|---|---|---|---|---|---|
| | Small | Large | Total | Small | Large | Total | |
| **Treatment Costs** | | | | | | | |
| **Total Capital Costs** | 677,400 | 2,258,000 | 2,935,400 | 1,241,900 | 790,300 | 2,032,200 | **4,967,600** |
| ***Annual O&M*** | *56,450* | *333,055* | *389,505* | *99,352* | *63,224* | *162,576* | ***552,081*** |
| ***Annualized Capital Costs*** | *104,997* | *233,703* | *338,700* | *188,543* | *88,062* | *276,605* | ***616,434*** |
| **Annual Utility Treatment Costs** | 161,447 | 566,758 | 728,205 | 287,895 | 152,415 | 440,310 | **$1,168,515** |
| **Monitoring and Reporting Cost** | | | | | | | |
| **Start-Up Costs** | 85 | 50 | 134 | 722 | 35 | 807 | **942** |
| **Annual Monitoring** | 18,371 | 15,190 | 33,561 | 62,027 | 23,408 | 85,435 | **118,995** |
| **State Costs** | | | | | | | |
| **Start-Up Costs** | | | | | | | **4,058** |
| **Annual Monitoring** | | | | | | | **13,593** |
| **Total Annual Costs** | | | | | | | **$1,306,103** |

## Exhibit 5.3
## Summary of Costs under the Proposed Stage 1 DBPR in December 1992 Dollars, 10 Percent Cost of Capital ($000)

| | Surface Water Systems | | | Ground Water Systems | | | All Systems |
|---|---|---|---|---|---|---|---|
| | Small | Large | Total | Small | Large | Total | |
| **Treatment Costs** | | | | | | | |
| **Total Capital Costs** | 600,000 | 2,000,000 | 2,600,000 | 1,100,000 | 700,000 | 1,800,000 | **4,400,000** |
| ***Annual O&M*** | *50,000* | *295,000* | *345,000* | *88,000* | *56,000* | *144,000* | ***489,000*** |
| ***Annualized Capital Costs*** | *93,000* | *207,000* | *300,000* | *167,000* | *78,000* | *245,000* | ***546,000*** |
| **Annual Utility Treatment Costs** | 143,000 | 502,000 | 645,000 | 225,000 | 135,000 | 390,000 | **$1,035,000** |
| **Monitoring and Reporting Cost** | | | | | | | |
| **Start-Up Costs** | | | | | | | **834** |
| **Annual Monitoring** | | | | | | | **105,399** |
| **State Costs** | | | | | | | |
| **Start-Up Costs** | | | | | | | **3,594** |
| **Annual Monitoring** | | | | | | | **12,040** |
| **Total Annual Costs** | | | | | | | **$1,156,867** |

## 5.4 Compliance Treatment Forecast

The compliance treatment forecast is the basis of the cost analysis. The compliance treatment forecast is the culmination of the analysis of systems, their treatment practices, and changes to those practices required by the Stage 1 DBPR. There are four major categories of systems affected by this rule: large

surface water, small surface water, large ground water, and small ground water systems. There is a different compliance treatment forecast for each category.

This section will review several key contributions to the final Stage 1 DBPR compliance treatment forecast. First, analyses conducted to support the rule when it was first proposed in 1994 are reviewed in the light of new data. The compliance treatment forecast for large surface water systems is discussed, as significant changes in this forecast affect the estimated costs of the rule. Changes in small system forecasts are also reviewed. Finally, the impact of the enhanced coagulation treatment technique on the overall compliance treatment forecast is examined. Exhibit 5.5 displays the entire compliance treatment forecast at the end of this section.

### 5.4.1 Comparison with Previous Analyses

This section compares the analysis conducted in 1994 (when the rule was first proposed) with the assumptions about treatment practices and effectiveness that are the basis for the current rule. The forecast of how many systems must make changes in their treatment practices to comply with the rule underpins the cost estimates. An extensive cost analysis was prepared for the 1994 RIA, and it is useful to briefly review how it was developed and how this cost analysis differs.

The 1994 RIA was supported by an elaborate modeling apparatus known as the DBP Regulatory Analysis Model (DBPRAM). The DBPRAM, which was actually a collection of analytical models, used Monte Carlo simulation techniques to produce national forecasts of compliance and resulting DBP exposure reduction for different regulatory scenarios. The model is described in Appendix K.

One of the first activities of the TWG in 1997 was to revisit the modeling tools and re-examine the results with new assumptions regarding the effectiveness of enhanced coagulation in the presence of predisinfection. A central component of the DBPRAM apparatus is the Water Treatment Plant model. Initial investigations concluded that the manner in which predisinfection is characterized in the Water Treatment Plant model makes it impossible to distinguish the effects of the changes in the Stage 1 DBPR, since the model makes simplifying assumptions about the point of predisinfection and restricts marginal analysis of shifting this point. In the 1994 analysis, the point of predisinfection did not matter since the proposal called for elimination of IESWTR credit for predisinfection and the analyses assumed predisinfection would be eliminated.

The "3-X-3 matrix" (Exhibits 3.5a, 3.5b, and 3.5c) is used to define whether and to what extent systems must adopt enhanced coagulation, by dividing systems into nine possible categories based on influent TOC and alkalinity characteristics and identifying removal targets for each category.

The major role of the DBPRAM model in the 1994 RIA was to help verify assumptions for a compliance treatment forecast. The driving factor in the 1994 RIA became the degree to which water systems would have to cross over the threshold from standard treatment technologies to more expensive technologies such as GAC, ozone, chlorine dioxide, and membranes. Focusing on this feature, the M-DBP TWG designed an approach to re-evaluating the 1994 national cost analysis by re-evaluating the manner in which newly available information and changes in the proposed rules would affect this advanced technology threshold in the compliance treatment forecast.

Two sets of data were provided to the TWG that documented levels of TOC, TTHM, HAA5, and predisinfection practices for groups of water systems. The 1996 Water Industry Data Base (WIDB) data

set provided data for 308 water systems nationwide. The AWWSCo data set provided 2 years of data (1991 and 1992) for 52 plants located primarily in the Northeast and Midwest.

Using these two data sets and experience and knowledge of these particular plants, the TWG was able to undertake a plant-by-plant assessment of the prospective compliance choices of the plants likely to change treatment practices under the Stage 1 DBPR. By computing the percentage of systems forecast to require the more expensive advanced treatments, it was possible to see how results compared with the 1994 RIA. This analysis is detailed in the next section.

### 5.4.2 Compliance Treatment Forecast for Large Surface Water Systems

The review of the previous analysis formed the basis for determining whether the compliance treatment forecast had changed since 1994 and, if so, in which ways. A sub-group of the M-DBP TWG consisting of individuals familiar with the 1994 DBPRAM analyses as well as the WIDB and AWWSCo data sets performed the re-evaluation of the compliance treatment forecast based on the rule changes. They made case-by-case evaluations of each water system in the data set for which TTHM or HAA5 exceeded 64 $\mu$g/L or 48 $\mu$g/L, respectively. These numbers are design targets for maximum contaminant levels (MCLs) of 80 $\mu$g/L and 60 $\mu$g/L, reflecting the need for utilities to build in an operational safety margin of 20 percent.

Exhibit 5.4 presents a side-by-side comparison of compliance treatment forecasts for large water systems developed for the 1994 Stage 1 DBPR RIA, the 1998 Stage 1 DBPR RIA (using 1996 WIDB data), and the 1991/92 AWWSCo data.

The compliance treatment forecast developed for the 1994 RIA using the DBPRAM (Column 2 of Exhibit 5.4) indicates that 17 percent of systems would adopt advanced treatments (ozone, chlorine dioxide, GAC, or membranes) in order to comply with the Stage 1 DBPR MCLs. In many instances, the adoption of advanced technologies was forecast as a result of the companion requirements of the IESWTR to increase disinfection to assure a less than $10^{-4}$ (1 in 10,000) annual risk level for giardiasis, the illness associated with the protozoa *Giardia*.

Since the 1994 proposal, the IESWTR requirement to achieve a $10^{-4}$ risk level for giardiasis has been replaced with a "disinfection benchmark" requirement intended to preserve the status quo of disinfection practices. Systems are required under the IESWTR to establish a profile of DBP data prior to a change in their disinfection practices. As a result, there are expected to be fewer systems (6.5 percent) having to adopt advanced technologies. In addition, probable compliance choices can be evaluated based on the existing treatment configuration and performance rather than having to first predict the effects of changes in disinfection, as was done with the DBPRAM.

## Exhibit 5.4
## Comparisons of Large System Compliance Treatment Forecasts

| | 1998 Stage 1 DBPR RIA (Analysis 1996 WIDB) | | 1994 Stage 1 DBPR RIA | | Analysis of AWWSCo 1991-1992 Data | |
|---|---|---|---|---|---|---|
| | Percent | Number | Percent | Number | Percent | Number |
| Treatment | (1) | | (2) | | (3) | |
| (A) No Further Treatment | 39.0% | 544 | 27.7% | 386 | 22.0% | 307 |
| (B) Chlorine/Chloramines | 16.6% | 231 | 2.9% | 41 | 28.0% | 391 |
| (C) Enhanced Coagulation + Chloramines | 19.0% | 265 | 9.7% | 136 | 35.0% | 488 |
| (D) Enhanced Coagulation + Chlorine | 19.0% | 265 | 43.0% | 600 | | |
| (E) Ozone, Chlorine Dioxide, GAC, Membranes | 6.5% | 90 | 16.6% | 232 | 15.0% | 209 |
| Total* | 100.0% | 1,395 | 100.0% | 1,395 | 100.0% | 1,395 |

*Detail may not add to total due to independent rounding.

The TWG reviewed the data for 73 of 308[1] systems in the 1996 WIDB data set (24 percent) that had either TTHM > 64 $\mu$g/L or HAA5 > 48 $\mu$g/L (Exhibit 5.4, Column 1, Rows B and E). The systems were evaluated at a plant level, incorporating multiple plant compliance strategies where applicable and other data such as that available from the 1996 ICR plant schematics (Exhibit 5.4, Column 1, Row E). Based on the case-by-case analysis of this sample, the TWG predicted that 20 of the 73 systems would require advanced technologies (ozone, chlorine dioxide, GAC, membranes) in order to comply with the proposed MCLs. This equates to 6.5 percent (20/308) (Exhibit 5.4, Column 1, Row E). The TWG assigned another 51 systems (16.6 percent) to a compliance category consisting of various combinations of relatively low cost strategies, such as moving the point of predisinfection and using chloramines (Exhibit 5.4, Column 1, Row B).

### 5.4.3 Enhanced Coagulation Treatment Technique

The TWG did not forecast of the number of systems in the WIDB data set that would have to install enhanced coagulation in compliance with the treatment technique portion of the Stage 1 DBPR. Because several years have passed since the 1992-1993 RegNeg process, it is likely that some water systems have already moved ahead with implementation of enhanced coagulation. Indeed, it is probably the case that some systems were achieving enhanced coagulation even before it was given its name during the RegNeg process. In order to complete a compliance treatment forecast of the final Stage 1 DBPR, it is necessary to know what proportion of the universe is already achieving enhanced coagulation and what proportion will have to employ enhanced coagulation.

[1] Percentages reported here differ from those computed earlier by members of the TWG due to a correction in the denominator. Previous calculations used 399 systems as a denominator, but since 91 of them did not report TTHM or HAA5 data, they should not be included in the computations. In addition, a 1998 quality review of the 1996 WIDB conducted after the TWG met resulted in different denominators and numerators in each category (see Exhibit 4.4), although the results of the analysis are consistent with TWG findings.

The 1996 WIDB data are the best available source of information from which to develop enhanced coagulation estimates. For this analysis, large surface water systems served as the universe of total surface water systems. The 1996 WIDB provides data on influent TOC, effluent TOC, and alkalinity by plant as well as TTHM and HAA5 data by system. Using this information, an assessment of the extent to which enhanced coagulation is already in place has been developed. The estimates can be developed through the following sequence of steps and assumptions.

**Assumption:** **It is reasonable to match plant-level TOC with the system-level TTHM and HAA5 data.**

**Assumption:** **All compliance targets require an operational buffer.** In meeting TTHM and HAA5 MCL targets of 80 $\mu$g/L and 60 $\mu$g/L, utilities are projected to allow a 20 percent buffer to ensure consistent compliance and will attempt to achieve levels of 64 $\mu$g/L and 48 $\mu$g/L, respectively. In meeting TOC removal targets, utilities will design their systems allowing a 15 percent buffer. Thus, the 2.0 mg/L TOC trigger for enhanced coagulation becomes a design target of 1.7 mg/L.

**Step 1:** **Sort the percent of systems that are below all compliance targets.** These systems meet the compliance requirement under the rule (TTHMs < 64 $\mu$g/L; HAA5 < 48 $\mu$g/L; and TOC < 1.7 mg/L) and will not need to take any additional action. The computation estimates that *10 percent* of all systems take no action.

**Step 2:** **Calculate the percent of systems that are below both 64 $\mu$g/L and 48 $\mu$g/L, but have source water TOC > 1.7 mg/L.** This is the universe of systems that would not have to use enhanced coagulation to meet MCLs but that might have to use it to meet the treatment technique requirements of the rule. This sorting results in an estimate that 62 percent of all systems fall in this category. The next step determines what portion of these 62 percent are already using enhanced coagulation.

| Total Systems: 221 100% | | Alkalinity (mg/L) | | |
|---|---|---|---|---|
| | | ≤ 60 | 60 to 120 | > 120 |
| Influent TOC (mg/L) | > 1.7 to ≤ 3.4 | Systems: 31 14.0% | Systems: 46 20.8% | Systems: 22 10.0% |
| | 3.4 to 6.8 | Systems: 33 14.9% | Systems: 43 19.5% | Systems: 29 13.1% |
| | > 6.8 | Systems: 2 0.9% | Systems: 5 2.3% | Systems: 4.5% |

Information is estimated from the 1996 WIDB and represents the percentage of the total 221 systems.

**Step 3: Sort all systems from Step 2 into the 3-X-3 matrix (above).** Calculate the number of systems in each of the nine cells of the matrix (categorizing by influent TOC and alkalinity) used to define enhanced coagulation requirements. In this version of the matrix, the number of systems

in each row is calculated using a buffer. For example, on the basis of a threshold of 1.7 mg/L TOC, systems incorporate a 15 percent buffer to consistently meet 2.0mg/L.

**Step 4:** **Further sort each matrix cell to determine the proportion of systems that meet or do not meet the enhanced coagulation TOC removal target for the cell.** Each cell has a removal target; systems either exceed or fall short of this target. For sorting, each system's TOC removal (based on the 1996 WIDB) has a 15 percent buffer applied to the removal value (TOC removal value X 0.85 = TOC removal value with buffer). The number of systems is tabulated in the 3-X-3 matrix.

**Step 5:** **Calculate the proportion of systems meeting enhanced coagulation requirements as a percentage of all systems in the 3-X-3 matrix.** The proportion of systems meeting enhanced coagulation TOC removal targets with buffer in each cell of the matrix is weighted by the proportion of all systems that fall into the cell. These weighted values are combined across the nine cells to produce a single composite estimate of the proportion of all systems that already meet the enhanced coagulation TOC removal targets. This computation produces an estimate of 46 percent (of systems in the 3-X-3 matrix).

**Step 6:** **Apply the results from the 3-X-3 matrix analysis to the total universe of systems.** The number of systems that might have to meet enhanced coagulation targets (due solely to the treatment technique requirement) is 62 percent of all systems (from Step 2). From Step 5, the proportion of systems that already meet the enhanced coagulation target removals is 46 percent. Multiplying these two figures together yields an estimate that 29 percent of all systems already meet enhanced coagulation targets and will require no further compliance action.

**Step 7:** **Add the "no action" systems together.** Summing the 10 percent of systems that have TOC < 1.7 mg/L (from Step 1) to the 29 percent that have TOC > 1.7 mg/L and TTHM and HAA5 < 64 $\mu$g/L and 48 $\mu$g/ L respectively, and that already meet the enhanced coagulation targets (from Step 6), yields an estimate that *39 percent of systems* will have to take no further action in order to comply with the treatment technique requirement in the rule.

**Step 8:** **Establish the number of systems that need to comply with the treatment technique.** Add the 39 percent (from Step 7) to the 23.1 percent of systems that were assigned to compliance choices by the TWG based on their need to meet the 80 $\mu$g/L and 60 $\mu$g/L MCLs (16.6 percent chlorine/chloramines (Cl2/NH2Cl)) and 6.5 percent other advanced technologies), yields a total of 62 percent. That leaves *38 percent* unaccounted for. These 38 percent are assumed to be the systems that will have to change treatment and incur costs in order to meet enhanced coagulation TOC removal targets. As a default assumption, 50 percent of these systems currently use chlorine as their primary disinfectant and 50 percent use chloramines.

The resulting compliance treatment forecast for large surface water systems is summarized in Column 1 ("Analysis of 1996 WIDB Data") of Exhibit 5.4.

A parallel case-by-case analysis was performed by members of the M-DBP TWG using the AWWSCo 1991-92 data representing 52 systems and summarized in Column 3 ("Analysis of AWWSCo 1991-1992 Data") of Exhibit 5.4. The results differ and potentially reflect a number of factors: 1) more adverse DBP control conditions in the waters represented in this data set and 2) a predisposition to chloramines in this data set.

The full compliance treatment forecast for both surface water and ground water systems is displayed in Exhibit 5.5.

**Exhibit 5.5**
**Compliance Treatment Forecast by Type of Treatment—**
**Surface and Ground Water Systems**

| Treatment | Surface Water Systems | | | | | |
|---|---|---|---|---|---|---|
| | Small Systems < 10,000 | | Large Systems ≥ 10,000 | | All Systems | |
| | # Systems | % Systems | # Systems | % Systems | # Systems | % Systems |
| No Further Treatment | 1,549 | 30.0% | 544 | 39.0% | 1,577 | 24.0% |
| Cl2/NH2Cl | 826 | 16.0% | 232 | 16.6% | 1,058 | 16.1% |
| Enhanced Coagulation | 1,983 | 38.4% | 265 | 19.0% | 2,248 | 34.3% |
| EC and Cl2/NH2Cl | 465 | 9.0% | 265 | 19.0% | 730 | 11.1% |
| Oz/NH2Cl | 184 | 3.6% | 29 | 2.1% | 213 | 3.3% |
| EC and Oz/NH2Cl | 0 | 0.0% | 29 | 2.1% | 29 | 0.4% |
| EC and GAC10 | 0 | 0.0% | 2 | 0.2% | 2 | 0.0% |
| EC and GAC20 | 0 | 0.0% | 2 | 0.2% | 22 | 0.0% |
| Chlorine Dioxide | 0 | 0.0% | 22 | 1.6% | 22 | 0.3% |
| Membranes | 157 | 3.0% | 4 | 0.3% | 161 | 2.5% |
| **Total*** | **5,165** | **100%** | **1,395** | **100%** | **6,560** | **100%** |
| | **Ground Water Systems** | | | | | |
| | **Small Systems ≤ 10,000** | | **Large Systems ≥ 10,000** | | **All Systems** | |
| | # Systems | % Systems | # Systems | % Systems | # Systems | % Systems |
| No Further Treatment | 59,847 | 88.0% | 1,122 | 85.0% | 60,969 | 88.0% |
| Cl2/NH2Cl | 5,403 | 7.9% | 119 | 9.0% | 5,522 | 7.8% |
| Oz/NH2Cl | 0 | 0.0% | 26 | 2.0% | 26 | 0.0% |
| Membranes | 2,921 | 4.3% | 53 | 4.0% | 2,974 | 4.3% |
| **Total*** | **68,171** | **100%** | **1,320** | **100%** | **69,491** | **100%** |

* Detail may not add to total due to independent rounding.

### 5.4.4 Compliance Treatment Forecast for Ground Water Systems

The compliance treatment forecast for ground water systems did not change from the 1994 proposal because there were no changes in the MCLs, and the enhanced coagulation requirements do not apply to ground water systems.

### 5.4.5 Compliance Treatment Forecast for Small Surface Systems

The changes in the compliance treatment forecast described so far address compliance in large surface and ground water systems. Small systems face a different set of compliance choices because the current TTHM standard of 100 $\mu$g/L does not currently apply to them and they are therefore "starting from scratch" in applying DBP controls.

Compliance treatment forecasts for small surface water systems are based on the assumption that the same percentage of small systems would have to resort to expensive, advanced technologies (ozone or membranes) as predicted for large systems (6.5 percent). This is based on the implicit assumption that the character of source waters is roughly the same in both small and large systems.

The split between ozone and membranes is about 50:50 overall, but is predicted to differ within the small system size categories. The very small categories (serving less than 500 people) are projected to rely primarily on membranes, whereas the larger small categories (serving 500 to 10,000 people) are predicted to rely much more heavily on ozone. Moreover, a heavier reliance on ozone is predicted in these size categories than in the 1994 RIA because of the differences in the IESWTR. In the 1994 proposal, the IESWTR was projected to require higher levels of inactivation. This, in turn, limited the applicability of ozone due to concerns for generation of higher levels of biologically assimilable organic carbon that could exacerbate biofilm problems in distribution systems and due to increased bromate formation. Since the current IESWTR requires no increase in inactivation levels, these concerns that previously limited the predicted use of ozone are less constraining.

It is believed that the percentage of small systems that will comply with enhanced coagulation is roughly comparable to that assumed for large systems (49 percent large versus 47.4 percent small). It is further believed that about 16 percent of systems will comply with the simple act of adding chloramines and that 30 percent of systems will have to take no compliance action at all.

## 5.5 Estimated System Costs of the Stage 1 DBPR

The estimated cost of compliance with the provisions of the Stage 1 DBPR is a function of compliance options from the compliance treatment forecast and the unit costs of each option. The greatest portion of the costs arises from compliance with the treatment options of the rule. Additional contaminant monitoring, implementation, and State costs form a smaller portion of the total costs. This section summarizes the analysis providing a national cost of compliance.

### 5.5.1 Estimated Cost of Treatment

Exhibit 5.6 displays the annual treatment cost (7 percent cost of capital) associated with the rule. Estimated costs are broken down in several ways. Costs differ by type of water system being regulated, in this case small ground water systems, large ground water systems, small surface water systems, and large surface water systems.

## Exhibit 5.6
## Annual Treatment Costs (Capital and O&M) of the Stage 1 DBPR by Treatment Type ($000s at 7 Percent Cost of Capital)

| Treatment | Surface Water Systems | | Ground Water Systems | | Total |
|---|---|---|---|---|---|
| | Small | Large | Small | Large | |
| **Chlorine/Chloramines** | $2,643 | $7,482 | $10,180 | $2,153 | **$22,458** |
| **Enhanced Coagulation/Chlorine** | 16,369 | 90,408 | 0 | 0 | **106,777** |
| **Enhanced Coagulation/Chloramines** | 5,323 | 98,971 | 0 | 0 | **104,294** |
| **Ozone/Chloramines** | 10,870 | 10,924 | 0 | 6,054 | **27,848** |
| **Enhanced Coagulation/Ozone/Chloramines** | 0 | 20,917 | 0 | 0 | **20,917** |
| **Enhanced Coagulation/GAC10** | 0 | 2,623 | 0 | 0 | **2,623** |
| **Enhanced Coagulation/GAC20** | 0 | 7,272 | 0 | 0 | **7,272** |
| **Chlorine Dioxide** | 0 | 5,722 | 0 | 0 | **5,722** |
| **Membranes** | 10,649 | 19,345 | 168,132 | 96,083 | **294,209** |
| **Total** | **$45,854** | **$263,664** | **$178,312** | **$104,290** | **$592,120** |

The estimated costs presented in this RIA incorporate the modified Stage 1 DBPR compliance treatment forecast. The model permits replication of the cost estimates for water systems by multiplying forecast percentages by the number of systems within a size category, and then multiplying the result by unit costs and annual average flows. These costs constitute that portion of total costs attributed to implementation of treatment options.

The 1994 cost estimates differ from costs estimated in this RIA. Exhibits 5.2 and 5.3 present corresponding costs estimates completed as part of the 1994 economic analysis. The total annual cost for surface water systems in the 1994 RIA was $645 million per year in 1992 dollars; for ground water systems the total was $390 million. Cumulatively, treatment costs equaled $1,035 million. The same cumulative figure updated to 1998 dollars is $1,168 million.

The 1994 calculations were based on a cost of capital of 10 percent; 1998 figures are calculated at a 7 percent cost of capital. Using the final compliance treatment forecast and applying current assumptions and unit costs, 1998 costs for treatment equal $327 million for surface water systems and $317 million for ground water systems at the 10 percent cost of capital. The cumulative total is $644 million, or a reduction of $391 million over the 1994 figures.

The reduction in costs comes from the review of the compliance treatment forecast and new unit costs in many categories. One issue is the proportion of the estimated cost in the 1994 economic analysis that was attributable to enhanced coagulation. While enhanced coagulation by itself is not very expensive in terms of the cost per household, it can add up to a large sum nationally when it is broadly implemented. In 1994, enhanced coagulation alone accounted for $307 million of the estimated total $728 million (1998 dollars) for surface water treatment cost, or about 42 percent.

In comparison, enhanced coagulation in this RIA is responsible for $211 million. Enhanced coagulation accounts for 36 percent of this estimated total, or 10 percent less than in 1994. Two major factors cause this drop in estimated costs: 1) halving of the number of systems estimated to employ advanced technologies (e.g., ozone, GAC), and 2) assuming that some systems have already implemented enhanced coagulation.

The above compliance treatment forecasts and cost estimates are subject to considerable uncertainty, due to the difficulty in establishing compliance scenarios. Supporting tables and cost model outputs are included in Appendices A through D of this document.

### 5.5.2 Estimated Cost of Monitoring and State Implementation

Exhibit 5.1 summarizes the monitoring and State implementation cost estimates. Monitoring costs are divided into start-up and annual costs. Start-up costs have been annualized over the same 20-year period as used for capital cost annualization. Unit cost estimates for the costs of annual sampling were originally estimated in 1994; these unit costs have been adjusted for inflation to 1998 dollars.

All systems will be required to monitor under the Stage 1 DBPR. Systems will monitor for influent water quality parameters (TOC and alkalinity), disinfectant residuals (chlorine, chloramines, chlorine dioxide) and DBPs (TTHM, HAA5, bromate, chlorite). The extensive monitoring described in the rule ensures the effectiveness of the treatment regime employed. Exhibit 5.7 summarized which systems will have to perform monitoring for the different contaminants being regulated under the Stage 1 DBPR.

**Exhibit 5.7**
**Monitoring Activities Required to Comply with the Stage 1 DBPR**

| System Size (population served) | Small Surface Water Systems | Large Surface Water Systems | Small Ground Water Systems | Large Ground Water Systems |
|---|---|---|---|---|
| TOC Routine/Reduced | ✓ | ✓ | | |
| Alkalinity Routine/Reduced | ✓ | ✓ | | |
| TTHM Routine/Reduced | ✓ | [1] | ✓ | [1] |
| HAA5 Routine/Reduced | ✓ | ✓ | ✓ | ✓ |
| Bromate Routine/Reduced | ✓ | ✓ | | ✓ |
| Chlorite Daily [2] | | ✓ | | |
| Chlorite Monthly [2] | | ✓ | | |
| Chlorine | [3] | [3] | ✓ | ✓ |
| Chlorine Dioxide [2] | | ✓ | | |
| Chloramines | [3] | [3] | ✓ | ✓ |
| Total Costs ($1998) (000s) | $10,867 | $14,619 | $38,803 | $26,326 |

[1] Large systems are already monitoring under the 1979 TTHM Rule.
[2] Only required for systems that use chlorine dioxide.
[3] Already monitoring under the Surface Water Treatment Rule.

Monitoring requirements in the rule specify sites and sampling frequency and serve as the basis for the cost estimates. The monitoring cost model factors the frequency and number of samples per site, the number of sites per system, and the time (burden hours) and cost for each sample. The total costs and number of samples are calculated annually and do not reflect the staging of the requirements for large and small systems.

This analysis includes several assumptions that, when taken together, conservatively estimate the costs. *Routine* monitoring is the base monitoring activity; *reduced* monitoring can be applied if a system meets certain water quality targets. This estimate assumes all systems perform routine monitoring in lieu of estimating the number of systems that could apply at some point for reduced monitoring.

Surface water systems serving fewer than 75,000 people are assumed to have one sampling site per system; larger systems are assumed to have two sites. For ground water systems, multiple wells drawing from the same aquifer are considered to be a single plant. Ground water systems with multiple wells drawing from different aquifers are considered multiple plants. To reflect this, systems serving fewer than 10,000 people are assumed to have one aquifer, those serving between 10,000 and 50,000 people one and a half aquifers, for those serving between 50,000 and 100,000 people two aquifers, and for those serving at least 100,000 people three aquifers.

The full cost calculation and list of assumptions for monitoring are displayed in Appendix E-4.

## 5.6 Small System Impacts—Regulatory Flexibility Act Analysis

The Regulatory Flexibility Act provides that if a rule has a significant impact on a substantial number of small entities, its proposal must be accompanied by a Regulatory Flexibility Analysis (RFA) to be made available for public comment. Under current policy, EPA regards any impact as a significant impact and any number of small entities as a substantial number. Thus, a Regulatory Flexibility Analysis is clearly required for the Stage 1 DBPR. The Regulatory Flexibility Analysis can be incorporated within other analyses—as is the case here—so long as it is clearly stated how the requirements are being met. The specific RFA requirements are as follows.

*1. Explain why the Agency is considering taking action.*

Since most water is not pure enough to be ingested directly from the source, utilities usually apply some form of contaminant control. Disinfection is one important practice used to meet the public health goal of providing safe water to the public. Utilities disinfect drinking water supplies by adding chemicals to kill or inactivate microbial contaminants.

Disinfection, however, poses health risks of its own. Byproducts may result from chemical interactions between DBP precursors in water and chemical disinfectants in plants and distribution systems of public water systems. Source water often carries substantial levels of organic material that, when mixed with disinfectants, form new compounds. Some of these byproducts, including those that are the subject of this rule (TTHM and HAA5), are potentially associated with health risks, such as some cancers and reproductive and developmental effects.

However, because disinfection is effective in reducing microbial contamination, reducing disinfection to decrease DBPs can increase the risk to the public from microbial contamination. This is known as a "risk-risk tradeoff."

Due to the inconclusiveness of past scientific research and the "risk-risk tradeoff," the development of regulations is difficult. However, recent research results concerning the health risks associated with DBPs supports moving ahead with the development of the Stage 1 DBPR.

While recognizing these uncertainties, EPA believes, for the reasons cited below, that the Stage 1 DBPR is needed for protection of public health from exposure to DBPs.

1) There is a large population potentially exposed to DBPs in drinking water in the U.S.

2) Since the discovery of chlorination byproducts in drinking water in 1974, numerous toxicological studies have been conducted that have shown several DBPs to be carcinogenic in laboratory animals. Some DBPs have also been shown to cause reproductive or developmental effects in laboratory animals. While many of these studies have been conducted at high doses, EPA believes the studies provide evidence that DBPs present a potential public health problem that needs to be addressed.

3) Numerous epidemiology studies have been completed investigating the relationship between exposure to chlorinated drinking water and cancer. These studies have suggested an association, albeit small, between bladder, rectal, and colon cancer and exposure to chlorinated drinking water.

4) EPA recognizes there are data deficiencies in the information on the health effects from DBPs and the levels at which the health effects occur, but believes the weight-of-evidence represented by the available epidemiological and toxicological studies on DBPs support a potential hazard concern and warrant regulatory action at this time.

5) Because of the large number of people exposed to DBPs and because of the different risks that may result from exposure to DBPs, EPA believes the Stage 1 DBPR is needed to further prevent potential health effects from DBPs.

*2. State succinctly the objectives of, and legal basis for, the proposed rule.*

To address the complex issues associated with regulating DBPs, EPA launched a rule-making process in 1992 and convened a RegNeg Advisory Committee under the Federal Advisory Committee Act (FACA), representing a range of stakeholders affected by possible regulation. The RegNeg Committee met repeatedly over a period of 10 months and arrived at a consensus proposal for taking progressive steps toward addressing both DBPs and microbial pathogens. The 1992 consensus-building process resulted in the three following regulatory proposals—

1) A staged approach to regulation of DBPs (referred to as the Stage 1 and Stage 2 DBPRs) incorporating MCLs, MRLDs, and treatment technique requirements;

2) A companion IESWTR designed to improve control of microbial pathogens and prevent inadvertent reductions in microbial safety as a result of DBP control efforts, and;

3) An ICR to collect information necessary to reduce many key uncertainties prior to subsequent negotiations regarding the Stage 2 DBPR requirements.

In 1997, a similar FACA process was implemented with the Microbial-Disinfectants/Disinfection Byproducts (M-DBP) Advisory Committee. The M-DBP Committee convened to analyze new data available since 1994, review previous assumptions made during the RegNeg process, and move the rule forward on the expedited schedule mandated under the 1996 Amendments to the Safe Drinking Water Act (SDWA). The efforts of this committee resulted in the drafting of the Stage 1 DBPR.

The Stage 1 DBPR uses a combination of new MCLs, MRDLs, and a treatment technique requirement to improve control of disinfectants and DBPs. The rule applies to all utilities defined as community or non-transient/non-community systems that treat their water with a chemical disinfectant. (Community systems are public water systems that regularly serve at least 25 year-round residents; non-transient/non-community systems generally include businesses and similar fixed establishments.)

In the Stage 1 DBPR, EPA establishes MCLGs and MCLs for previously unregulated byproducts (except in the case of TTHMs). EPA is setting MCLGs of 0 for chloroform, bromodichloromethane, bromoform, bromate, and dichloroacetic acid, and MCLGs of 0.06 mg/L for dibromochloromethane, 0.3 mg/L for trichloracetic acid, and 0.8 mg/L for chlorite. In addition, EPA is setting MRDLGs for chlorine and chloramines at 4.0 mg/L and 0.8 mg/L for chlorine dioxide.

The Stage 1 DBPR sets a new, more restrictive MCL for TTHMs at 0.08 mg/L (80 $\mu$g/L). EPA is adding MCLs for HAA5 of 0.06 mg/L (60 $\mu$g/L), for bromate of 0.01 mg/L, and for chlorite of 1.0 mg/L. In

addition to these byproduct MCLs, EPA is setting MRDLs for chlorine and chloramines of 4.0 mg/L and 0.8 mg/L for chlorine dioxide.

EPA identifies several technologies that utilities can use to meet the MCLs and MRDLs. These include using alternate disinfectants, such as ozone, or alternative treatment practices, such as enhanced coagulation/enhanced softening or membrane filters.

3. *Describe, and where feasible, estimate the number of small entities to which the proposed rule will apply.*

Exhibit 5.8 summarizes the small entities that will be affected by the Stage 1 DBPR. All systems will be required to perform monitoring activities under the rule, though not all systems will have to modify their treatment techniques to comply with the MCLs and MRDLs. Of 5,165 small surface water systems, the majority, 70 percent, will have to modify their treatment techniques. Of 68,171 small ground water systems, 12 percent will have to modify their treatment techniques.

Most of these small systems required to modify treatment will use chloramines, a low-cost treatment technique, to treat their water, though a small portion, 4 percent, will have to treat using higher-cost membrane technology. While all systems will have to monitor under the rule, these costs generally tend to be lower than modifying treatment.

4. *Describe the projected reporting, recordkeeping, and other compliance requirements of the rule, including an estimate of the classes of small entities that will be subject to the requirements and the type of professional skills necessary for preparation of reports or records.*

As previously stated, all small systems will have to perform monitoring under the Stage 1 DBPR. Monitoring consists primarily of sampling water for precursors, DBPs, and residual chemicals from the disinfection process. Exhibit 5.9 summarizes the average sampling activities and the estimated burden for complying with the rule. While ground water systems have to take many more samples to monitor chlorine and chloramines, this sampling requires relatively little time compared to TTHM and HAA5 sampling. The analysis of water samples must be conducted at EPA-certified laboratories.

This information is displayed in greater detail in both Appendix E-4 and in the accompanying document, *Information Collection Request for the Stage 1 DBPR.*

## Exhibit 5.8
## Small Entities Affected by the Stage 1 DBPR

| System Size (population served) | Estimated Number of Systems to Modify Treatment and Monitor | Estimated Number of Systems to Monitor Only | Total Number of Systems |
|---|---|---|---|
| **Surface water systems** | | | |
| 25-100 | 732 | 314 | 1,046 |
| 100-500 | 707 | 303 | 1,010 |
| 500-1,000 | 592 | 254 | 845 |
| 1,000-3,300 | 772 | 331 | 1,103 |
| 3,300-10,000 | 813 | 348 | 1,161 |
| **Ground water systems** | | | |
| 25-100 | 3,721 | 26,755 | 30,476 |
| 100-500 | 2,800 | 20,134 | 22,934 |
| 500-1,000 | 795 | 5,713 | 6,508 |
| 1,000-3,300 | 718 | 5,164 | 5,882 |
| 3,000-10,000 | 290 | 2,081 | 2,371 |
| **Totals** | **11,940** | **61,397** | **73,336** |

## Exhibit 5.9
## Summary of Annual Monitoring Activities and Estimated Burden

| System Size (population served) | Estimated Number of Systems to Monitor | Total Estimated Annual Samples | Total Estimated Annual Burden (hours) |
|---|---|---|---|
| **Surface water systems** | | | |
| 25-100 | 1,046 | 37,200 | 19,000 |
| 100-500 | 1,010 | 36,800 | 18,600 |
| 500-1,000 | 845 | 35,800 | 18,900 |
| 1,000-3,300 | 1,103 | 46,800 | 24,700 |
| 3,300-10,000 | 1,161 | 49,200 | 26,000 |
| **Ground water systems** | | | |
| 25-100 | 30,476 | 247,200 | 71,700 |
| 100-500 | 22,934 | 250,600 | 64,700 |
| 500-1,000 | 6,508 | 76,900 | 19,300 |
| 1,000-3,300 | 5,882 | 152,800 | 31,300 |
| 3,000-10,000 | 2,371 | 150,300 | 27,400 |
| **Totals** | **73,336** | **1,083,600** | **321,600** |

5. *Identify, to the extent practicable, all relevant Federal rules that may duplicate, overlap, or conflict with the proposed rule.*

The IESWTR, promulgated concurrently with the Stage 1 DBPR, will further control for microbial contamination and prevent increases in microbial risk. These rules were developed *in tandem* since microbial contamination and disinfection are directly related. Both rules will be promulgated in November 1998.

The IESWTR is intended to improve control of pathogens such as *Cryptosporidium* as well as assure no significant increase in microbial risk as systems act to meet the new DBP MCLs under the Stage 1 DBPR. With the exception of a sanitary survey requirement that applies to all surface water systems, the IESWTR applies only to public drinking water systems using surface water or ground water under the direct influence of surface water (GWUDI) as a source, using rapid granulated filtration treatment technology, and serving 10,000 or more persons.

Major features of the rule include a new MCLG for *Cryptosporidium*, limitations on turbidity, a disinfection benchmark and, for all surface water systems or GWUDI systems, a sanitary survey requirement. In addition, the IESWTR adds *Cryptosporidium* to the definition of GWUDI and to watershed control requirements for unfiltered systems, as well as requiring that newly constructed finished water reservoirs be covered.

The discussion below summarizes the small system impact analysis, regulatory alternatives relevant to small systems, and impact mitigation measures considered in the RegNeg process.

### 5.6.1 Small System Impact Quantification

Throughout the rule development process, small systems were defined as those serving fewer than 10,000 people. This definition was used because there is an existing SDWA standard of 100 $\mu$g/L for TTHMs that applies only to systems serving more than 10,000 people. Surface and ground water systems serving fewer than 10,000 people are presently unregulated with respect to DBPs. There are, as a result, two different baseline conditions from which water systems will approach additional DBP control.

The major type of impact is the requirement to install and operate water treatment equipment to meet specific standards of quality in the delivered water. These requirements pertain primarily to systems that actually treat or disinfect their water. Systems that purchase treated water from another source may see an increase in their wholesale costs, but a data base sufficient to track all the wholesale treated water transactions in the country does not exist. Impacts are therefore evaluated in terms of the systems that treat water. The data with which to characterize the capacities and flows of these facilities does exist and provides an adequate basis for assessing total capital and operating costs.

It is estimated that there are a total of 76,051 community and non-transient non-community water systems that treat water. Of these, an estimated 73,336 (96 percent) serve fewer than 10,000 people. Despite their overwhelming dominance in terms of industry structure, these systems provide water to only 22 percent of the total population served by public water supplies.

The 73,336 small system universe consists of 68,171 small ground water systems and 5,165 small surface water systems. Ground water has historically been inexpensive to develop and has been of relatively good quality, requiring little treatment for microbial contaminants. This accounts, in part, for

the proliferation of small ground water systems across the country. Of particular note, most ground waters have much lower levels of TOC than surface waters and are, therefore, much less susceptible to DBP formation. Ironically, the lower levels of TOC make TOC removal with coagulation less cost-effective and may cause systems to have to resort to more expensive technologies of GAC and membranes if precursor removal is necessary.

### Impacts On Small Groundwater Systems

Of the total 68,171 small groundwater systems, it is estimated that 8,323 (12 percent) will have to modify treatment to comply with the Stage 1 DBPR. The TWG forecast that 5,403 (8 percent) systems will comply with the very inexpensive technology of chloramines while 2,921 (4 percent) systems will require more expensive membrane treatment systems. This will result in $998 million in total capital costs of treatment.

### Impacts On Small Surface Water Systems

Of the 5,165 small surface water systems, it is estimated that 3,616 (70 percent) will have to modify treatment to comply with the Stage 1 DBPR. The TWG forecast that 3,459 systems (67 percent of the total) will comply with cost-effective combinations of enhanced coagulation, chloramines, and ozone. Another 157 (3 percent) systems will require more expensive membrane treatment systems. This will result in $243 million in total capital costs of treatment.

System operators are assumed to project system upgrades using a least-cost algorithm, one in which technologies that provide similar levels of protection or compliance are evaluated on a cost basis, with selection biased towards the least expensive. Unit costs for ozone treatment, for example, exceed those for membranes in the smallest two size categories. These systems are expected to select membranes for treatment. Conversely, when ozone costs are more favorable than membranes, systems more heavily select ozone. The compliance forecast used to estimate costs incorporates this assumption.

The highest portion of small surface water system costs are projected in the largest small system size category (3,300-10,000 people served). This is due to several factors, including the large absolute number of systems in this category, the increased system flows, and high membrane costs. Most systems in this category using an advanced technology are assumed to use ozone, rather than install membranes.

## 5.6.2 System-Level Impacts on Cash Flow and Viability

Exhibits 5.7 and 5.8 present cash flow impact analyses of the major small system compliance scenarios described above disaggregated across several size categories of small water systems. The percentage increase in total operating expenses and the ratio of the increase in operating costs to net operating revenue are good measures of the impact of a regulation on the cash flow—and therefore on the economic viability—of a small entity.

There is no hard and fast rule, or threshold, for evaluating these indicators. The major benefit of these indicators is that they permit a display of the pattern of impacts involved in a regulatory compliance scenario. It is clear from these indicators that the impacts will be significant where the more expensive technologies are involved and where the systems are the smallest. It is equally clear that the pattern of impacts is very unequal; there are many small systems for which the impact of compliance under these scenarios will be comparatively small, due to better source water with fewer TOC precursors.

As stated previously, the impact of DBP regulation is inherently a function of unique, site-specific circumstances. The results in Exhibit 5.10 and 5.11, based on the 1996 Community Water Systems Survey, reflect this pattern. The Stage 1 DBPR will leave many small ground water systems untouched, will affect small surface water systems most intensely, and will produce a mixture of relatively low-cost and relatively high-cost outcomes among the small systems that will have to modify treatment in order to comply. The pattern of the impacts results from the raw water characteristics; there is no systematic aspect of the rule that singles out small systems as compliance targets.

On the surface, the more severe impacts on cash flow illustrated in the exhibits imply potential threats to the viability of these hardest-hit small water systems. The RFA typically uses such measures to assess the risk of small business failures resulting from regulatory proposals. In many economic sectors, the failure of a small business results in the closure of the business. In the drinking water arena, however, interpretation is not so straightforward. Most often, it is not acceptable to discontinue provision of water service to a community. The small system segment of the water industry is constantly undergoing restructuring activity wherein new ownership and institutional arrangements replace old ones. Currently there is an increased level of such restructuring activity and the projection is that this trend will continue. The trend results in part from SDWA compliance pressures. There is a wide range of interpretation regarding whether this trend is beneficial and promising or detrimental.

**Exhibit 5.10**
**Regulatory Flexibility Act Cash Flow Analysis for Small Surface Water Systems ($000)**

| Pop. per System | No. Systems | Total Revenue | Op. Exp. | Net Total Rev. | Total DBP Cost | Incr. DBP Cost | Post-DBP Op. Exp. | Post-DBP Net Rev. | Increase Op. Exp. (%) | DBP Cost as % Net Rev. |
|---|---|---|---|---|---|---|---|---|---|---|
| **Systems Complying by Cl2/NH2Cl, Enhanced Coagulation, Oz/NH2Cl, or Combination** | | | | | | | | | | |
| **25-100** | 663 | $10 | $15 | ($5) | $535 | $1 | $16 | ($6) | 5.5 | (19.4) |
| **101-500** | 650 | 120 | 57 | 63 | 1,260 | 2 | 59 | 61 | 3.4 | 3.1 |
| **500-1K** | 583 | 120 | 103 | 17 | 3,499 | 6 | 109 | 11 | 5.9 | 33.9 |
| **1K-3.3K** | 761 | 304 | 232 | 72 | 8,333 | 11 | 243 | 61 | 4.7 | 15.3 |
| **3.3K-10K** | 801 | 840 | 650 | 190 | 21,578 | 27 | 677 | 163 | 4.1 | 14.2 |
| **Systems Complying by Membranes** | | | | | | | | | | |
| **25-100** | 69 | $10 | $15 | ($5) | $475 | $7 | $22 | ($12) | 46.7 | (140.0) |
| **101-500** | 57 | 120 | 57 | 63 | 1,690 | 30 | 87 | 33 | 52.6 | 47.6 |
| **500-1K** | 8 | 120 | 103 | 17 | 885 | 111 | 214 | (94) | 107.8 | 652.9 |
| **1K-3.3K** | 11 | 304 | 232 | 72 | 2,418 | 220 | 452 | (148) | 94.8 | 305.5 |
| **3.3K-10K** | 12 | 840 | 650 | 190 | 5,182 | 432 | 1,082 | (242) | 66.5 | 66.5 |

## Exhibit 5.11
## Regulatory Flexibility Act Cash Flow Analysis for Small Ground Water Systems

| Pop. per System | No. Systems | Total Revenue | Op. Exp. | Net Total Rev. | Total DBP Cost | Incr. DBP Cost | Post-DBP Op. Exp. | Post-DBP Net Rev. | Increase Op. Exp. (%) | DBP Cost as % Net Rev. |
|---|---|---|---|---|---|---|---|---|---|---|
| **Systems Complying by Cl2/NH2Cl, Enhanced Coagulation, Oz/NH2Cl, or Combination** | | | | | | | | | | |
| **25-100** | 2,415 | $22 | $2 | $20 | $3,552 | $1 | $3 | $19 | 50.0 | 5.0 |
| **101-500** | 1,818 | 57 | 26 | 31 | 3,027 | 2 | 28 | 29 | 7.7 | 6.5 |
| **500-1K** | 516 | 84 | 72 | 12 | 1,043 | 2 | 74 | 10 | 2.8 | 16.7 |
| **1K-3.3K** | 466 | 194 | 170 | 24 | 1,105 | 2 | 172 | 22 | 1.2 | 8.3 |
| **3.3K-10K** | 188 | 617 | 509 | 108 | 1,453 | 8 | 517 | 100 | 1.6 | 7.4 |
| **Systems Complying by Membranes** | | | | | | | | | | |
| **25-100** | 1,306 | $22 | $2 | $20 | $8,989 | $7 | $9 | $13 | 350.0 | 35.0 |
| **101-500** | 983 | 57 | 26 | 31 | 29,361 | 30 | 56 | 1 | 115.4 | 96.8 |
| **500-1K** | 279 | 84 | 72 | 12 | 29,200 | 105 | 177 | (93) | 145.8 | 875.0 |
| **1K-3.3K** | 252 | 194 | 170 | 24 | 55,240 | 219 | 389 | (195) | 128.8 | 912.5 |
| **3.3K-10K** | 102 | 617 | 509 | 108 | 45,341 | 445 | 954 | (337) | 87.4 | 412.0 |

The issue of regulatory impacts as a contributor to restructuring trends was considered in evaluating small system impacts. A preliminary issue discussed by the TWG concerned the fact that the cost forecasts are based upon the assumption that small systems facing a regulatory requirement to install expensive treatments have no choice but to do so. This ignores the role of prospective compliance costs as incentives that may promote alternative choices by water systems and market responses by equipment and service providers.

Faced with extreme costs, many small systems may elect to connect to a another water system nearby. Half of all small water systems are located within metropolitan regions where distances between water systems may not present a prohibitive barrier, given the cost of the alternative. Small systems driven to consolidation as a result of these regulations will do so primarily because it is their least-cost approach to compliance. The impact estimates that assume comprehensive installation of treatment equipment on a small scale may also be an overestimate of the actual impact.

The prospective expenditures for DBP control are of such magnitude that a market response from manufacturers and service providers seems likely. Increased demand for O&M services could create broader markets for contract O&M services and allow for these services to deliver at lower cost. Although least-cost optimization by water systems and cost-reducing market adaptations by suppliers may place downward pressures on costs, the cost estimates need to first be developed without dilution by cost-minimizing assumptions in order to give the correct signal to trigger these very reactions at the start. These trends and market forecasts are, therefore, not included in the cost estimates.

There are differing views regarding induced restructuring of small systems. On one hand, there are thousands of small water systems that are, by the usual financial measures, very viable enterprises under current circumstances. These systems would be forced to entertain notions of consolidation or other forms of restructuring only as a result of regulations. Small system advocates note correctly that all of the above impact analysis considers the impact of only one set of regulations on these small entities, whereas the total force behind small system failure and/or restructuring is a result of the cumulative impact of all SDWA regulations. Notably, the most significantly affected category of systems—those treating surface water—are presently faced with the impacts of the Surface Water Treatment Rule and will have to also face the impacts of an Interim Enhanced Surface Water Treatment Rule. These impacts are not included in the exhibits.

Conversely, it is also true that there are thousands of small water systems that are persistent violators of current drinking water standards—accounting for 90 percent of all violations, including violations of fundamental protective requirements such as the coliform standard. These persistent violations may, in effect, indicate that business failure has already occurred in these systems in terms of performance. Experience shows that when financial data are available for such systems, they confirm that compliance default and financial default are correlated.

Public health officials have long been concerned about the ability of small systems to adequately treat surface water. Increased knowledge of microbial risks and recent experiences with outbreaks of waterborne disease have strengthened these convictions. That some small surface water systems are likely candidates for restructuring and likely to show significant impacts from DBP regulation is not a surprise. It is a manifestation of a larger trend stemming from new understandings in this area of public health protection.

Considering this broader context, the assessment of the net effects of SDWA-induced restructuring enters a grey area. Some of this restructuring activity must be attributed to an inevitable baseline change in the business environment of the industry. The change happens to involve water quality issues that are the subject of regulation. Because regulation is imperfect, there is some potential to force more than an optimal level of restructuring through over-regulation, but it is not clear where that line should be drawn. In addition, it is possible to make regulatory decisions that are underprotective, in which case the costs are borne in terms of health effects. The level that is optimal, or most cost-effective, for the nation as a whole may not be optimal for all systems affected, especially when there are broad differences in costs resulting from differences in the scale of operations. A potential solution to this paradox is to consider the alternative of having different standards of protection for large systems versus small systems. This option was proposed and considered in the RegNeg deliberations, as described in the next section.

### 5.6.3 Small System Regulatory Alternatives

One of several participants in the RegNeg process representing the interests of small water systems disagreed with the consensus proposal that had been developed for the Stage 1 DBPR and subsequently withdrew. The issues that led to the withdrawal were manifest in the discussion of several regulatory alternatives. Three alternatives were involved.

- Option 1: TTHM standard of 100 $\mu$g/L for systems serving fewer than 10,000 people; and TTHM standard of 80 $\mu$g/L and HAA5 standard of 60 $\mu$g/L for systems serving more than 10,000 people.

- 80/60/4 Opt.: TTHM and HAA5 standards of 80 $\mu$g/L and 60 $\mu$g/L with an additional standard of 4.0 mg/L for TOC; applicable to all water systems.

- Final Rule: TTHM and HAA5 standards of 80 $\mu$g/L and 60 $\mu$g/L coupled with a treatment technique requirement mandating enhanced coagulation in systems with influent TOC greater than 2.0 mg/L.

The essence of the Stage 1 DBPR is to apply the most inexpensive form of TOC removal—enhanced coagulation—to a large segment of surface water systems, yielding virtually the same exposure profiles as if the more expensive technologies were applied to a smaller segment of the surface water universe at the extreme end of the spectrum of water quality conditions. The rule is much more cost-effective due to reliance on the less-expensive technology and also because it considers a combination of technologies (EPA, 1994).

The difference in the cost estimates for the different options results, in part, from the cost-effectiveness of the treatment technique approach and also from methodological changes that consider combinations of technologies.

There were several other issues discussed concerning this option as an alternative to the Stage 1 DBPR. These are briefly summarized as follows.

- There was some support for a TTHM standard of 100 $\mu$g/L for small systems as a reasonable first step. This will enable small systems to draw on the experience of larger systems in meeting this level. Going to lower levels of TTHMs, extending regulation to haloacetic acids, and introducing TOC removal were seen as steps into more foreign territory. On this basis, a TTHM standard of 100 $\mu$g/L for small systems was supported by some as a better interim step.

- The argument favoring the rule as proposed over the alternate proposal discussed above consisted of at least three points: 1) that cost impacts would not be significantly different, as outlined above; 2) that the experience with the current TTHM MCL of 100 $\mu$g/L suggests that a head-long rush to chloramines and possible compromising of microbial protection could result from simple extension of this standard to small systems; and, 3) that since a best available technologies concept that begins with TOC removal through enhanced coagulation is the direction in which the later regulations may be headed, it might be a waste of small system resources to structure Stage 1 in a manner that encourages them to select different and potentially incompatible control strategies.

- There was some discussion of the issue of creating a double standard of public health protection by having a less stringent standard for small systems. Some small system negotiators made the point that unaffordable regulations that push small systems into non-compliance also result in a double standard of public health protection. However, the alternative of a small system TTHM MCL of 100 $\mu$g/L was considered only in the context of an interim Stage 1 DBPR target.

In summary, the debate over the Stage 1 DBPR covered two of the important categories of alternatives to be considered in an RFA: performance versus design standards, and relaxed standards for small entities. In traditional effluent-oriented, or externality-oriented, areas of environmental economics, performance standards are often more economically efficient than design standards, and relaxed standards for small

entities may be economically justifiable. In this application to protection of drinking water supplies, all the reverse conclusions hold.

The treatment technique approach is shown to be more cost-effective than the MCL approach for TOC removal. Moreover, an MCL approach to byproduct control could trigger compliance choices that might have to be reversed by subsequent regulations.

### 5.6.4 Small System Impact Mitigation

Two major strategies for mitigation of impacts on small systems were considered by the RegNeg Committee: 1) extended timetables for compliance, and 2) variances and exemptions. These are discussed in this section.

#### Extended Compliance Timetable

The Stage 1 DBPR incorporates an extended timetable for small system compliance. While the compliance date of the rule requirements for large surface water systems is in 2001, compliance by small surface water systems is not required until 2003. The compliance date for all ground water systems is 2003. The extended timeframe for smaller systems to achieve compliance is to allow for simultaneous compliance with the Long Term 1 Enhanced Surface Water Treatment Rule (LT1) and the Ground Water Disinfection Rule and their associated compliance deadlines. Additionally, it allows small systems to wait for the capital improvements that will come from implementation in large systems and a lower cost of implementation given a competitive market for the technologies used.

#### Variances and Exemptions

There was extensive discussion of the prospects for small system relief through exercise of the variance and exemption provisions of the SDWA.

## 5.7 Combined Effect of the Stage 1 DBPR and the IESWTR

Because the Stage 1 DBPR and IESWTR were developed *in tandem* to address the risks of DBPs while not compromising protection against microbial contaminants, it is important to examine the combined effects of both rules as well as those expected to be implemented in the next several years.

While the IESWTR may impose additional costs to large surface water systems beyond those described in this chapter for the Stage 1 DBPR, these systems may see greater benefits as well. The anticipated impact of both rules at a 7 percent cost of capital is summarized in Exhibit 5.12.

## Exhibit 5.12
## Cost Impact of Current and Expected Rule-Makings

| System Types | Current and Expected Rules | | |
|---|---|---|---|
| | D/DBP Stage 1 ($000) | Interim ESWT ($000) | Other Rule-makings Planned |
| Small Surface Water | $ 56,804 | $ 0 | Stage 2 DBPR<br>Long-term ESWTR 1 (LT1) |
| Large Surface Water | 278,321 | 291,165 | Stage 2 DBPR<br>Long-term ESWT 2 (LT2) |
| Small Ground Water | 218,062 | 0 | Stage 2 DBPR<br>Ground Water Disinfection |
| Large Ground Water | 130,651 | 0 | Stage 2 DBPR<br>Ground Water Disinfection |
| ***Subtotal*** | **$ 683,838** | **$ 291,165** | ..... |
| States | 17,342 | 15,556 | ..... |
| ***Totals*** | **$ 701,180** | **$ 306,721** | ..... |

# 6: Assessing Net Benefits of the Stage 1 DBPR

## 6.1 Alternative Approaches for Assessing Benefits of the Stage 1 DBPR

In light of the scientific uncertainties surrounding the risk estimates and limited data availability, EPA explored several alternative approaches to assessing the net benefits of the Stage 1 DBPR:

- Overlap of Benefit and Cost Estimates;
- Minimizing Total Social Losses;
- Breakeven Analysis;
- Household Costs; and
- Decision-Analytic Model.

## 6.2 Overlap of Benefit and Cost Estimates

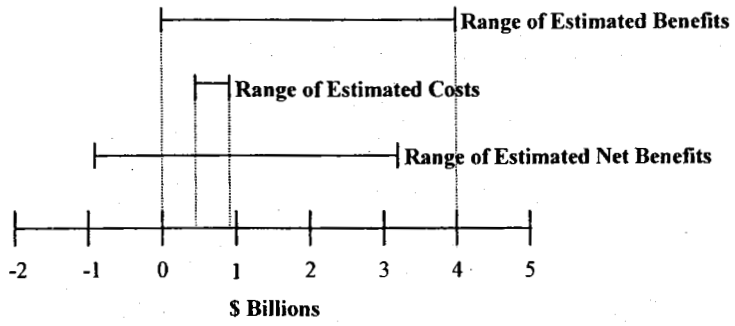
One method to characterize net benefits is to compare the relative ranges of benefits and costs. Conceptually, an overlap analysis tests whether there is enough of an overlap between the range of benefits and the range of costs for there to be a reasonable likelihood that benefits will exceed costs. In a theoretical case where the high end of the range of benefits estimates does not overlap the low end of the range of cost estimates, a rule would be difficult to justify based on traditional benefit/cost rationale (although it may be based on law).

For the Stage 1 DBPR, the two overlap analyses show that there is substantial overlap in the estimates of benefits and costs (Exhibit 6.1a and 6.1b). The exhibits portray the range of quantified benefits extending from zero to over $4 billion.[1] The zero end of the range of estimated benefits represents the possibility that there is essentially no health benefit from reducing exposure to DBPs. The $4 billion end of the range assumes a 24 percent reduction in the incidence of 9,300 annual bladder cancer cases attributable to DBPs. The high end of the benefits range could potentially exceed $4 billion by a large amount if the non-quantified benefits are included.

[1] Refer to Section 4.11.

**Exhibit 6.1a Conceptual Overlap of the Estimated Benefits and Costs of the Stage 1 DBPR**


**Exhibit 6.1b Overlap of the Ranges of the Estimated Benefits and Costs of the Stage 1 DBPR**




The range of cost estimates is significantly smaller, ranging from $500 million to $900 million annually (based on the central tendency estimate plus or minus the standard deviation). Although cost estimates have uncertainty, this degree of uncertainty is of little consequence to the decisions being made given the scale of the uncertainty in the benefits.

### Interpreting the Results

The overlap analysis shows that there is substantial basis for the Stage 1 DBPR. Benefits exceed the costs over a wide range of the possible estimates of each. More detail on the nature of this overlap is provided in the Breakeven Analysis later in this chapter.

## 6.3 Minimizing Total Social Losses Analysis

Minimizing Total Social Losses analysis, sometimes called "minimizing regrets" analysis, is a decision-aiding tool that is suited for use in situations where it is impossible to pin down the exact nature and extent of a risk. The basic premise of Minimizing Total Social Losses analysis is to estimate total social costs for policy alternatives over a range of plausible risk scenarios. The actual, or "true" risk is unknowable, so instead this analysis asks what range and level of risks could be true, and then evaluates the total costs to society if that particular risk turns out to be the "true" value. Total social costs include both the cost to implement the policy option, plus costs related to residual (i.e., remaining) health damages at that risk level after implementation of the policy option.

The decision-maker compares the total costs of the policy alternatives for each potential risk scenario. The policy alternative with the lowest total costs within a risk scenario represents the "minimal loss" alternative for that scenario. That is, if that risk scenario turns out to be true, the decision-maker has made the right decision, the one that minimizes costs. If the decision-maker has chosen one of the other policy options and that risk scenario turns out to be true, you have incurred "losses" in the form of the social costs higher than the lowest-cost alternative. These potential losses are calculated for a range of potential risk scenarios. The decision-maker can then evaluate the policy options based on the potential losses if he or she guesses wrong, trying to avoid the greatest potential losses across the range of risk scenarios.

The following discussion defines the steps in developing a minimizing social losses analysis for the Stage 1 DBPR.

***Step 1: Define the policy options to be considered***

The Regulatory Negotiation (RegNeg) Committee considered a range of alternatives as described in Chapter 3, before settling on a staged-rule approach. For the purposes of this analysis, the No Action (i.e., leaving the current DBP regulatory requirements as they are) is compared against the Stage 1 DBPR alternative and a stronger policy intervention option as represented by the RegNeg placeholder provisions for the Stage 2 DBPR.

***Step 2: Define the range of plausible risk scenarios to evaluate***

Based on the toxicological data, 1 to 100 cancer cases attributable to DBPs was chosen as the low end of the plausible risk range with 10,000 cases (based on the meta-analysis and PAR analysis) as the high end of the plausible risk range. To illustrate break points and trends within the 1 to 10,000 range, intermediate points of 1,000, 2,500, 5,000, and 7,500 cancer cases are also calculated.

***Step 3: Define Implementation Costs of Stage 1 DBPR for policy alternatives***

In the case of the No Action alternative, the total implementation costs of the Stage 1 DBPR are $0. The revised costs described in Chapter 5 are used as the total implementation costs for Stage 1 ($701.18 million annual cost). The implementation cost estimates for the stronger intervention alternative have not been revised since the 1994 RIA. For the purposes of this analysis, the Stage 2 placeholder costs from the 1994 RIA have been updated to a 1998 price level to $2.892 billion and are used as an estimate for the stronger intervention option (EPA, 1994). These estimates are used in Exhibit 6.2.

*Step 4: Estimate Residual Health Damages*

The residual health damages are the number of cancer cases remaining after the implementation of each action. After the implementation of the "No Action" alternative, obviously all of the potential cancer cases remain. The cancer cases are expected to be reduced, however, by implementation of the Stage 1 DBPR and the stronger intervention alternative. The mean reduction in DBPs (as estimated using data for TTHMs as a proxy for all DBPs) estimated in the exposure reduction analysis (see Appendix G) is 24 percent for Stage 1 and 40 percent for Stage 2 (see Appendix G-4). Exhibits 6.3a, 6.3b, and 6.3c contain the estimated residual number of cancer cases for each risk scenario and alternative action.

*Step 5: Monetize Residual Health Damages*

Health costs associated with the residual cancer cases then need to be calculated. Based on current fatality rates, it is assumed that 77 percent of bladder cancer cases are nonfatal, valued at the willingness-to-pay (WTP) to avoid a cancer case, and 23 percent of the cases result in fatality, valued at the value per statistical life (VSL).

## Exhibit 6.2
## Stage 1 DBPR Minimizing Total Social Costs Analysis
**(Billions of Dollars, 1998 Price Level)**

| | Risk Scenarios | | | | | | |
|---|---|---|---|---|---|---|---|
| | <1 Cancer Case | 100 Cancer Cases | 1,000 Cancer Cases | 2,500 Cancer Cases | 5,000 Cancer Cases | 7,500 Cancer Cases | 10,000 Cancer Cases |
| **No Action** | | | | | | | |
| Cost of DBP Rule Option | $ 0 | $ 0 | $ 0 | $ 0 | $ 0 | $ 0 | $ 0 |
| Residual Health Costs [1] | $ 0 | $ 0.176 | $ 1.755 | $ 4.388 | $ 8.776 | $ 13.164 | $ 17.552 |
| Total Social Costs | $ 0 | $ 0.176 | $ 1.755 | $ 4.388 | $ 8.776 | $ 13.164 | $ 17.552 |
| ***Excess Social Losses*** | ***$ 0*** | ***$ 0*** | ***$ 0*** | ***$ 0.352*** | ***$ 1.405*** | ***$ 2.458*** | ***$ 4.129*** |
| **Stage 1** | | | | | | | |
| Cost of DBP Rule Option | $ 0.701 | $ 0.701 | $ 0.701 | $ 0.701 | $ 0.701 | $ 0.701 | $ 0.701 |
| Residual Health Costs [1, 2] | $ 0 | $ 0.131 | $ 1.335 | $ 3.335 | $ 6.670 | $ 10.005 | $ 13.340 |
| Total Social Costs | $ 0.701 | $ 0.832 | $ 2.036 | $ 4.036 | $ 7.371 | $ 10.706 | $ 14.041 |
| ***Excess Social Losses*** | ***$ 0.701*** | ***$ 0.656*** | ***$ 0.281*** | ***$ 0*** | ***$ 0*** | ***$ 0*** | ***$ 0.617*** |
| **Strong Intervention (RegNeg Stage 2 Placeholder)** | | | | | | | |
| Cost of DBP Rule Option | $ 2.892 | $ 2.892 | $ 2.892 | $ 2.892 | $ 2.892 | $ 2.892 | $ 2.892 |
| Residual Health Costs [1, 3] | $ 0 | $ 0.106 | $ 1.053 | $ 2.633 | $ 5.266 | $ 7.899 | $ 10.531 |
| Total Social Costs | $ 2.892 | $ 2.998 | $ 3.945 | $ 5.525 | $ 8.158 | $ 10.791 | $ 13.423 |
| ***Excess Social Losses*** | ***$ 2.892*** | ***$ 2.823*** | ***$ 2.190*** | ***$ 1.489*** | ***$ 0.787*** | ***$ 0.085*** | ***$ 0*** |

[1] Mean values from Monte Carlo Simulation

[2] Assumes 24 percent reduction in exposure (see Appendix G)

[3] Assumes 40 percent reduction in exposure (see Appendix G)

**Gray border represents least total social cost alternative if that risk scenario proves to be true.**

## Exhibit 6.3a
## Residual Damages Monte Carlo Simulation Summary: No Action Scenario
## (Billions of Dollars)

| | Calculation | Baseline Cancer Cases | | | | | |
|---|---|---|---|---|---|---|---|
| **No Action** | A | 100 | 1,000 | 2,500 | 5,000 | 7,500 | 10,000 |
| **Percent Reduction** | B | 0% | 0% | 0% | 0% | 0% | 0% |
| **Total Cancer Cases Avoided** | C = (A x B) | 0 | 0 | 0 | 0 | 0 | 0 |
| **Number of Fatal Residual Cancer Cases** | D = ((A - C) x 23%) | 23 | 230 | 575 | 1,150 | 1,725 | 2,300 |
| **Number of Nonfatal Residual Cancer Cases** | E = ((A - C) x 77%) | 77 | 770 | 1,925 | 3,850 | 5,775 | 7,700 |
| **Total Cases** | F = (D + E) | 100 | 1,000 | 2,500 | 5,000 | 7,500 | 10,000 |
| **Mean Dollar Damages from Fatal Residual Cancer Cases** | G = D x lognormal dist., mean $0.5600 bil. | $ 0.130 | $ 1.302 | $ 3.254 | $ 6.508 | $ 9.762 | $ 13.016 |
| **Mean Dollar Damages from Nonfatal Residual Cancer Cases** | H = E x dist., median $0.0006 bil. | $ 0.045 | $ 0.454 | $ 1.134 | $ 2.268 | $ 3.402 | $ 4.536 |
| **Total Dollars** | I = G Dist. + H Dist. | $ 0.176 | $ 1.755 | $ 4.388 | $ 8.776 | $ 13.164 | $ 17.552 |

NOTE: Mean values resulting from the Monte Carlo simulation may not precisely match mathematically derived values.

## Exhibit 6.3b
## Residual Damages Monte Carlo Simulation Summary: Stage 1 DBPR
## (Billions of Dollars)

| | Calculation | Baseline Cancer Cases | | | | | |
|---|---|---|---|---|---|---|---|
| **No Action** | A | 100 | 1,000 | 2,500 | 5,000 | 7,500 | 10,000 |
| **Percent Reduction** | B | 24% | 24% | 24% | 24% | 24% | 24% |
| **Total Cancer Cases Avoided** | C = (A x B) | 24 | 240 | 600 | 1,200 | 1,800 | 2,400 |
| **Number of Fatal Residual Cancer Cases** | D = ((A - C) x 23%) | 17 | 175 | 437 | 874 | 1,311 | 1,748 |
| **Number of Nonfatal Residual Cancer Cases** | E = ((A - C) x 77%) | 59 | 585 | 1,463 | 2,926 | 4,839 | 5,852 |
| **Total Cases** | F = (D + E) | 76 | 760 | 1,900 | 3,800 | 5,700 | 7,600 |
| **Mean Dollar Damages from Fatal Residual Cancer Cases** | G = D x lognormal dist., mean $0.5600 bil. | $ 0.096 | $ 0.990 | $ 2.473 | $ 4.946 | $ 7.419 | $ 9.892 |
| **Mean Dollar Damages from Nonfatal Residual Cancer Cases** | H = E x dist., median $0.0006 bil. | $ 0.035 | $ 0.345 | $ 0.862 | $ 1.724 | $ 2.585 | $ 3.447 |
| **Total Dollars** | I = G Dist. + H Dist. | $ 0.131 | $ 1.335 | $ 3.335 | $ 6.670 | $ 10.005 | $ 13.340 |

NOTE: Mean values resulting from the Monte Carlo simulation may not precisely match mathematically derived values.

## Exhibit 6.3c
## Residual Damages Monte Carlo Simulation Summary: Strong Intervention
## (Billions of Dollars)

| | Calculation | Baseline Cancer Cases | | | | | |
|---|---|---|---|---|---|---|---|
| **No Action** | **A** | 2,500 | 1,000 | 2,500 | 5,000 | 7,500 | 10,000 |
| **Percent Reduction** | **B** | 40% | 40% | 40% | 40% | 40% | 40% |
| **Total Cancer Cases Avoided** | **C** = (A x B) | 40 | 400 | 1,000 | 2,000 | 3,000 | 4,000 |
| **Number of Fatal Residual Cancer Cases** | **D** = ((A - C) x 23%) | 14 | 138 | 345 | 690 | 1,035 | 1,380 |
| **Number of Nonfatal Residual Cancer Cases** | **E** = ((A - C) x 77%) | 46 | 462 | 1,155 | 2,310 | 3,465 | 4,620 |
| **Total Cases** | **F** = (D + E) | 60 | 600 | 1,500 | 3,000 | 4,500 | 6,000 |
| **Mean Dollar Damages from Fatal Residual Cancer Cases** | **G** = D x lognormal dist., mean $0.5600 bil. | $ 0.079 | $ 0.781 | $ 1.952 | $ 3.905 | $ 5.857 | $ 7.810 |
| **Mean Dollar Damages from Nonfatal Residual Cancer Cases** | **H** = E x dist., median $0.0006 bil. | $ 0.027 | $ 0.272 | $ 0.680 | $ 1.361 | $ 2.041 | $ 2.722 |
| **Total Dollars** | **I** = G Dist. + H Dist. | $ 0.106 | $ 1.053 | $ 2.633 | $ 5.266 | $ 7.899 | $ 10.531 |

NOTE: Mean values resulting from the Monte Carlo simulation may not precisely match mathematically derived values.

Cancer cases that end in fatality are valued at a VSL estimate derived from previous EPA efforts. The result is a distribution of values represented by a lognormal distribution with a mean of $5.6 million and standard deviation of $3.16 million (updated to current price level). Nonfatal cancer cases can be valued as the WTP to avoid a nonfatal case of bladder cancer or the less complete concept of the cost of the illness (COI—treatment costs and lost productivity). A WTP value specifically for avoiding a case of bladder cancer was not available in the current literature. As a substitute, a distribution of WTP values derived from a study of chronic bronchitis is used in this analysis (mean value of $587,500 per nonfatal case). Please refer to Section 4.10 and Appendix H for a complete explanation of the derivation of the monetary values for the health endpoints.

The monetary values of the residual health damages are calculated using a Monte Carlo simulation drawing from the distributions for the VSL and WTP to avoid nonfatal bladder cancer. The resulting mean values of the simulation can be found in Exhibits 6.3a, 6.3b, and 6.3c. Appendix I contains the full results of the Monte Carlo simulation.

### *Step 6: Calculate Total Social Costs*

The total social costs for each alternative and plausible risk scenario are calculated by adding the cost of the rule option and the residual health costs and are presented in Exhibit 6.2 (page 6-4).

*Step 7: Determine least-cost alternative and social losses*

Looking down each column in Exhibit 6.2, the policy option (i.e., row) with the lowest total social costs in that column is the "least-cost" option. In other words, if the risk estimate for that column turns out to be the "true" risk, the option with the lowest total social costs is the "right" choice (i.e., the one that minimizes costs). Each of the other two policy options incur excess costs, referred to as social losses. To calculate the social loss associated with a given policy option, simply subtract the cost of the least-cost option from the cost of the other option.

In Exhibit 6.1, the least cost option for each risk scenario is indicated by the grey border. Taking the example of 5,000 cancer cases, the least cost option at $7.371 billion total social costs is the Stage 1 DBPR. If the number of cancer cases attributable to DBPs turns out to be 5,000 per year, then choosing the Stage 1 DBPR option is the correct choice, the one that minimizes costs to society. Choosing the No Action alternative results in social losses of $1.405 billion ($8.776-$7.371) and choosing the Strong Intervention results in social losses of $0.787 billion ($8.158-$7.371).

### Interpreting the Results

If there were perfect information on which risk scenario is closest to the "true risk" attributable to DBPs, the choice of options would be easily apparent from Exhibit 6.2. Even if there were information that allowed the assigning of probabilities to each risk scenario, a calculation of expected values could identify the least-cost option based on the probability that each risk scenario might be true. In the case of cancer and DBPs in drinking water, the state of the science does not currently allow conclusively choosing a risk scenario (column) or accurately assigning probabilities. Fortunately, further analysis can help identify preferences among the policy options (rows).

### Minimizing Maximum Losses

When it is impossible to narrow the range of plausible risks, decision theory suggests using an approach that minimizes the maximum loss (Hillier and Lieberman, 1990). In plain English, the option that cuts losses and minimizes downside risk should be preferred. To do this, a look across the rows in Exhibit 6.4 identifies the value of the largest potential social loss in that row. For the No Action alternative, the largest potential loss is at the 10,000 cancer case risk scenario ($4.129 billion). For the Stage 1 alternative, the largest potential loss is at the less than 1 cancer case risk level ($0.701 billion). For Strong Intervention, the largest loss is also at the less than 1 cancer case level ($2.892 billion).

With the Stage 1 DBPR option, the largest possible loss is $0.701 billion, but the largest possible loss is over 4 times as much with Strong Intervention ($3 billion) and almost 6 times as much with No Action ($4 billion). In light of the scientific uncertainty regarding risk, choosing Stage 1 minimizes the maximum loss.

The 1994 RegNeg and 1997 M-DBP Committees implicitly applied this type of "minimizing maximum loss" framework when developing and evaluating the DBP regulatory options. The RegNeg and M-DBP Committees recognized that they could not narrow the potential range of cancer risk (1 to 10,000 cases) or develop a central tendency for the risk. Instead, they developed a regulatory option (Stage 1) that minimizes the maximum potential loss across the range of risks.

## Exhibit 6.4
## Stage 1 DBPR Minimizing Maximum Loss Analysis
**(Billions of Dollars, 1998 Price Level)**

| | Risk Scenarios | | | | | | |
|---|---|---|---|---|---|---|---|
| | <1 Cancer Case | 100 Cancer Cases | 1,000 Cancer Cases | 2,500 Cancer Cases | 5,000 Cancer Cases | 7,500 Cancer Cases | 10,000 Cancer Cases |
| **No Action** | | | | | | | |
| Cost of DBP Rule Option | $ 0 | $ 0 | $ 0 | $ 0 | $ 0 | $ 0 | $ 0 |
| Residual Health Costs [1] | $ 0 | $ 0.176 | $ 1.755 | $ 4.388 | $ 8.776 | $ 13.164 | $ 17.552 |
| Total Social Costs | $ 0 | $ 0.176 | $ 1.755 | $ 4.388 | $ 8.776 | $ 13.164 | $ 17.552 |
| ***Excess Social Losses*** | ***$ 0*** | ***$ 0*** | ***$ 0*** | ***$ 0.352*** | ***$ 1.405*** | ***$ 2.458*** | ***$ 4.129*** |
| **Stage 1** | | | | | | | |
| Cost of DBP Rule Option | $ 0.701 | $ 0.701 | $ 0.701 | $ 0.701 | $ 0.701 | $ 0.701 | $ 0.701 |
| Residual Health Costs [1, 2] | $ 0 | $ 0.131 | $ 1.335 | $ 3.335 | $ 6.670 | $ 10.005 | $ 13.340 |
| Total Social Costs | $ 0.701 | $ 0.832 | $ 2.036 | $ 4.036 | $ 7.371 | $ 10.706 | $ 14.041 |
| ***Excess Social Losses*** | ***$ 0.701*** | ***$ 0.656*** | ***$ 0.281*** | ***$ 0*** | ***$ 0*** | ***$ 0*** | ***$ 0.617*** |
| **Strong Intervention (RegNeg Stage 2 Placeholder)** | | | | | | | |
| Cost of DBP Rule Option | $ 2.892 | $ 2.892 | $ 2.892 | $ 2.892 | $ 2.892 | $ 2.892 | $ 2.892 |
| Residual Health Costs [1, 3] | $ 0 | $ 0.106 | $ 1.053 | $ 2.633 | $ 5.266 | $ 7.899 | $ 10.531 |
| Total Social Costs | $ 2.892 | $ 2.998 | $ 3.945 | $ 5.525 | $ 8.158 | $ 10.791 | $ 13.423 |
| ***Excess Social Losses*** | ***$ 2.892*** | ***$ 2.823*** | ***$ 2.190*** | ***$ 1.489*** | ***$ 0.787*** | ***$ 0.085*** | ***$ 0*** |

[1] Mean values from Monte Carlo Simulation

[2] Assumes 24 percent reduction in exposure (see Appendix G)

[3] Assumes 40 percent reduction in exposure (see Appendix G)

**Gray border represents maximum excess social loss for each alternative action (row).**

**STAGE 1 MINIMIZES THE MAXIMUM EXCESS SOCIAL LOSS.**

## 6.4 Breakeven Analysis

Breakeven analysis represents another approach to assessing the benefits of the Stage 1 DBPR given the scientific uncertainties. Breakeven is a standard benchmark of cost effectiveness and economic efficiency and is essentially the point where the benefits of the Stage 1 DBPR are equal to the costs. Normally, the benefits and costs of an option are calculated separately and then compared to assess whether and by what amount benefits exceed costs. In the case of the Stage 1 DBPR, independently estimating benefits is difficult, if not impossible, because of the 10,000-fold uncertainty surrounding the risk. Instead, the breakeven analysis works backwards from those variables that are less uncertain. In this case, implementation costs for the rule and the monetary value associated with the health endpoints are used to calculate what baseline risk and risk reduction estimates are needed for the rule to just pay for itself in avoided health damages associated with bladder cancer.

The first step in the breakeven analysis is to calculate the number of bladder cancer cases that would need to be avoided for the benefits of avoiding those cases to be equal to the cost of the rule. The simple calculation is to divide the annual costs of the rule ($701.18 million) by the value per cancer case to derive the number of cancer cases needed to cover the costs of the rule. The value of a cancer case differs based on whether the cancer case ends in fatality. Fatal cancer cases are valued at the VSL with a mean of $5.6 million and a standard deviation of $3.16 million, as mentioned earlier and described in depth in Appendix H. It is assumed that 23 percent of all bladder cancer cases are fatal and are, therefore, assigned the VSL.

For the nonfatal bladder cancer cases, comprising 77 percent of the total, two alternative methods for determining the value are used to calculate the breakeven point. The first, described in a previous section, uses a value from a study that estimates the WTP to avoid a case of chronic bronchitis as a substitute for the WTP to prevent a nonfatal case of bladder cancer (a distribution with a mean value of $587,500). The second method estimates the COI for a nonfatal cancer case, including treatment costs and lost productivity. The COI, estimated at $121,000, is an incomplete measure because it does not include the value for pain and suffering or risk aversion, but involves less uncertainty because it is derived directly from the costs of medical care. Appendix H contains a more detailed discussion of the derivation of the WTP and COI estimates for nonfatal bladder cancer.

A Monte Carlo simulation was used to develop a distribution of the number of cancer cases avoided necessary to breakeven. Results can be found in Appendix J.

At the median, using the WTP value and a cost of capital rate of 7 percent, the Stage 1 DBPR would need to avoid 438 bladder cancer cases per year to break even, of which 101 are assumed to be fatal and 337 are nonfatal (Exhibit 6.5). Using the COI value, the Stage 1 DBPR would need to avoid 574 bladder cancer cases per year to break even (132 fatal and 442 nonfatal) (Exhibit 6.6).

## Exhibit 6.5
## Breakeven Analysis Willingness-to-Pay (WTP) Summary

| *If you assume the following:* | 3% Cost of Capital | 7% Cost of Capital |
|---|---|---|
| Implementation cost of the rule | $626.48 million | $701.18 million |
| Value per statistical life saved (mean of lognormal distribution, standard deviation of $3.16 million) | $5.6 million | $5.6 million |
| Willingness-to-pay to avoid a case of bladder cancer (median) | $587,500 | $587,500 |
| Percent of fatal bladder cancer cases | 23 percent | 23 percent |
| Percent of nonfatal bladder cancer cases | 77 percent | 77 percent |
| ***Total number of cancer cases prevented to break even (at median)*** | 391 | 438 |
| Fatal cancer cases | 90 | 101 |
| Nonfatal cancer cases | 301 | 337 |
| ***Reduction in exposure necessary to reach breakeven at given baseline attributable risk*** | | |
| 1,000 baseline attributable cases requires | 39 percent reduction | 44 percent reduction |
| 5,000 baseline attributable cases requires | 8 percent reduction | 9 percent reduction |
| 10,000 baseline attributable cases requires | 4 percent reduction | 4 percent reduction |
| ***Baseline attributable risk necessary to reach breakeven at given exposure reductions*** | | |
| 30 percent reduction in exposure | 1,300 attributable cases | 1,460 attributable cases |
| 24 percent reduction in exposure | 1,630 attributable cases | 1,825 attributable cases |
| 18 percent reduction in exposure | 2,170 attributable cases | 2,435 attributable cases |

The breakeven number of cases provides only part of the information needed to assess under what beliefs the Stage 1 DBPR will break even. Two other factors, the baseline number of attributable bladder cancer cases and the percent reduction in exposure due to the Stage 1 DBPR, combine to give us the number of cancer cases avoided by the rule. In general, these two factors have an inverse relationship with respect to the breakeven point: the higher the baseline number of cases, the lower the reduction needs to be to break even. Conversely, the lower the baseline number of cases, the higher the reduction in risk needs to be. Exhibit 6.7 contains a graph that addresses the question: "What range of baseline risk and risk reduction due to the Stage 1 DBPR would you need to reach these breakeven cancer cases?"

Exhibit 6.7 displays two breakeven lines assuming a 7 percent discount rate, one calculated with WTP and one with COI to value nonfatal cancer cases. Each point on the line represents the combination of baseline attributable cancer cases and percent reduction in exposure needed to produce the breakeven cases. For WTP, the combination of baseline number of cancer cases and percent reduction in exposure at each point on the dark, solid line produces 438 cancer cases avoided. For example, at 1,000 attributable cancer cases, the associated percent reduction is approximately 44 percent. At 5,000 cancer cases, the percent reduction is 9 percent. For the COI (dark, dashed line), each point on the line produces 574 breakeven cancer cases. Graphically, at any combination of baseline risk and percent reduction in the area to the right of the lines, the Stage 1 DBPR would exceed breakeven (benefits would exceed costs) and at any combination in the area to the left of the lines, the costs of compliance would exceed the benefits (counting only the those attributable to the reduction of bladder cancer risk).

## Exhibit 6.6
## Breakeven Analysis Cost-of-Illness (COI) Summary

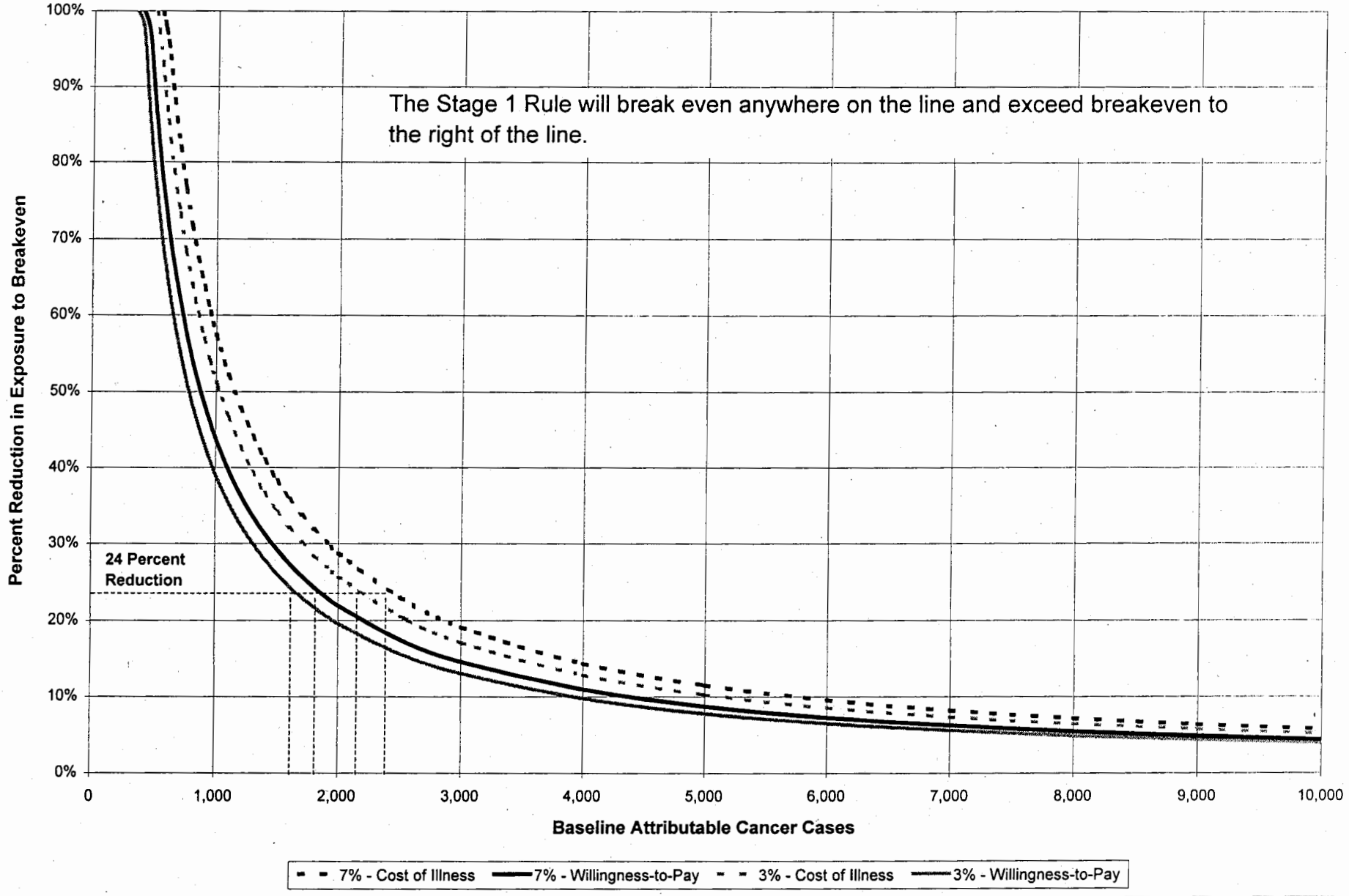
| *If you assume the following:* | 3% Cost of Capital | 7% Cost of Capital |
|---|---|---|
| Implementation cost of the rule | $626.48 million | $701.18 million |
| Value per statistical life saved (mean of lognormal distribution, standard deviation of $3.16 million) | $5.6 million | $5.6 million |
| Cost-of-illness for a case of bladder cancer | $121,000 | $121,000 |
| Percent of fatal bladder cancer cases | 23 percent | 23 percent |
| Percent of nonfatal bladder cancer cases | 77 percent | 77 percent |
| ***Total number of cancer cases need to prevent to break even (at median)*** | 513 | 574 |
| Fatal cancer cases | 118 | 132 |
| Nonfatal cancer cases | 395 | 442 |
| ***Reduction in exposure necessary to reach breakeven at given baseline attributable risk*** | | |
| 1,000 baseline attributable cases requires | 51 percent reduction | 57 percent reduction |
| 5,000 baseline attributable cases requires | 10 percent reduction | 12 percent reduction |
| 10,000 baseline attributable cases requires | 5 percent reduction | 6 percent reduction |
| ***Baseline attributable risk necessary to reach breakeven at given exposure reductions*** | | |
| 30 percent reduction in exposure | 1,710 attributable cases | 1,915 attributable cases |
| 24 percent reduction in exposure | 2,140 attributable cases | 2,390 attributable cases |
| 18 percent reduction in exposure | 2,850 attributable cases | 3,190 attributable cases |

Three estimates of percent reduction are of particular importance. The exposure reduction analysis described earlier estimated that the Stage 1 DBPR will reduce exposure by 24 percent, with a 25$^{th}$ percentile value of 18 percent and a 75$^{th}$ percentile value of 30 percent. If the reduction in exposure is assumed to be 24 percent, the baseline number of attributable bladder cancer cases necessary to reach breakeven (at a 7 percent discount rate) would be 1,825 assuming a WTP measure and 2,390 assuming a COI measure. A 30 percent reduction results in breakeven attributable cases of 1,460 for WTP and 1,915 for COI. At 18 percent reduction, the breakeven attributable cases rises to 2,435 for WTP and 3,190 for COI.

Exhibit 6.7 also displays the breakeven points at a 3 percent social discount rate. Assuming an annual implementation cost of $626.5 million (at 3 percent annualization), the Stage 1 DBPR would need to prevent 391 bladder cancer cases (at the median) using a WTP measure and 513 cases using a COI measure. At a 24 percent reduction in exposure, this translates into 1,630 attributable cases for WTP and 2,140 for COI.

**Exhibit 6.7**

**Percent Reduction in Exposure Needed to Break Even by Baseline Number of Attributable Cancer Cases**



### Interpreting the Results

Using these two different measures to value nonfatal bladder cancer cases and percent reductions due to the Stage 1 DBPR with a mean of 24 percent and a range of 18 to 30 percent, the number of bladder cancer cases attributable to DBPs needs to be at least between 1,460 to 3,190 for the rule to break even at a 7 percent rate. In terms of the attributable risk, these values translate into population attributable risk (PAR) numbers of between 2.7 to 5.9 percent. In other words, if the actual PAR is between 2.7 and 5.9 percent and exposure reduction is between 18 and 30 percent, the Stage 1 DBPR will be cost-effective. These breakeven PAR values are well within the low to mid end of the range of PARs suggested by the epidemiological data (2 to 17 percent). Based on this breakeven analysis, there seems to be a reasonable likelihood that the Stage 1 DBPR will be cost-effective with the potential benefits at least equaling the costs.

## 6.5 Household Cost Analysis

A fourth approach for assessing the net benefits of the Stage 1 DBPR is to calculate the costs per household for the rule. Household costs provide a common-sense test of benefit/cost relationships and are another useful benchmark for comparing the WTP to reduce the possible risk posed by DBPs in drinking water. It is essentially a household level breakeven analysis. It works backwards from the costs to ask whether the implied amount of benefits (WTP) needed to cover costs is a plausible amount.[2]

An estimated 115,490,000 households are located in service areas of systems affected by the Stage 1 DBPR. Of these households, 71 million (62 percent) are served by large surface water systems. Approximately 4.2 million (4 percent) are served by small surface water systems. Large ground water systems served 24 million households (21 percent) and small ground water systems serve 15.7 million households (13 percent).

All of the households served by systems affected by the Stage 1 DBPR will incur some additional costs, even if the system does not have to change treatment to comply with the proposed rule, for monitoring. The costs calculated below include both monitoring and treatment costs.

The cumulative distribution of household costs for all of the systems and by each system type is displayed in Exhibit 6.8. The distributions show that the large percentage of households will incur small additional costs, with a small portion of systems facing higher costs. At the highest end of the distribution, approximately 1,400 households served by surface water systems in the 25-100 population size category switching to membrane technology will face an annual cost increase of $400 per year ($33 per month).

The households have been sorted into three cost categories for the ease of comparison (Exhibit 6.9). The first category includes households with a cost increase of less than $12 per year, less than $1 per month. The second category contains households with costs greater than $12 per year, but less than $120 per year ($10 per month). The third category includes households with cost increases greater than $120 per year to $400 per year ($33 per month).

---

[2] The calculations assume that all increases in costs are ultimately borne by consumers, either through direct charges from the utilities or through increased prices of goods passed on by producers. This assumptions overstates the cost to affected households because some of the price increases of goods may be borne by consumers outside of the service areas affected by the Stage 1 DBPR and not all increases are passed along to consumers, depending on the price elasticity of demand.

Across all system categories, 95 percent of the households (110.1 million) fall within the first category and will incur less than $1 per month additional costs due to the Stage 1 DBPR. An additional 4 percent (4.4 million) are in the second category at between $1 and $10 per month cost increase and 1 percent (1.0 million) are in the highest category ($10 to $33 per month).

For households served by large surface water systems (Exhibit 6.10), 98 percent will incur less than $1 per month, 2 percent will incur between $1 and $10 per month, and 0.03 percent will incur greater than $10 per month. The highest cost ($125 annually, $10 monthly) is faced by households served by systems in the 10,000 to 25,000 population size category implementing membrane technology.

For households served by small surface water systems (Exhibit 6.10), 71 percent will incur less than $1 per month, 28 percent will incur between $1 and $10 per month, and 1 percent will incur greater than $10 per month. The highest cost ($400 annually, $33 monthly) is faced by households served by systems in the 25-100 population size category implementing membrane technology.

For households served by large ground water systems (Exhibit 6.10), 95 percent will incur less than $1 per month, 4 percent will incur between $1 and $10 per month, and 1 percent will incur greater than $10 per month. The highest cost ($125 annually, $10.40 monthly) is faced by households served by systems in the 10,000 to 25,000 population size category implementing membrane technology.

For households served by small ground water systems (Exhibit 6.10), 91 percent will incur less than $1 per month, 5 percent will incur between $1 and $10 per month, and 4 percent will incur greater than $10 per month. The highest cost ($357 annually, $30 monthly) is faced by households served by systems in the 25-100 population size category implementing membrane technology.

In the small proportion of systems where household costs exceed $10 per month, these results are driven by the assumption that advanced technologies, such as membranes or ozone will be the selected treatment, as noted above. Additionally, two points must be made: 1) many of these systems may find less expensive means of compliance (e.g., use of point-of-use devices, selection of alternative source water, purchased water, or consolidation with other systems); and 2) if these systems do install advanced technologies such as membranes, they may reap additional water quality and/or compliance benefits beyond those associated with DBPs. For example, because membranes are so effective, systems that install membranes are likely to incur no significant compliance costs for future rulemakings.

### Interpreting the Results

Given the uncertain nature of the risks associated with DBPs, household costs provide a common sense estimate of WTP to reduce the risks: Would the average household (95 percent of households) be willing to pay less than $1 per month ($12 per year) to reduce the potential risks posed by DBPs? Would a small percentage of households (4 percent) be willing to pay between $1 per month ($12 per year) and $10 per month ($120 per year) to reduce the potential risks posed by DBPs? Would the remaining small percentage of households (1 percent) be willing to pay between $10 per month ($120 per year) and $33 per month ($400 per year) to reduce the potential risks posed by DBPs?

WTP studies are not available to directly answer these questions. Taking the $1 per month figure as a measure of implied public health benefit at the household level, it is useful to ask what benefits can be identified that could balance a $1 per month expenditure. First, it is entirely possible that there is much more than a dollar-a-month's worth of tangible health benefit based on the reduced risk of bladder cancer

alone. Second, the broad exposure to DBPs and the myriad possible health effects involved offer the possibility that there are significant additional health benefits of a tangible nature.

Finally, however, the preventive weighing and balancing of public health protection provides also a margin of safety—a hedge against uncertainties. Recent survey research conducted in the drinking water field provides compelling empirical evidence that the number one priority of water system customers is the safety of their water. There is no doubt, given the uncertainties, that part of the public health benefit of the Stage 1 DBPR is the intangible benefit of having an additional margin of safety. Although definitive economic research has not been performed to investigate the extent of household WTP for such a margin of safety, there is very strong evidence from conventional customer survey research implying a demand for this benefit.

**Exhibit 6.8**
**Cumulative Distribution of Annual Household Costs under the Stage 1 DBPR**

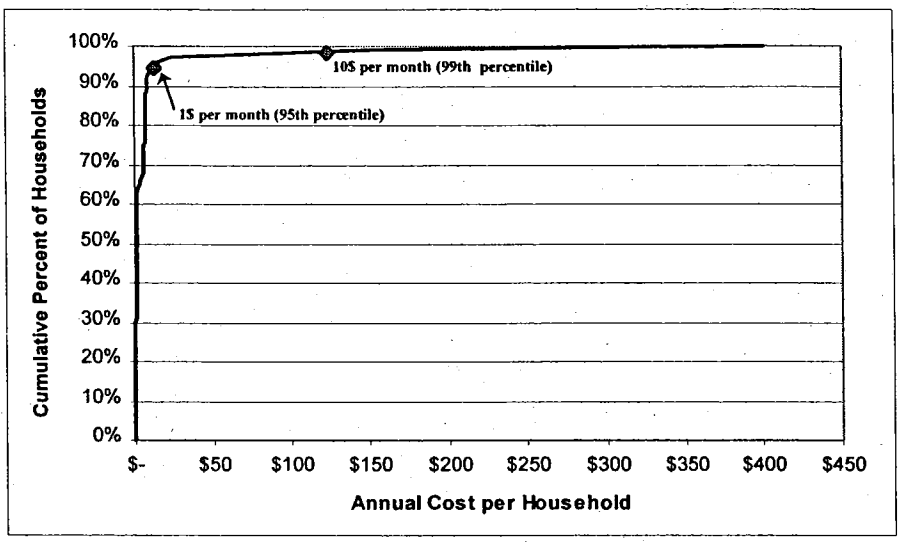


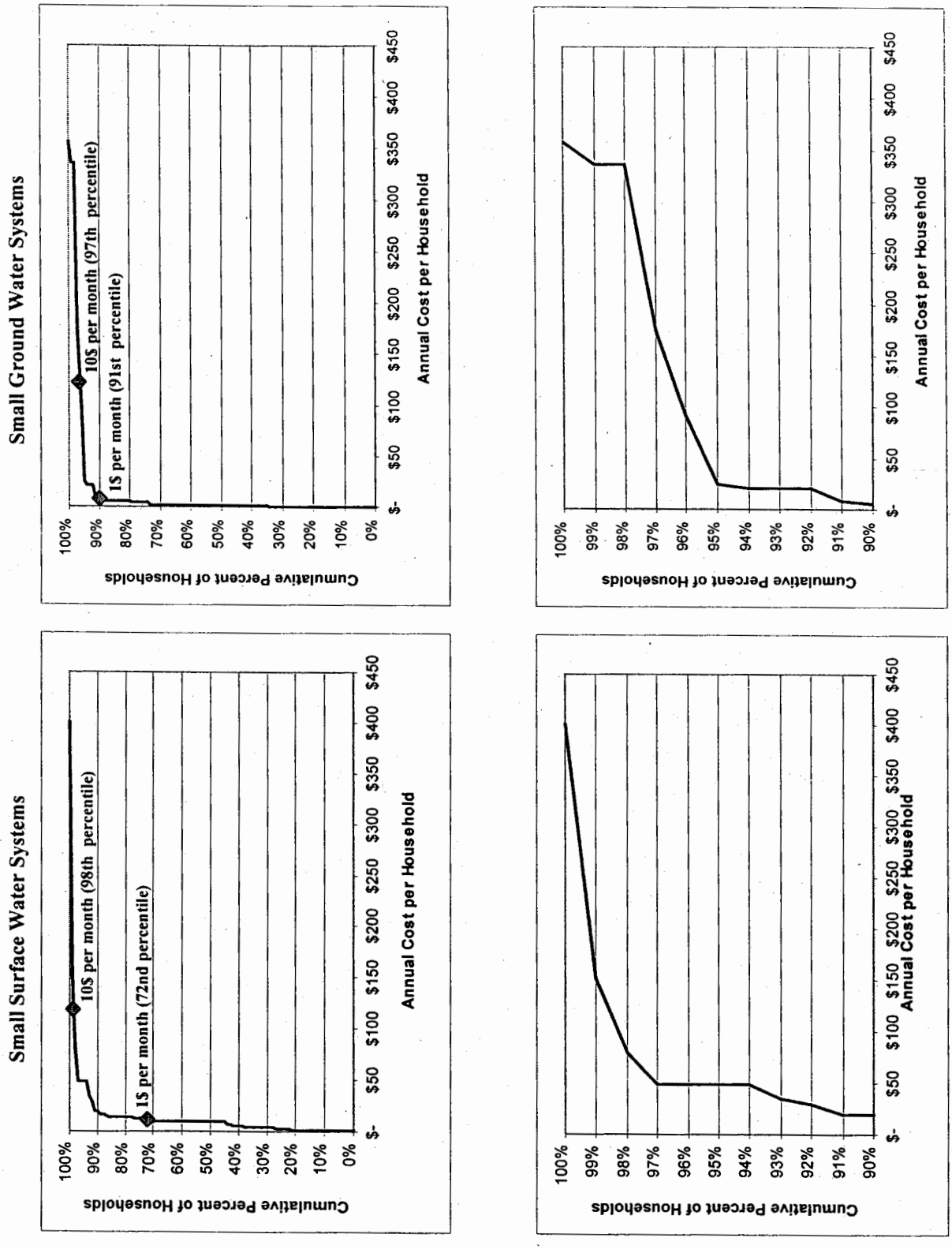
**Exhibit 6.9**
**Summary of the Number of Households and Percentage of Total Households in Each Cost Category**

| | All Systems | | $0 - $12 per Year Cost Per Household | | $12.01 - $120 per Year Cost Per Household | | $120.01 - $400 per Year Cost Per Household | |
|---|---|---|---|---|---|---|---|---|
| | Number of Households | Percent of Total | Number of Households | Percent of Total | Number of Households | Percent of Total | Number of Households | Percent of Total |
| Total | 115,490,000 | 100% | 110,093,000 | 95% | 4,387,000 | 4% | 1,011,000 | 1% |
| Large Surface Water | 71,378,000 | 61.8% | 69,870,000 | 60% | 1,489,000 | 1% | 20,000 | 0.02% |
| Small Surface Water | 4,267,000 | 3.7% | 3,009,000 | 3% | 1,204,000 | 1% | 54,000 | 0.05% |
| Large Ground Water | 24,174,000 | 20.9% | 22,969,000 | 20% | 939,000 | 1% | 266,000 | 0.2% |
| Small Ground Water | 15,671,000 | 13.6% | 14,245,000 | 12% | 755,000 | 1% | 671,000 | 0.6% |

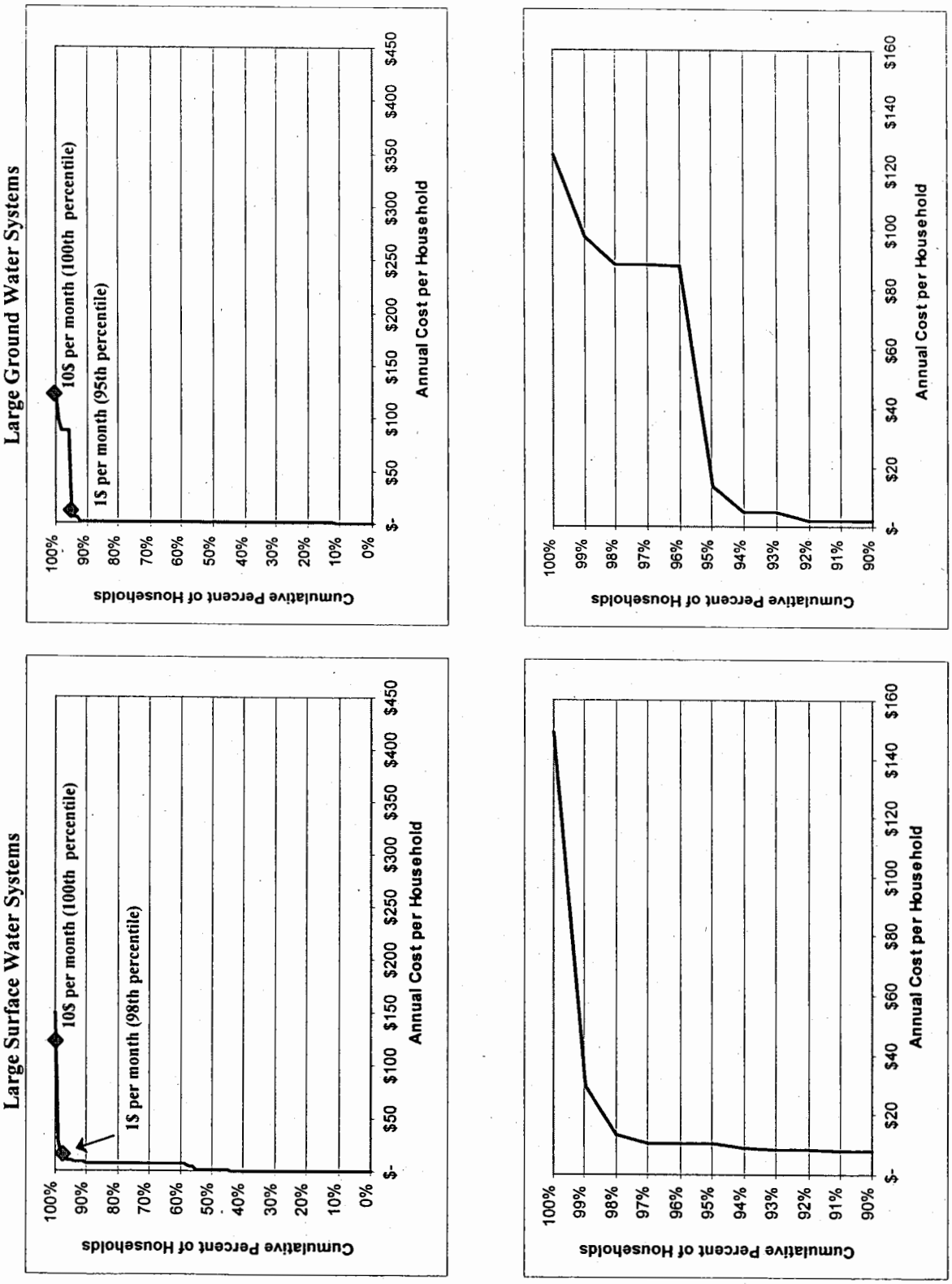
**Summary of the Number of Households and Percentage of Households in Each Cost Category by System Type**

| | All Systems | | $0 - $12 per Year Cost Per Household | | $12.01 - $120 per Year Cost Per Household | | $120.01 - $400 per Year Cost Per Household | |
|---|---|---|---|---|---|---|---|---|
| | Number of Households | Percent of System Category | Number of Households | Percent of System Category | Number of Households | Percent of System Category | Number of Households | Percent of System Category |
| Total | 115,490,000 | 100% | 110,093,000 | 95% | 4,387,000 | 4% | 1,011,000 | 1% |
| Large Surface Water | 71,378,000 | 100% | 69,870,000 | 98% | 1,489,000 | 2% | 20,000 | 0.03% |
| Small Surface Water | 4,267,000 | 100% | 3,009,000 | 71% | 1,204,000 | 28% | 54,000 | 1% |
| Large Ground Water | 24,174,000 | 100% | 22,969,000 | 95% | 939,000 | 4% | 266,000 | 1% |
| Small Ground Water | 15,671,000 | 100% | 14,245,000 | 91% | 755,000 | 5% | 671,000 | 4% |

## Exhibit 6.10a
## Cumulative Distribution of Annual Costs per Household in Small Systems



## Exhibit 6.10b
## Cumulative Distribution of Annual Costs per Household in Large Systems



## 6.6 Decision-Analytic Model

Total social cost of the proposed rule is a function of the annualized implementation cost, the number of bladder cancer cases that are attributable to DBPs in chlorinated water, and the effectiveness of the rule in reducing bladder cancers through reduced DBPs in drinking water. The baseline cost, the cost of not promulgating the rule, depends only on the number of bladder cancers attributable to DBPs. Of the three parameters, the best known is the implementation cost and the least-known is the number of attributable bladder cancer cases.

In the approach described below, uncertain information is modeled as probability functions. Expected total social costs are derived for the No Action and Stage 1 DBPR alternatives, revealing that the rule is superior. Finally, indifference points are determined. The indifference points show levels of the unknown parameters for which the No Action and Stage 1 DBPR alternatives would have equal total social costs.

### Characterizing Uncertain Information

Probability functions have been constructed to represent a set of reasonable assumptions about the three uncertain parameters. Exhibit 6.11 represents assumptions regarding implementation cost. The distribution is Gaussian (normal) with a central value of $0.701 billion and a standard deviation of $0.105 billion. The coefficient of variation (standard deviation divided by the mean) is 15 percent. Exhibit 6.12 represents the estimated assumptions regarding the effectiveness of the Stage 1 DBPR in reducing exposure to DBPs. Assuming that the reduction in bladder cancer risk is proportional to reductions in TTHM concentration, these figures represent the effectiveness in reducing bladder cancer. This distribution is also Gaussian but has a mean of 0.24 and a 25 percent coefficient of variation. This mean value is EPA's estimate of the reduction in exposure derived in Appendix G.

The uncertainty in attributable bladder cancers is not as simple. Approximately 54,500 new bladder cancer cases are diagnosed each year, but the fraction due to DBPs is largely unknown. As described earlier, since causality has not been proven, there may, in fact, be no bladder cancer cases due to DBPs. In this analysis, EPA has assumed a 20 percent probability that these DBPs do not cause bladder cancer. Based on the PAR estimates derived from the recent epidemiological studies described earlier, the range of PARs is estimated at between 0 percent to 20 percent. An upper bound of 20 percent for the PARs was deemed reasonable since all the calculated PARs in the 2 to 17 percent range were based on the central tendency estimate for each study. Exhibit 6.13 utilizes a uniform distribution to represent total uncertainty over that range, but allows for a 20 percent probability that the PAR is 0. The expected value of the PAR under this set of assumptions, denoted as E(PAR) is 8 percent.

### Computing Total Social Cost

Using the values per cancer case described in previous sections, one can use the probability functions to derive the expected total social costs. In the equations below, $f_{PAR}(PAR)$, $f_{ImplCost}(C)$, and $f_{Reduction}(r)$, denote the probability density functions for PAR, rule implementation cost, and percent reduction, respectively. The expected total social cost (in billions of dollars) of the No Action alternative is derived first:

$$E(Cost_{No\ Action}) = \int 54500\ cases * \$1.750/1000cases * PAR * f_{PAR}(PAR)\ dPAR$$

$$E(Cost_{No\ Action}) = \int 95.4 * PAR * f_{PAR}(PAR)\, dPAR$$

$$E(Cost_{No\ Action}) = 95.4 * E(PAR) = \$7.63 \text{ billion}$$

A bit more complex is the estimation of expected total social cost of the Stage 1 DBPR:

$$E(Cost_{Stage\ 1}) = \int c * f_{ImplCost}(c)\, dc + 95.4 \int\int PAR * (1-r)\, f_{PAR}(PAR)\, f_{reduction}(r)\, dr\, dPAR$$

$$E(Cost_{Stage\ 1}) = E(c) + 95.4 \int PAR * (1-E(r))\, f_{PAR}(PAR)\, dPAR$$

$$E(Cost_{Stage\ 1}) = E(c) + 95.4 * E(PAR) * (1-E(r))$$

$$E(Cost_{Stage\ 1}) = 0.702 + 95.4 * .08 * 0.76 = \$6.5 \text{ billion}$$

### Estimating the Indifference Points

The three key uncertain parameters are implementation (cost), attributable bladder cancers (PAR), and the effectiveness of the rule (r). Maintaining any two of these attributes as uncertain (represented by the probability functions described earlier), we ask what level of the third attribute would be needed to make the expected cost of the No Action equal to the expected cost of the rule. The indifference points derived through this analysis are as follows:

| Parameter | Indifference Point |
|---|---|
| **Implementation Cost (c)** | $1.831 billion |
| **Attributable bladder cancers** | PAR of 3.07 |
| **Rule Effectiveness** | 9.21 percent reduction |

The indifference points for implementation cost and rule effectiveness are unlikely levels. An implementation cost greater than $1.831 billion would favor the No Action alternative, but the probability of a greater cost is virtually zero. Similarly, an effective reduction of less than 9.21 percent would favor the No Action alternative, but the probability of such a low effectiveness is less than 0.01 percent, under the probability assumptions. New information on the cost or effectiveness, such as would be produced by new research or more accurate engineering or cost models, is not likely to make the No Action a more attractive alternative.

In contrast, the indifference point for the PAR, 3.07 percent, appears to be a reasonably likely level. The probability of a lesser PAR is 32 percent, which includes the assumed 20 percent allowance that the PAR may equal 0. New information could be quite valuable, especially if it would establish or reject causality. Although new information would be imperfect, the expected value of perfect information can be viewed as the upper bound on what should be spent for imperfect information. Derived using numerical integration, the expected value of perfect information on PAR is approximately $200 million. While this far exceeds the cost of typical epidemiological studies, the inability of such studies to test causality may

render a planned study's value far less that its cost. Still, the large expected value of perfect information suggests that a more in-depth value-of-information analysis could be beneficial.

### Interpreting the Results

This approach calculated expected total social costs for the Stage 1 DBPR and No Action alternatives under a set of reasonable assumptions. Uncertain parameters were modeled and their impacts on the decision were carefully evaluated and considered.

Under the given set of assumptions, the results indicate that the choice of the Stage 1 DBPR over the No Action alternative is not sensitive across the reasonable range of possible values for both implementation cost or percent reduction in exposure. However, the choice is sensitive to the assumed values for the attributable bladder cancer cases. Exhibit 6.14 displays the distribution of the estimated Stage 1 DBPR net benefits given the above input assumptions. The results suggest that there is a one-in-three chance that net benefits could be negative and a two-in-three chance that the net benefits could be positive.

**Exhibit 6.11**
**Density Function of Implementation Costs**

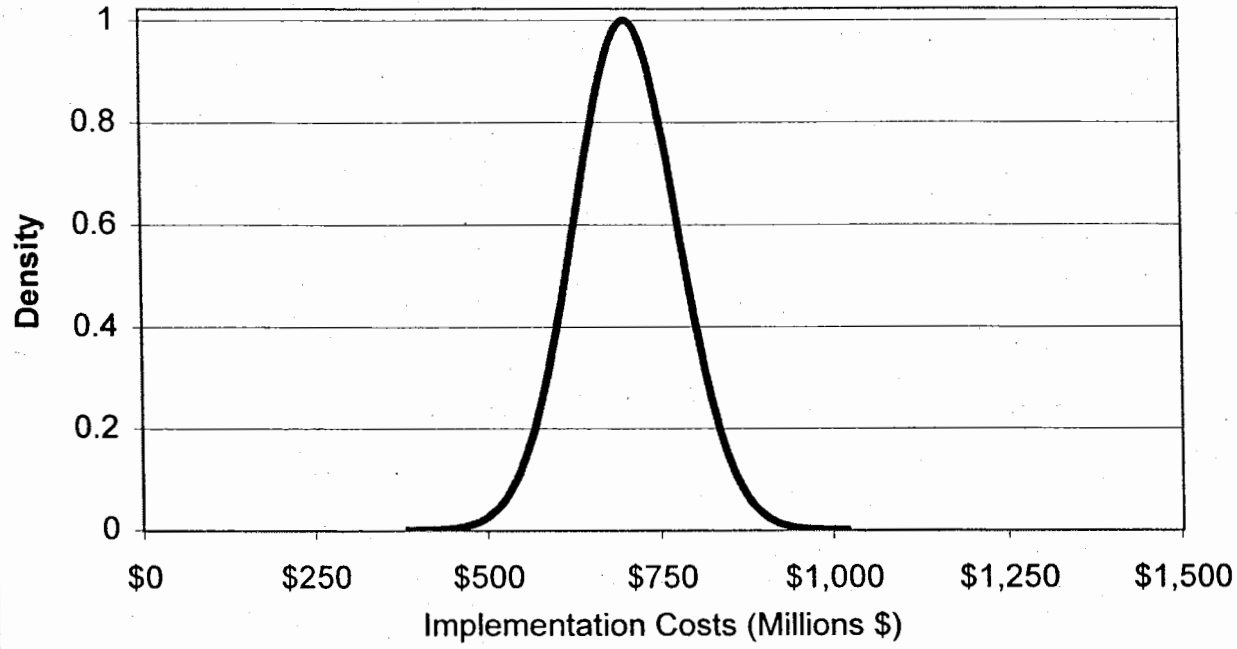



**Exhibit 6.12**
**Density Function of Exposure Reduction**

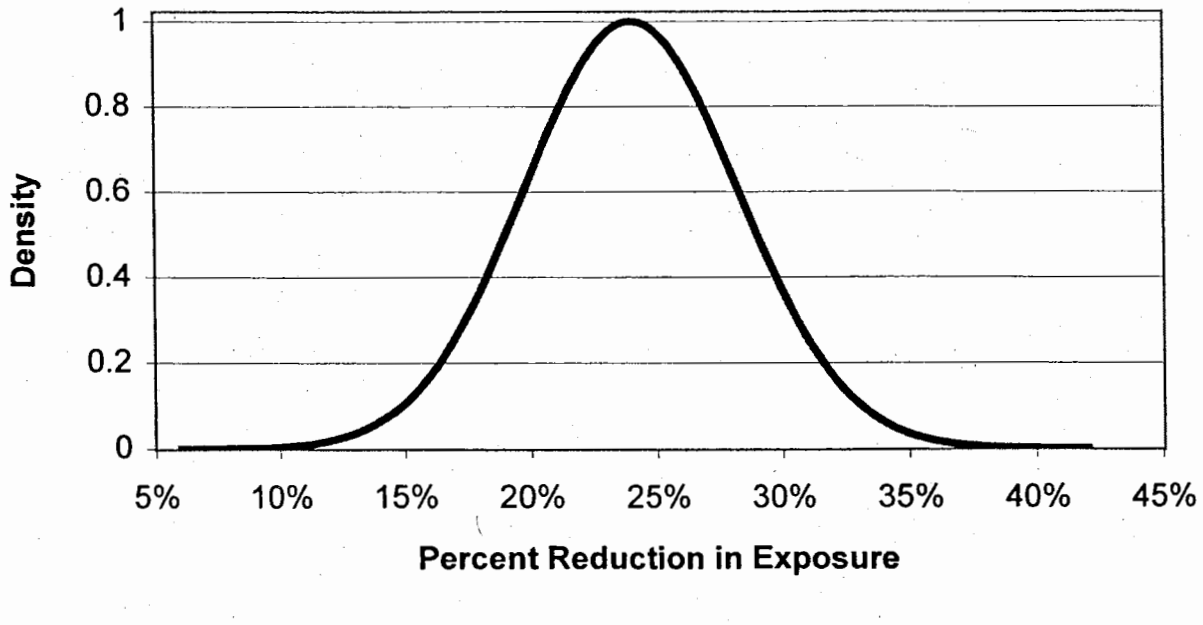


**Exhibit 6.13**
**Density Function of PAR Estimates**

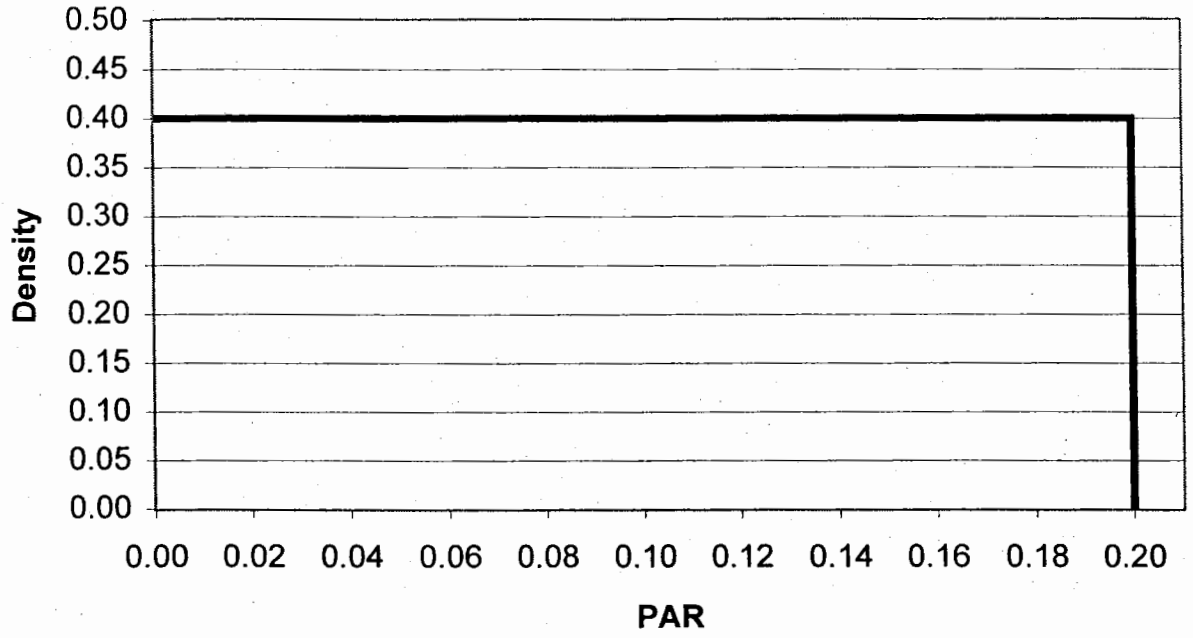
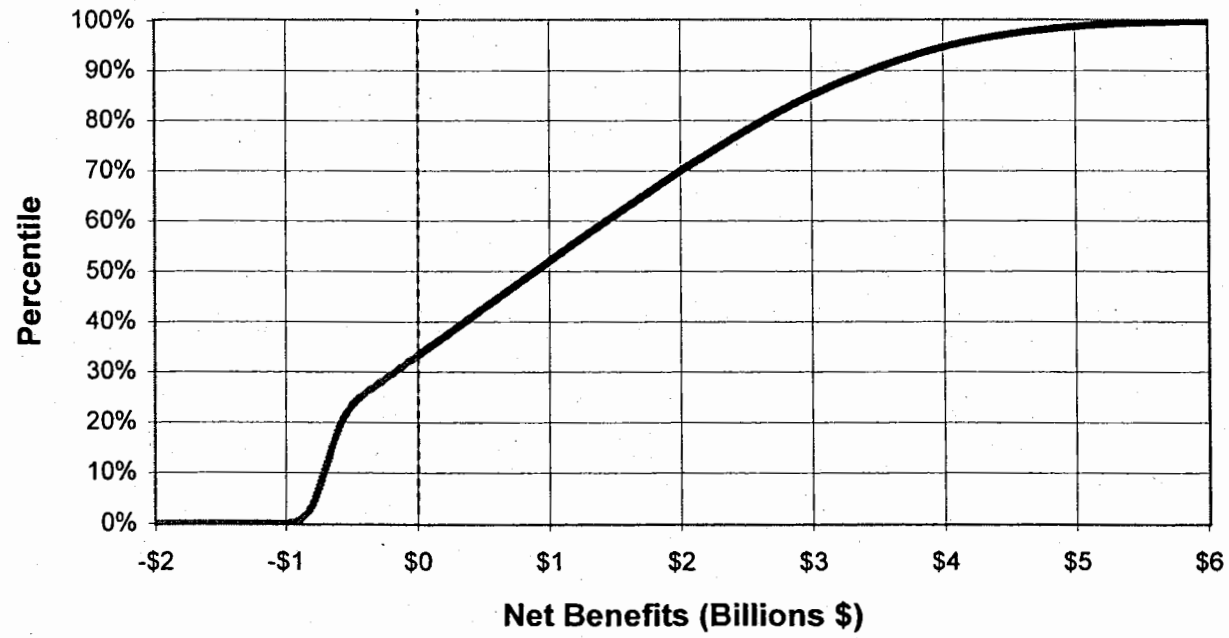



**Exhibit 6.14**
**Cumulative Distribution of Predicted Net Benefits**



# 7: The Economic Rationale for Regulation

## 7.1 Introduction

This chapter of the analysis discusses the economic rationale for choosing a regulatory approach to address the public health consequences of drinking water contamination. The economic rationale is provided in response to Executive Order Number 12866, *Regulatory Planning and Review*, which states:

> [E]ach agency shall identify the problem that it intends to address (including, where applicable, the failures of the private markets or public institutions that warrant new agency action) as well as assess the significance of that problem (Section 1, b(1)).

In addition, OMB guidance dated January 11, 1996, states that "in order to establish the need for the proposed action, the analysis should discuss whether the problem constitutes a significant market failure" (p.3). Therefore, the economic rationale laid out in this section should not be interpreted as the agency's approach to implementing the Safe Drinking Water Act (SDWA). Instead, it is the agency's justification, as required by the Executive Order, for a *regulatory approach* to this public health issue.

## 7.2 Statutory Authority for Promulgating the Rule

The 1996 reauthorization for the Safe Drinking Water Act (SDWA) mandated new drinking water requirements. EPA's general authority to set Maximum Contaminant Level Goals (MCLGs) and the National Primary Drinking Water Rule (NPDWR) was modified to apply to contaminants that "may have an adverse effect on the health of persons," are "known to occur or there is a substantial likelihood that the contaminant will occur in public water systems with a frequency and at levels of public health concern," and for which "in the sole judgment of the Administrator, regulation of such contaminant presents a meaningful opportunity for health risk reductions for persons served by public water systems" (1996 SDWA, as amended).

The 1996 Amendments also require the promulgation of the Interim Enhanced Surface Water Treatment Rule (IESWTR) and a Stage 1 Disinfectants/Disinfection Byproducts Rule (Stage 1 DBPR) by November 1998. In addition, the 1996 Amendments require EPA to promulgate a Final Enhanced Surface Water Treatment Rule and a Stage 2 DBPR by November 2000 and May 2002, respectively.

## 7.3 The Economic Rationale for Regulation

In addition to the statutory directive to regulate disinfection byproducts, there is also economic rationale for government regulation. In a perfectly competitive market, market forces guide buyers and sellers to attain the best possible social outcome. A perfectly competitive market occurs when there are many producers of a product selling to many buyers, and both producers and consumers have complete knowledge regarding the products of each firm. There must also be no barriers to entry in the industry, and firms in the industry must not have any advantage over potential new producers. Several factors in the public water supply industry do not satisfy the requirements for a perfect market and lead to market failures that require regulation.

First, water utilities are natural monopolies. A natural monopoly exists when it is not economically efficient to have multiple suppliers competing to build multiple systems of pipelines, reservoirs, wells, and other facilities. Instead, a single firm or government entity performs these functions under public control. Under monopoly conditions, consumers are provided only one level of service with respect to the quality attribute of the product, in this case drinking water quality. If they do not believe the margin of safety in public health protection is adequate, they cannot simply switch to another water utility.

Second, there are high information and transaction costs that impede public understanding of the health and safety issues concerning drinking water quality. The type of health risks potentially posed by trace quantities of drinking water contaminants involve analysis and distillation of complex toxicological data and health sciences. EPA is currently in the final stages of developing the Consumer Confidence Report rule that will make water quality information more easily available to consumers. The Consumer Confidence Report rule will require community water systems to mail their customers an annual report on local drinking water quality. However, consumers would still have to analyze this information for its health risk implications. Even if informed consumers are able to engage utilities regarding these health issues, the costs of such engagement-transaction costs (measured in personal time and commitment) present another significant impediment to consumer expression of risk preference.

SDWA regulations are intended to provide a level of protection from exposure to drinking water contaminants that would not otherwise occur in the existing market environment of public water supply. The regulations set minimum performance requirements for all public water supplies in order to protect all consumers from exposure to contaminants. SDWA regulations are not intended to restructure market mechanisms or to establish competition in supply; rather, SDWA standards establish the level of service to be provided in order to better reflect public preference for safety. The Federal regulations remove the high information and transaction costs by acting on behalf of all consumers in balancing the risk reduction and the social costs of achieving this reduction.

# References


58 FR 51735. Executive Order 12866. "Regulatory Planning and Review." October 4, 1993.

59 FR 38668. Preamble to the 1994 proposed Stage 1 DBPR.

62 FR 59388. Preamble to the 1997 Notice of Data Availability.

63 FR 15674. Preamble to the 1998 Notice of Data Availability.

American Cancer Society. 1998. "Cancer Facts and Figures." http://www.cancer.org/

Amy, G., M. Siddiqui, K. Ozekin, H. W. Zhu and C. Wang. 1995. "Empirically Based Models for Predicting Chlorination and Ozonation By-Products: Haloactic Acids, Chloral Hydrate, and Bromate." EPA Draft Report Number Cx 819579, Cooperative Agreement: Univerisity of Colorado and EPA.

Aschengrau A, S. Zierler and A. Cohen. 1993. "Quality of Community Drinking Water and the Occurrence of Late Adverse Pregnancy Outcomes." Arch. Env. Health. 48:105-113.

Bove F, M. Fulcomer, J. Klotz, J. Esmart, E. Dufficy, R. Zagraniski and J. E. Savrin. 1992b. "Public Drinking Water Contamination and Birthweight, and Selected Birth Defects: A Case-Control Study (Phase IV-B)." New Jersey Department of Health. May 1992. 23.

Bove F, M. Fulcomer, J. Klotz, J. Esmart, E. Dufficy, R. Zagraniski and J. E. Savrin. 1992a. "Public Drinking Water Contamination and Birthweight, Fetal Deaths, and Birth Defects: A Cross-Sectional Study (Phase IV-A)." New Jersey Department of Health. April 1992.

Bried, E.M. and R.M. Scheffler. 1992. "The Financial Stages of Cancer in the Elderly." Oncology. Supplement: 6(2).

Bull, R.J. and F. Kopfler. 1991. "Health Effects of Disinfectants and Disinfection By-Products." Denver, Colorado: American Water Works Association Research Foundation.

Cantor, K.P., R. Hoover and P. Hartge. 1985. "Drinking Water Source and Bladder Cancer: A Case-Control Study." In: R.L. Jolley, R.J. Bull and W.P. Davis, eds. *Water Chlorination: Chemistry, Environmental Impact and Health Effects*. 5(1).

Cantor, K.P., C.F. Lunch, M. Hildesheim, M. Dosemeci, J. Lubin, M. Alavanja and G.F. Craun. 1998. "Drinking Water Source and Chlorination Byproducts I. Risk of Bladder Cancer." Epidemiology: 9.

Chestnut, L.G., A. Alberni and D. Mills. 1997. "Monetary Valuation of Human Mortality Risks in Cost-Benefit Analyses of Environmental Programs."

# References


Cragle, D.L., C.M. Shy, R.J. Struba and E.J. Siff. 1985. "A Case-Control Study of Colon Cancer and Water Chlorination in North Carolina." In: R.L. Jolley, R.J. Bull and W.P. Davis, eds. *Water Chlorination: Chemistry, Environmental Impact and Health Effects*. Chelsea, MI.: Lewis Publishers, Inc. Cropper and Krupnick. 1989. "The Social Costs of Chronic Heart and Lung Disease." Resources for the Future Discussion Paper. QE 89-16-REV.

Doyle, T.J., W. Sheng, J.R. Cerhan, C.P. Hong, T.A. Sellers, L.H. Kushi and A.R. Folsom. 1997. "The Association of Drinking Water Source and Chlorination By-Products with Cancer Incidence Among Postmenopausal Women in Iowa: A Prospective Cohort Study." American Journal of Public Health: 87(7).

Freedman, M., K.P. Cantor, N.L. Lee, L.S. Chen, H.H. Lei, C.E. Ruhl and S.S. Wang. 1997. "Bladder Cancer and Drinking Water: A Population-Based Case Control Study in Washington County, Maryland." Cancer Causes and Control.

Freeman, A.M. 1979. "The Benefits of Environmental Improvement: Theory and Practice." Resources for the Future. Johns Hopkins University Press.

Haas, C.N. and J.B. Rose. 1995. "Developing an Action Level for *Cryptosporidium*." Journal of the American Water Works Association: 89(9).

Hildesheim, M.E., K.P. Canbor, C.F. Lynch, M. Dosemeci, J. Lubin, M. Alavanja and G.F. Craun. 1997. "Drinking Water Source and Chlorination Byproducts: Risk of Colon and Rectal Cancers." Epidemiology: 9(1).

Hillier, F.S. and G.L. Lieberman. 1990. *Introduction to Mathematical Programming*. McGraw Hill.

King, W.D., and L.D. Marrett. 1996. "Case-Control Study of Bladder Cancer and Chlorination By-Products in Treated Water (Ontario, Canada)." Cancer Causes Control: 7.

Klotz, J.B. and L.A. Pyrch. 1998. "A Case-Control study of Neural Tube Defects and Drinking Water Contaminants." New Jersey Department of Health and Senior Services. Sponsored by Agency for Toxic Substances and Disease Registry.

Komulainen, H., V. M. Kosma, S. L. Vaittinen, T. Vartianen, E. Kaliste-Korhonen, S. Lotjonen, R. K. Tuominen and J. Tuomisto. 1997. "Carcinogenicity of the Drinking Water Mutagen 3-Chloro-4-(Dichloromethyl)-5-Hydroxy-2(5H)-Furanone in the Rat." 848-856.

Kramer, M. D., C. F. Lynch, P. Isacson and J. W. Hanson. 1992. "The Association of Waterborne Chloroform with Intrauterine Growth Retardation." Epidemiology. 3:407-413.

# References


Krasner, Stuart. April 1997. "Issue Paper on Enhanced Coagulation to the M-DBP Advisory Committee."

Krasner, Stuart. April 9, 1997. "Issue Paper on MCLs for DBPs."

McGeehin, M.A., J.S. Reif, J.C. Becher and E.J. Mangione. 1993. "Case Control Study of Bladder Cancer and Water Disinfection Methods in Colorado." American Journal of Epidemiology. 138.

Morris, R.D., A.M. Audet, I.F. Angelillo, T.C. Chalmers and F. Mosteller. 1992. "Chlorination, Chlorination By-Products, and Cancer." American Journal of Public Health.

National Cancer Institute. 1997. http://www.nci.nih.gov/

National Research Council. 1983. "Risk Assessment in the Federal Government: Managing the Process." Washington, DC.: National Academy Press.

Office of Management and Budget; Guidance. "Economic Analysis of Federal Regulations Under Executive Order 12866." January 11, 1996. p. 3.

Riley, G.F., A.L. Potosky, J.D. Lubits and L.G. Kessler. 1995. "Medicare Payments from Diagnosis to Death for Elderly Cancer Patients by Stage at Diagnosis." Medical Care: 33(8).

Savitz, D. A., K. W. Andrews and L. M. Pastore. 1995. "Drinking Water and Pregnancy Outcome in Central North Carolina: Source, Amount, and Trihalomethane Levels." Environ. Health Perspectives. 103(6), 592-596.

Unfunded Mandates Reform Act of 1995 (UMRA), P.L. 104-4. "Unfunded Mandates Reform Act for the D/DBPR."

U.S. Bureau of Labor Statistics. 1998. http://www.bls.gov/

U.S. Environmental Protection Agency. July, 1998. "Technologies and Costs for Control of Disinfection By-Products." Office of Ground Water and Drinking Water. Standards and Risk Reduction Branch. Standards and Risk Management Division.

U.S. Environmental Protection Agency. June 24, 1998. "Cost and Technology Document for Controlling Disinfectants and Disinfection Byproducts." Washington, DC.: Office of Ground Water and Drinking Water Resource Center.

U.S. Environmental Protection Agency. March 31, 1998. DBP Notice of Data Availability. Federal Register.

# References

U.S. Environmental Protection Agency. 1998a. "Quantification of Cancer Risk from Exposure to Chlorinated Water." Office of Science and Techology, Office of Water. Washington, DC. March 13, 1998.

U.S. Environmental Protection Agency. 1998b. "Health Risk Assessment/Characterization of the Drinking Water Disinfectant Byproduct Chlorine Dioxide and the Degradation Byproduct Chlorite." Office of Science and Techology, Office of Water. Washington, DC. March 13, 1998.

U.S. Environmental Protection Agency. 1998c. "Health Risk Assessment/Characterization of the Drinking Water Disinfectant Byproduct Chloroform." Office of Science and Techology, Office of Water. Washington, DC. March 13, 1998.

U.S. Environmental Protection Agency. 1997. "Summaries of New Health Effects Data." Office of Science and Technology, Office of Water. Washington, DC. October 1997.

U.S. Environmental Protection Agency. 1997. "The Benefits and Costs of the Clean Air Act, 1970-1990." Prepared for U.S. Congress.

U.S. Environmental Protection Agency. 1994. "Health Care Costs and Productivity Losses Due to Superfund."

U.S. Environmental Protection Agency. 1994. "Regulatory Impact Analysis of Proposed Disinfectant/Disinfection Byproduct Regulations." Washington, DC. EPA-###-R-93-###.

U.S. Environmental Protection Agency. Undated. *Introduction to IRIS.* http://www.epa.gov/ngispgm3/iris/intro.html/

Viscusi, W.K., W.A. Magat and J. Huber. 1991. "Pricing Environmental Health Risks: Survey Assessments of Risk-Risk and Risk-Dollar Trade-Offs for Chronic Bronchitis." Journal of Environmental Economics and Management: 21.

Waller, K., S.H. Swan, G. DeLorenze and B. Hopkins. 1998. "Trihalomethanes in Drinking Water and Spontaneous Abortion." Epidemiology: 9(2).

Yannick, R. and L.A. Ries. 1994. "Cancer in Older Persons. Magnitude of the Problem—How do We Apply What We Know?" Cancer.

Young, T.B., D.A. Wolf and M.S. Kanarek. 1987. "Case-Control Study of Colon Cancer and Drinking Water Trihalomethanes in Wisconsin." International Journal of Epidemiology: 16(190).