Economic Analysis for the Final Long Term 2 Enhanced Surface Water Treatment Rule

Contents

Chapter 6: Cost Analysis

Chapter 7: Economic Impact Analysis

Chapter 8: Comparison of Benefits and Costs of the LT2ESWTR

Appendices

Exhibits

Executive Summary

Chapter 1: Introduction

Chapter 2: Statement of Need for the Rule

Chapter 3: Consideration of Regulatory Alternatives

Chapter 4: Baseline Conditions

Chapter 5: Benefits Analysis

Chapter 6: Cost Analysis

Chapter 7: Economic Impact Analysis

Chapter 8: Comparison of Benefits and Costs of the LT2ESWTR

Acronyms and Notations

AIDS	Acquired Immunodeficiency Syndrome
AIPC	All Indian Pueblo Council
AMWA	Association of Metropolitan Water Agencies
ASDWA	Association of State Drinking Water Administrators
AWWA	American Water Works Association
CC-PCR	Cell culture and polymerase chain reaction
CCR	Consumer Confidence Report Rule (1998)
CDBG	Community Development Block Grant
CDC	Centers for Disease Control and Prevention
CFE	Combined Filter Effluent
CFU	Colony forming unit
CL2	Chlorine
CLM	Chloramines
CLO2	Chlorine Dioxide
COI	Cost of Illness
CPI	Consumer Price Index
CSFII	Continuing Survey of Food Intakes by Individuals
CWS	Community Water System
CWSS	Community Water Systems Survey
DBPs	Disinfection Byproducts
DWSRF	Drinking Water State Revolving Fund
EA	Economic Analysis
EO	Executive Order
FACA	Federal Advisory Committees Act
FBRR	Filter Backwash Recycling Rule (May, 2001)
FR	Federal Register
FS	Flowing stream
FTE	Full-time Equivalent Employee
GDP	Gross Domestic Product
GWR	Ground Water Rule (proposed 2000)
GWUDI	Ground Water Under the Direct Influence of Surface Water
HAA5	Haloacetic Acids [total of five]
HPC	Heterotrophic Plate Count
HRRCA	Health Risk Reduction and Cost Analysis
ICR	Information Collection Request
ICR	Information Collection Rule (1996)
ICRSS	Information Collection Rule Supplemental Survey
ICRSSM	Information Collection Rule Supplemental Survey Medium Systems
ICRSSL	Information Collection Rule Supplemental Survey Large Systems
ICMA	International City/County Management Association
IDSE	Initial Distribution System Evaluation
IESWTR	Interim Enhanced Surface Water Treatment Rule (1998)
IMS	Immunomagnetic separation
IRFA	Initial Regulatory Flexibility Analysis
IRIS	Integrated Risk Information System
LCR	Lead and Copper Rule (1992)
LRAA	Locational Running Annual Average
LSP	Lab Spiking Program

LT1ESWTR	Long Term 1 Enhanced Surface Water Treatment Rule (January, 2002)
LT2ESWTR	Long Term 2 Enhanced Surface Water Treatment Rule (under development)
MCL	Maximum Contaminant Level
MCLG	Maximum Contaminant Level Goal
MCMC	Markov Chain Monte Carlo [algorithm]
M-DBP	Microbial-Disinfectants/Disinfection Byproducts [Advisory Committee]
MF	Microfiltration
MG	Million gallons
MGD	Million Gallons per Day
mg/L	Milligrams per Liter
MILY	Morbidity Inclusive Life Year
MRDL	Maximum Residual Disinfectant Level
MRDLG	Maximum Residual Disinfectant Level Goal
MRL	Minimum Reporting Level
MWRA	Massachusetts Water Resources Authority
NCSL	National Conference of State Legislatures
NCWS	Noncommunity water system
NF	Nanofiltration
NGA	National Governors' Association
NIH	National Institutes of Health
NLC	National League of Cities
NODA	Notice of Data Availability
NPDWR	National Primary Drinking Water Regulations
NRDC	Natural Resources Defense Council
NRWA	National Rural Water Association
NTNCWS	Nontransient Noncommunity Water System
NTU	Nephelometric Turbidity Unit
O3	Ozone
OGWDW	Office of Ground Water and Drinking Water
OMB	Office of Management and Budget
O&M	Operations and Maintenance
O&P	Overhead and Profit
POE	Point of entry
POU	Point of Use
ppb	Parts per Billion
ppm	Parts per Million
PWS	Public Water System
PWSS	Public Water Systems Supervision [Grants Program]
QA/QC	Quality Assurance/Quality Control
QALY	Quality Adjusted Life Year
RAA	Running Annual Average
RF	Roughing Filter
RFA	Regulatory Flexibility Act
RIA	Regulatory Impact Analysis
RL	Reservoir/Lake
RO	Reverse Osmosis
RUS	Rural Utility Service
SAB	Science Advisory Board
SBAR	Small Business Advocacy Review
SBREFA	Small Business Regulatory Enforcement Fairness Act
SDWA	Safe Drinking Water Act (1974)

SDWIS	Safe Drinking Water Information System
SER	Small Entity Representative
SF	Secondary Filter
SW	Surface Water
SWAT	Surface Water Analytical Tool
Stage 1 DBPR	Stage 1 Disinfectants and Disinfection Byproducts Rule (1998)
Stage 2 DBPR	Stage 2 Disinfectants and Disinfection Byproducts Rule (under development)
SWTR	Surface Water Treatment Rule (1989)
T&C	Technologies and Cost
TCR	Total Coliform Rule (1989)
TMF	Technical, Managerial, and Financial
TNCWS	Transient Noncommunity Water System
TOC	Total Organic Carbon
TT	Treatment Technique
TTHMs	Total Trihalomethanes
TTHMR	Total Trihalomethane Rule (1979)
TWG	Technical Workgroup
UF	Ultrafiltration
UMRA	Unfunded Mandates Reform Act
USDA	United States Department of Agriculture
UV	Ultraviolet [Light Disinfection]
μg/L	Micrograms per Liter
VSL	Value of a Statistical Life
WC	Watershed Control
WTP	Willingness to Pay

Health Risk Reduction and Cost Analysis

Under the Safe Drinking Water Act (SDWA) Amendments of 1996, when proposing a national primary drinking water regulation that includes a maximum contaminant level (MCL), the U.S. Environmental Protection Agency (EPA or the Agency) must conduct a health risk reduction and cost analysis (HRRCA). A HRRCA addresses seven requirements, all of which are addressed in this Economic Analysis (EA) for the Long Term 2 Enhanced Surface Water Treatment Rule (LT2ESWTR).

HRRCA Crosswalk Summary

HRRCA Requirement	Addressed in this Economic Analysis
Quantifiable and nonquantifiable health risk reduction benefits	Chapter 5 (All sections and exhibits) Chapter 7 (Section 7.7; Exhibit 7.4) Chapter 8 (Sections 8.2.1, 8.2.3, 8.3; Exhibits 8.1–8.4, 8.6–8.10, 8.12-8.16, 8.19)
Quantifiable and nonquantifiable health risk reduction benefits from co-occurring contaminants	Chapter 5 (Section 5.6.4)
Quantifiable and nonquantifiable costs	Chapter 6 (All sections and exhibits) Chapter 7 (Sections 7.2, 7.6, 7.7, 7.8; Exhibits 7.2, 7.3, 7.4, 7.9) Chapter 8 (Sections 8.2.2, 8.3; Exhibit 8.1, 8.5, 8.11, 8.17, 8.18)
Incremental costs and benefits associated with regulatory alternatives	Chapter 5 (Section 5.5; Exhibit 5.30) Chapter 6 (Sections 6.13; Exhibit 6.22) Chapter 7 (Section 7.7; Exhibit 7.4) Chapter 8 (Section 8.3; Exhibits 8.13, 8.18, 8.19)
Effects of the contaminants on the general population and sensitive subpopulations	Chapter 5 (Sections 5.2.2, 5.2.8) Chapter 7 (Section 7.9)
Increased health risk that may occur as a result of compliance	Chapter 2 (Section 2.3)
Other relevant factors (quality and uncertainty of information)	Chapter 4 (Section 4.8; Exhibit 4.30) Chapter 5 (Section 5.4; Exhibits 5.28 and 5.29) Chapter 6 (Section 6.11; Exhibits 6.19 and 6.20) Chapter 8 (Section 8.4; Exhibit 8.21)

Executive Summary

This document presents the Economic Analysis (EA), prepared by the U.S. Environmental Protection Agency (EPA), of the benefits and costs of the Long Term 2 Enhanced Surface Water Treatment Rule (LT2ESWTR). Executive Order 12866 requires Federal agencies to conduct an analysis of the benefits and costs of proposed and final rules that cost more than $100 million annually.

ES.1 Need for the Rule

More than 14,000 public water systems (PWSs), serving approximately 180 million people in the United States and its Territories, use surface water, including ground water under the direct influence of surface water (GWUDI), as their source. These sources often carry microbial pathogens, such as *Giardia*, *E. coli*, and *Cryptosporidium*. Among pathogens in drinking water, *Cryptosporidium* is of particular concern because it is resistant to standard drinking water disinfectants such as chlorine. Ingestion of *Cryptosporidium* causes cryptosporidiosis, a gastrointestinal illness; health effects in sensitive subpopulations may be severe, including death. There is no effective cure for cryptosporidiosis (Framm and Soave 1997). The LT2ESWTR protects public health by requiring PWSs with the highest measured source water levels of *Cryptosporidium* to provide treatment for this pathogen. These vulnerable systems include both filtered systems with elevated levels of *Cryptosporidium* in their source water and all unfiltered systems (i.e., systems meeting the filtration avoidance criteria of the Surface Water Treatment Rule (40 CFR 141.71)), which currently provide little treatment for *Cryptosporidium*. The LT2ESWTR will also reduce the public health risk associated with uncovered finished water reservoirs, which are susceptible to microbial contamination, including *Cryptosporidium*.

EPA will also be promulgating the Stage 2 Disinfectants and Disinfection Byproducts Rule (Stage 2 DBPR), which addresses disinfection byproduct (DBP) formation. The two rules are to be promulgated concurrently to ensure that protection against microbial pathogens is not compromised by efforts to reduce DBP formation. The Stage 2 DBPR and LT2ESWTR represent the final stage of a two-stage strategy to reduce risk from microbial pathogens and DBPs that was developed in a regulatory negotiation effort in 1992 and 1993.[1] These rules reflect recommendations presented by the Stage 2 Microbial and Disinfection Byproducts (M-DBP) Federal Advisory Committee Agreement in Principle, signed in September 2000 (USEPA 2000e).

ES.2 Consideration of Regulatory Alternatives

The Stage 2 M-DBP Advisory Committee met from March 1999 to September 2000 to evaluate whether and to what degree EPA should revise microbial standards to protect public health. The committee reached consensus on an approach for addressing *Cryptosporidium* risk in unfiltered systems

[1]The key outcomes of the 1992-1993 regulatory negotiation effort were to proceed with rules addressing DBPs and microbial pathogens in two stages and to collect relevant information from PWSs for use in the development of these rules and the analysis of their impacts. This two-stage approach was subsequently incorporated into the 1996 Safe Drinking Water Act (SDWA) Amendments. The first stage of the M-DBP rulemaking process culminated with the joint promulgation of the Stage 1 DBPR and the Interim Enhanced Surface Water Treatment Rule (IESWTR) by EPA in December 1998.

and microbial risk in uncovered finished water reservoirs without formally identifying alternative regulatory approaches. For filtered systems, however, several alternatives were considered. All involved a compliance scheme whereby systems choose from a “toolbox” of treatment and managerial options for meeting additional *Cryptosporidium* treatment requirements. The first would have required a single level of additional treatment or removal for all systems regardless of source water *Crytosporidium* levels. The other three alternatives (A2-A4) based their treatment requirements on the *Cryptosporidium* levels in a plant’s source water, as determined by a period of source water monitoring. The alternatives are shown in Exhibit ES.1.

Exhibit ES.1: Summary of Treatment Requirements for Filtered Systems as a Function of Source Water *Cryptosporidium* Concentrations

Source Water *Cryptosporidium* Monitoring Results (oocysts/L)	Additional Treatment Requirements
Alternative A1	
2.0 log treatment required for all systems	
Alternative A2	
< 0.03	No action
≥ 0.03 and < 0.1	0.5 log
≥ 0.1 and < 1.0	1.5 log
≥ 1.0	2.5 log
Alternative A3 - Preferred Alternative	
< 0.075	No action
≥ 0.075 and < 1.0	1 log
≥ 1.0 and < 3.0	2 log
≥ 3.0	2.5 log
Alternative A4	
< 0.1	No action
≥ 0.1 and < 1.0	0.5- log
≥1.0	1.0 log

Notes: "Additional treatment requirements" are for systems with conventional treatment in full compliance with existing rules (the IESWTR and LT1ESWTR). Requirements for systems with other treatment types may differ, and are presented in chapter 1.

The term "log treatment" is used to express the expected percent reduction of a contaminant. For example, 1 log treatment is expected to provide 90 percent reduction of a contaminant and 2 log treatment provides 99 percent reduction. Compliance with the log treatment requirements is not based on quantifying the actual reduction; instead, other finished water quality or operational conditions are used to determine compliance. This is consistent with previous SWTRs.

In this EA, EPA estimates and compares the costs and benefits of all regulatory alternatives. The cost and benefit data presented in section ES.4 are for the Preferred Regulatory Alternative (A3), while section ES.5 presents comparisons of the cost and benefit estimates for all of the alternatives.

ES.3 Summary of the LT2ESWTR Requirements

The LT2ESWTR applies to all PWSs that use surface water or GWUDI (excluding those that purchase all their water). It builds on the SWTR, IESWTR, and the LT1ESWTR by improving control of microbial pathogens, specifically *Cryptosporidium*. Unlike the previous rules, the LT2ESWTR bases its treatment requirements on a system's source water *Cryptosporidium* concentration and the type of treatment already provided. It requires systems to monitor their source water for *Cryptosporidium*, and based on the results, to meet one of four levels of treatment for *Cryptosporidium* (with the first level requiring no additional treatment). The levels of treatment needed at each level will be reassessed in the future based on a second round of source water monitoring under the current rule.

For those systems that do not already provide filtration, the LT2ESWTR has specific requirements to inactivate two or three logs of *Cryptosporidium*, depending on source water monitoring results. It also requires systems with uncovered finished water reservoirs either to cover the reservoirs or to provide additional treatment to the reservoir effluent.

Exhibit ES.2 illustrates each rule activity for the Preferred Regulatory Alternative. The implementation schedules for small and large systems differ; Exhibit ES.3 presents the implementation time line.

Exhibit ES.2: Overview of Key LT2ESWTR Requirements

Systems Subject to the LT2ESWTR

Public water systems using surface water or ground water under direct influence of surface water that are subject to the SWTR. Systems with uncovered finished reservoirs.

Requirements for Uncovered Unfinished Reservoirs

Cover reservoirs or treat discharge to achieve 4 log virus, 3 log *Giardia*, and 2 log *Cryptosporidium* inactivation.

Initial Monitoring for Unfiltered Systems

Monitor *Cryptosporidium* in source water to determine treatment requirements. Exemptions are available for systems that purchase all of their water, provide at least 3 log of treatment, or have 2 years of historical *Cryptosporidium* data.

Large systems (serving at least 10,000 people): sample *Cryptosporidium* monthly for 2 years. Small systems: sample twice per month for 1 year.

Treatment Requirements for Unfiltered Systems

Systems with *Cryptosporidium* levels $\leq$0.01 oocysts/L: provide 2 log inactivation. Systems with *Cryptosporidium* levels >0.01 oocysts/L: must provide 3 log inactivation.

Treatment Options for Unfiltered Systems

Meet *Cryptosporidium* inactivation requirements using ozone, chlorine dioxide, or ultraviolet light.

Initial Monitoring for Filtered Systems

Conduct initial *Cryptosporidium* monitoring to establish bin classification. Exemptions are available for systems that purchase all of their water, provide at least 5.5 log of treatment, or have 2 years of historical *Cryptosporidium* data.

Large systems (serving at least 10,000 people): must monitor monthly for 2 years for *Cryptosporidium*, *E. coli*, and turbidity. Small systems: monitor *E. coli* biweekly for 1 year. If *E. coli* levels exceed trigger, monitor *Cryptosporidium* twice per month for 1 year.

Bin Classification and Treatment Requirements for Filtered Systems

Systems are placed in 1 of 4 "action bins" based on monitoring results. Systems with levels <0.075 oocysts/L: no action. Systems with levels >0.075 but <1.0 oocysts/L: provide additional 1 log treatment. Systems with levels >1.0 but <3.0 oocysts/L: provide an additional 2 log treatment. Systems with levels $\geq$3.0 oocysts/L: provide an additional 2.5 log treatment.

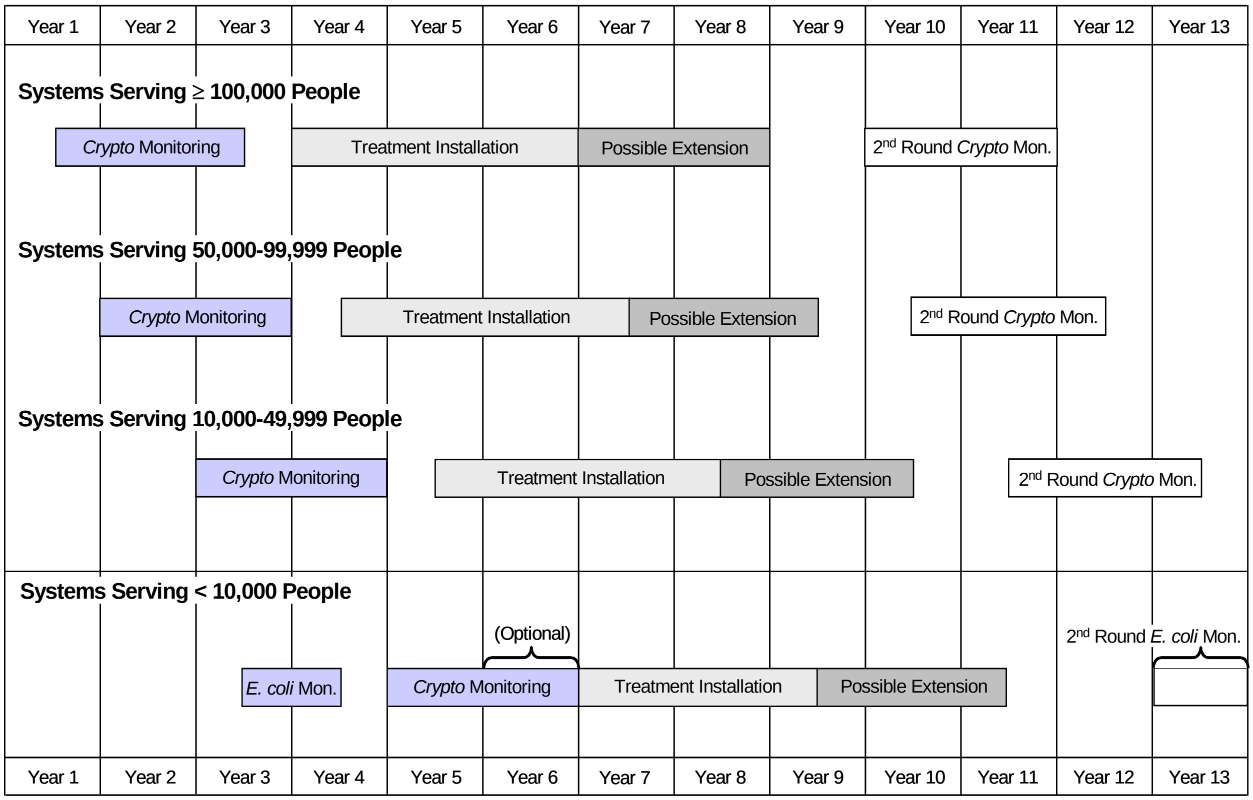
Treatment Options for Filtered Systems

Select from a "toolbox" of treatment or management options.

Future Monitoring and Reassessment

Six years after initial bin classification, conduct a second round of monitoring. Methods, frequency, locations, etc., for this round may change based on stakeholder input, which could lead to a rule amendment. State/primacy agency may also assess any changes in watershed/source water as part of the sanitary survey and determine appropriate action, which could include requiring implementation of additional toolbox options.

Exhibit ES.3: Implementation Timeline for LT2ESWTR for Filtered Systems



Note: This exhibit does not show the reassessment of treatment levels following the second round of source monitoring.

ES.4 National Benefits and Costs of the LT2ESWTR

The benefits resulting from implementation of the LT2ESWTR are due to reductions in the numbers of infectious *Cryptosporidium* oocysts and other pathogens reaching consumers. EPA has quantified the benefits of this rule in terms of avoided endemic cryptosporidiosis illnesses and associated deaths. The effects of reductions in other pathogens, if any, were not quantified.

Cryptosporidium can reach the consumer when there is a significant breakdown in the treatment process, but also under normal operating conditions. This EA focuses on the benefits that result from reducing only the continuous, relatively low levels of *Cryptosporidium* exposure that can occur even under normal operating conditions. Requiring additional treatment is also expected to reduce the frequency and severity of outbreaks; these benefits, however, are not quantified.

The costs incurred for LT2ESWTR activities are associated with rule implementation, source water monitoring, and adding treatment.

ES.4.1 Benefit Estimates

The quantified benefits of the LT2ESWTR are the estimated reduction in the number of illnesses and deaths associated with endemic *Cryptosporidium*. There are also benefits that cannot currently be quantified but are likely to be substantial. These are summarized in Exhibit ES.4 and discussed in Chapter 5.

Exhibit ES.4: Summary of Nonquantified Benefits and Groups Affected

Type of Benefit	Nonquantified Benefits	Group(s) Affected
Health benefits	Reduction in risk to sensitive subpopulations (mortality for those with AIDS and other sensitive subpopulations has been quantified)	Immunocompromised individuals served by systems that make changes to or add treatment
	Reduction in health risk during outbreaks (and response costs)	All individuals served by systems that make changes to or add treatment, including those now served by uncovered finished water reservoirs, (between 46 and 66 million people)
	Reduction in co-occurring or emerging pathogen risk	
	Reduction in endemic morbidity and mortality risk associated with uncovered finished water reservoirs	All individuals receiving water from uncovered finished water reservoirs
	Reduction in health risks from certain DBPs	All individuals served by systems that install physical disinfection technologies like membranes or UV[1]
Nonhealth Benefits	Improved aesthetic water quality	All individuals served by systems that make changes to or add treatment that is likely to reduce taste and odor problems (e.g., ozone)
	Costs of consumers' attempts to avert possible risks	Consumers in systems that cease using uncovered finished water reservoirs (through covering or taking such reservoirs off-line) my have greater confidence in water quality. This may result in less averting behavior that reduces both out-of-pocket costs (e.g., purchase of bottled water) and opportunity costs (e.g., time to boil water).

[1] Systems that install chemical disinfection technologies like ozone may increase certain DBPs.

EPA developed a risk assessment model to predict the illnesses and deaths avoided using certain variables, including the uncertainty in those variables. (Uncertainty means the degree of lack of knowledge of those variables' values.) The variables are occurrence of *Cryptosporidium* in source water, infectivity, water treatment used, average daily water consumption per capita, morbidity, and mortality. To allow a comparison of benefits with the costs of implementing the rule, the estimates of morbidity and mortality are multiplied by a calculated cost of illness (COI) and a standard value of a statistical life, respectively.

There are three data sets for source water occurrence, designated as ICR, ICRSSL, and ICRSSM. The ICR data set is the Information Collection Rule data that all large systems collect. The ICRSSL and ICRSSM data sets represent 40 large systems and 40 medium-size systems from the Information Collection Rule Supplemental Surveys. EPA judges each of these data sets to be equally likely to represent the true distribution of *Cryptosporidium* in source waters for all systems. (Each set has advantages and disadvantages that counteract those of other sets, as described in Chapter 4.) All benefit and cost analyses are carried out using each data set to provide a range of possible benefits and costs. In addition to using the three occurrence data sets, this EA monetizes benefits with two values of COI—referred to as Enhanced and Traditional (see Exhibits ES.6a and ES.6b).

For *Cryptosporidium* infectivity (i.e., the likelihood of exposure to a particular dose of *Cryptosporidium* resulting in infection), EPA considered results from human volunteer feeding studies. Results from three studies were evaluated for the proposed LT2ESWTR, and results from three newer studies were added in the analysis for the final LT2ESWTR. Further, EPA used six different model forms to estimate dose-response relationships with these study results. This analysis and results are described in Chapter 5 and Appendix N.

Variability in host susceptibility, response at very low oocyst doses typical of drinking water ingestion, and the relative infectivity and occurrence of different *Cryptosporidium* isolates in the environment are uncertain. To address this uncertainty, three sets of estimates are presented in this Executive Summary: a "high" estimate based on the model which showed the highest mean baseline risk, a "medium" estimate, based on the model and data used at proposal, which is in the middle of the range of estimates produced by the six models using the newly available data, and a "low" estimate, based on the model which showed the lowest mean baseline risk. These estimates are not upper and lower bounds on illnesses avoided and benefits; for each model, a distribution of effects is estimated, and the "high" and "low" estimates show only the means of these distributions for two different model choices.

Exhibit ES.5 summarizes the estimates of avoided illnesses and deaths resulting from the LT2ESWTR. Exhibits ES.6a and ES.6b summarize the monetized value of those estimates for Enhanced and Traditional COI values (annualized over a 25-year period and discounted at 3 percent and 7 percent) The Traditional COI includes only values of medical costs and lost work time (including some portion of nonmarket household production). The Enhanced COI also includes the values of lost personal (non-work) time, such as child care and homemaking (to the extent not covered by the traditional COI), time with family, and recreation, and lost productivity at work on days when workers are ill but go to work anyway.

Exhibit ES.5: Summary of Annual Illnesses and Deaths Avoided

Data Set	Annual Illnesses Avoided			Annual Deaths Avoided		
	Low	Medium	High	Low	Medium	High
Total after Full implementation						
ICR	358,732	964,360	1,459,126	76	207	314
ICRSSL	89,375	230,730	372,507	20	52	84
ICRSSM	177,101	455,170	711,123	39	100	156
Annual Average over 25 years						
ICR	264,980	712,732	1,078,796	57	154	232
ICRSSL	66,187	170,977	276,078	15	39	62
ICRSSM	130,918	336,652	438,203	29	74	116

Source: Chapter 8, Exhibit 8.3.

Note: High, medium and low estimates reflect the mean estimates for a range of dose-response modeling assumptions. See Appendix N for more detail.

Exhibit ES.6a: Summary of Monetized Benefits—Enhanced Cost of Illness

Data Set	Value of Benefits ($ Millions, 2003$)		
	Low	Medium	High
Annualized Value (at 3%, 25 Years)			
ICR	$ 687	$ 1,853	$ 2,822
ICRSSL	$ 177	$ 458	$ 744
ICRSSM	$ 344	$ 886	$ 1,393
Annualized Value (at 7%, 25 Years)			
ICR	$ 556	$ 1,501	$ 2,286
ICRSSL	$ 144	$ 371	$ 603
ICRSSM	$ 279	$ 718	$ 1,128

Exhibit ES.6b: Summary of Monetized Benefits—Traditional Cost of Illness

Data Set	Value of Benefits ($ Millions, 2003$)		
	Low	Medium	High
Annualized Value (at 3%, 25 Years)			
ICR	$ 497	$ 1,341	$ 2,047
ICRSSL	$ 130	$ 335	$ 546
ICRSSM	$ 250	$ 644	$ 1,014
Annualized Value (at 7%, 25 Years)			
ICR	$ 403	$ 1,089	$ 1,662
ICRSSL	$ 105	$ 272	$ 443
ICRSSM	$ 203	$ 523	$ 824

Source: Chapter 8, Exhibits 8.4a and 8.4b.

Note: High, medium and low estimates reflect the mean estimates for a range of dose-response modeling assumptions. See Appendix N for more detail.

ES.4.2 National and Household Cost Estimates

The total national costs of the LT2ESWTR include costs to systems and States/Primacy Agencies for implementation and compliance. This EA estimates costs for all rule-related activities: implementation, source water monitoring, adding treatment, and compliance reporting. EPA assumes nearly all surface water and GWUDI systems will incur rule implementation and initial source water monitoring costs. Compliance reporting costs are estimated only for those systems predicted to add treatment.

Approximately 90 percent[2] of the estimated total national costs are for systems to meet additional treatment requirements. EPA developed a least-cost approach to modeling treatment costs. The approach is constrained to reflect site-specific conditions. The following series of steps was used to develop treatment cost estimates for compliance with the rule.

1. Predict the percent of systems falling into each bin based on a model of source water occurrence.

2. Model unit costs for each treatment technology.

3. Develop a technology forecast for each bin using the least-cost approach and estimates of the maximum number of systems that will apply any one technology.

4. Calculate the number of plants selecting each technology.

5. Multiply the number of plants per technology by the technology's unit cost.

[2] Derived from Exhibit 6.3 using ICR data.

Exhibit ES.7 summarizes the system costs associated with the LT2ESWTR.

Exhibit ES.7: Summary of System Costs ($ Millions, 2003$)

Source: Exhibit 8.11.

Data Set	Capital and One-Time (Undiscounted at Full Implementation)			Operation and Maintenance (Undiscounted at Full Implementation)		
	Mean	90% Confidence Bound: Lower (5th %ile)	90% Confidence Bound: Upper (95th %ile)	Mean	90% Confidence Bound: Lower (5th %ile)	90% Confidence Bound: Upper (95th %ile)
	Nominal Costs					
ICR	$ 2,104	$ 1,715	$ 2,425	$ 55	$ 48	$ 64
ICRSSL	$ 1,526	$ 1,164	$ 1,743	$ 33	$ 26	$ 39
ICRSSM	$ 1,719	$ 1,372	$ 1,941	$ 39	$ 33	$ 45

Data Set	Total Annualized Costs at 3%			Total Annualized Costs at 7%		
	Mean	90% Confidence Bound: Lower (5th %ile)	90% Confidence Bound: Upper (95th %ile)	Mean	90% Confidence Bound: Lower (5th %ile)	90% Confidence Bound: Upper (95th %ile)
ICR	$ 133	$ 111	$ 160	$ 150	$ 125	$ 181
ICRSSL	$ 93	$ 72	$ 112	$ 107	$ 83	$ 129
ICRSSM	$ 106	$ 86	$ 126	$ 121	$ 99	$ 144

EPA assumes that systems will generally pass the costs of a new regulation on to their customers in the form of rate increases. Household costs, which are in units of *$ per household per year*, are estimated in order to provide a measure of the increase in water bills that could be expected to result from the LT2ESWTR. Exhibit ES.8 summarizes household costs for those systems predicted to require additional treatment.

Exhibit ES.8: Summary of Annual Household Cost Increases[1]
($ per Year, 2003$)

System Type/Size	Households	Mean	Median	90th Percentile	95th Percentile	Percent of Systems with Household Cost Increase < $12	Percent of Systems with Household Cost Increase < $120
ICR							
All CWS	68,857,992	$2.59	$0.21	$6.43	$9.97	96.49%	99.99%
CWS ≤ 10,000	5,587,602	$4.14	$0.56	$9.97	$14.79	91.19%	99.88%
CWS < 500	158,900	$13.09	$3.86	$28.66	$53.60	63.20%	98.87%
ICRSSL							
All CWS	68,857,992	$1.67	$0.09	$6.37	$6.42	97.96%	100.00%
CWS ≤ 10,000	5,587,602	$2.49	$0.36	$6.60	$9.37	96.46%	99.94%
CWS < 500	158,900	$8.58	$2.91	$17.44	$29.01	72.61%	99.50%
ICRSSM							
All CWS	68,857,992	$1.97	$0.09	$6.37	$6.85	97.47%	99.99%
CWS ≤ 10,000	5,587,602	$3.00	$0.49	$7.02	$11.39	95.19%	99.93%
CWS < 500	158,900	$10.10	$2.90	$26.24	$35.97	68.73%	99.31%
ICR - High							
All CWS	68,857,992	$2.84	$0.21	$6.43	$9.97	96.09%	99.99%
CWS ≤ 10,000	5,587,602	$4.58	$0.61	$11.50	$15.30	90.22%	99.86%
CWS < 500	158,900	$7.21	$2.91	$16.81	$26.25	75.79%	99.80%
ICRSSL - Low							
All CWS	68,857,992	$1.42	$0.03	$5.65	$6.42	98.37%	100.00%
CWS ≤ 10,000	5,587,602	$2.06	$0.23	$6.58	$7.47	97.21%	99.96%
CWS < 500	158,900	$14.42	$4.79	$30.00	$54.42	62.07%	98.58%

[1]Annualized at discount rates varied by system size and ownership (see Appendix J, Exhibit J.2).

Source: Exhibit 6.18.

ES.5 National Net Benefits and Summary of Comparison of Alternatives

The national net benefits (benefits remaining after costs are taken into account) for each of the regulatory alternatives are shown in Exhibit ES.9. The cells outlined in bold show where net benefits are highest for a particular combination of regulatory alternative, occurrence data set, cost of illness assumptions, and discount rate. The annualized net national benefits for the Preferred Alternative (A3 in Exhibit ES.1.) range from $18 million to $2.67 billion, depending on occurrence, infectivity model, cost of illness, and discount rates used.

From Exhibit ES.9, several important economic questions can be answered. First, the Preferred Alternative (A3) has positive net benefits under all assumptions, a key threshold test of the reasonableness of a regulation. This is also true for Alternatives A4 under all combinations of occurrence, cost of illness, and discount rates, and true for Alternative A1 and A2 for most of the combinations. In addition, this exhibit shows that the Preferred Alternative (A3) produces the highest net benefits of each alternative under 8 of 12 combinations of assumptions, and near the highest net benefits under 4 of 12 combinations.

Exhibit ES.9a: Comparison of Mean Net Benefits for All Regulatory Alternatives—Enhanced Cost of Illness ($Millions, 2003$)

Data Set	Rule Alternative	Annualized Value					
		3%, 25 Years			7%, 25 Years		
		Low	Medium	High	Low	Medium	High
ICR	A1	$ 260	$ 1,492	$ 2,447	$ 126	$ 1,098	$ 1,897
	A2	$ 498	$ 1,708	$ 2,655	$ 366	$ 1,333	$ 2,112
	A3 - Preferred	$ 527	$ 1,720	$ 2,662	$ 396	$ 1,351	$ 2,126
	A4	$ 550	$ 1,673	$ 2,566	$ 427	$ 1,328	$ 2,061
ICRSSL	A1	$ (223)	$ 156	$ 466	$ (265)	$ 15	$ 292
	A2	$ 43	$ 366	$ 647	$ 6	$ 257	$ 496
	A3 - Preferred	$ 65	$ 365	$ 632	$ 32	$ 264	$ 491
	A4	$ 87	$ 347	$ 589	$ 58	$ 261	$ 465
ICRSSM	A1	$ (58)	$ 578	$ 1,104	$ (132)	$ 358	$ 809
	A2	$ 198	$ 782	$ 1,285	$ 130	$ 591	$ 1,010
	A3 - Preferred	$ 218	$ 780	$ 1,267	$ 153	$ 597	$ 1,002
	A4	$ 230	$ 731	$ 1,171	$ 172	$ 569	$ 935

Exhibit ES.9b: Comparison of Mean Net Benefits for All Regulatory Alternatives—Traditional Cost of Illness ($Millions, 2003$)

Data Set	Rule Alternative	Annualized Value					
		3%, 25 Years			7%, 25 Years		
		Low	Medium	High	Low	Medium	High
ICR	A1	$ 64	$ 967	$ 1,649	$ (31)	$ 675	$ 1,256
	A2	$ 305	$ 1,190	$ 1,870	$ 211	$ 917	$ 1,481
	A3 - Preferred	$ 337	$ 1,208	$ 1,887	$ 243	$ 939	$ 1,502
	A4	$ 373	$ 1,193	$ 1,842	$ 285	$ 941	$ 1,478
ICRSSL	A1	$ (284)	$ 0	$ 214	$ (315)	$ -109	$ 90
	A2	$ (9)	$ 233	$ 432	$ (35)	$ 150	$ 324
	A3 - Preferred	$ 18	$ 242	$ 433	$ (7)	$ 166	$ 331
	A4	$ 46	$ 242	$ 418	$ 25	$ 175	$ 327
ICRSSM	A1	$ (165)	$ 306	$ 676	$ (218)	$ 138	$ 465
	A2	$ 99	$ 529	$ 890	$ 50	$ 387	$ 692
	A3 - Preferred	$ 124	$ 538	$ 889	$ 77	$ 402	$ 698
	A4	$ 148	$ 518	$ 840	$ 106	$ 398	$ 668

Notes: The traditional COI includes only values of medical costs and lost work time (including some portion of nonmarket household production). The enhanced COI also includes the values of lost personal (non-work) time such as child care and homemaking (to the extent not covered by the traditional COI), time with family, and recreation, and lost productivity at work on days when workers are ill but go to work anyway.
High, medium and low estimates reflect the mean estimates for a range of dose-response modeling. assumptions. See Appendix N for more detail.

Source: Exhibits 8.12a and 8.12b.

Another key economic test is whether the proposed rule is cost-effective. Exhibits ES.10a and ES.10b together show the annualized value of benefits and costs for the four alternatives, calculated for each combination of occurrence data sets, COI values, and discount rates. For each alternative, the graph plots the mean benefit versus its corresponding range of cost estimates (a 90 percent confidence bound shown as a vertical bar). A trend line connects the mean estimate of costs for each alternative. These graphs help to show the concept of cost-effectiveness and to compare the alternatives.

Cost-effectiveness can be defined simply as getting the greatest benefit for a given expenditure or imposing the least cost for a given level of benefit. In Exhibits ES.10a and ES.10b, the test would be to see if any regulatory alternative was to the right and completely below any other alternative on the graph. If so, the alternative to the right and below would be more cost-effective and would dominate the alternative that provided fewer benefits at higher costs.

In the strict sense, each of the regulatory alternatives is cost-effective—no regulatory alternative provides more benefits at the same or a lower cost than another, and no alternative can achieve lower costs for the same or a greater level of benefits than another. Thus, no alternative dominates any other or is more cost-effective. Instead, the alternatives offer increasing levels of benefits at increasing levels of cost. Chapter 8 provides additional analyses on cost effectiveness.

In addition to allowing a visual comparison of cost effectiveness, the exhibits show information about the incremental benefits of each alternative. Compared to Alternative A4, the Preferred Alternative achieves significant incremental benefits (the change in benefits from one alternative to another) at a relatively low increase in costs. The step from the Preferred Alternative to Alternative A2 achieves more benefits, but at a higher incremental rate. The step to Alternative A1 achieves a similar increase in benefits, but at a significantly higher cost. The Preferred Alternative, and perhaps Alternative A2, appear to be good values; other alternatives have either significantly fewer benefits for similar costs, or greater benefits at dramatically higher costs.

Exhibit ES.10a: Comparison of Mean—Enhanced Cost of Illness[1]

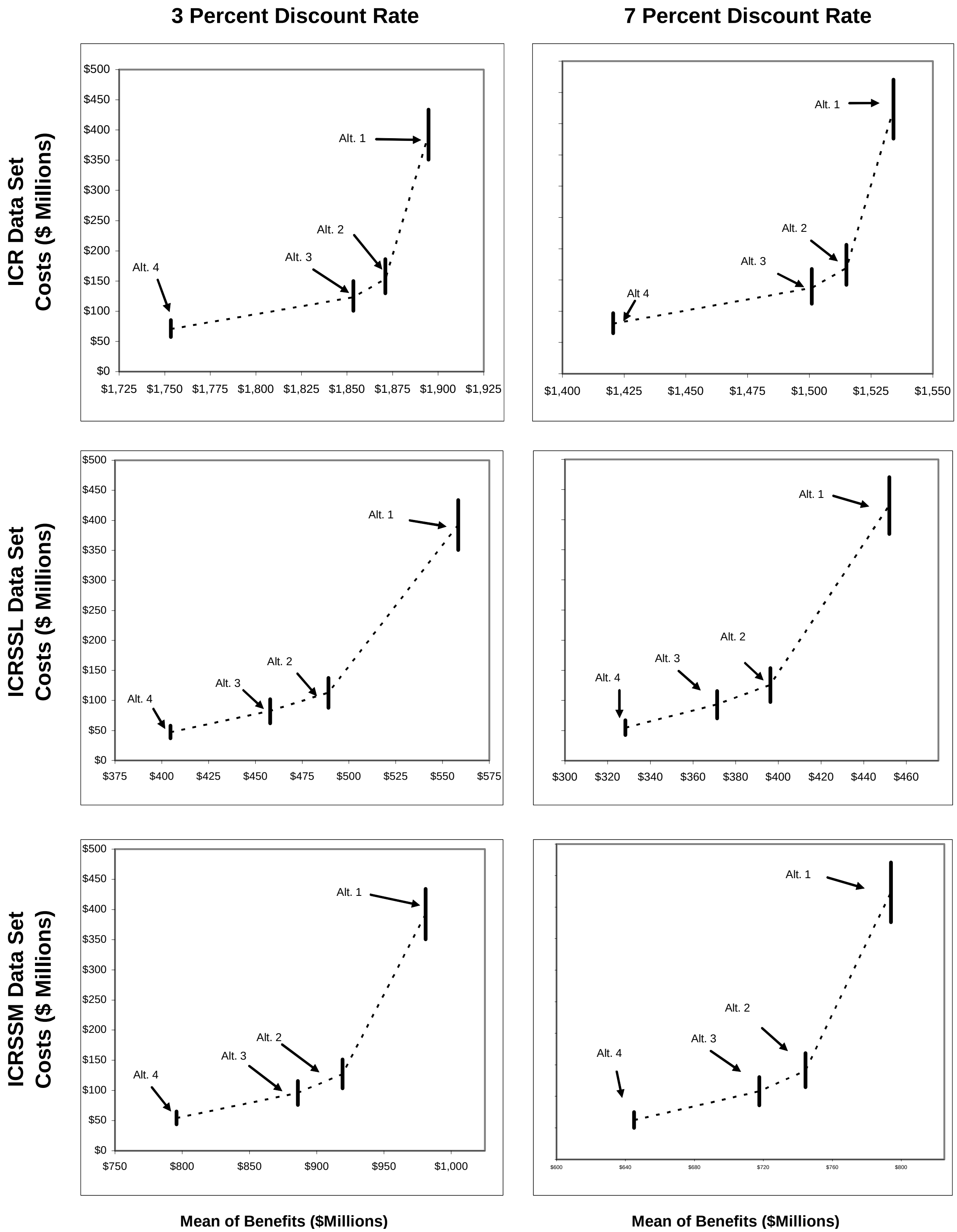
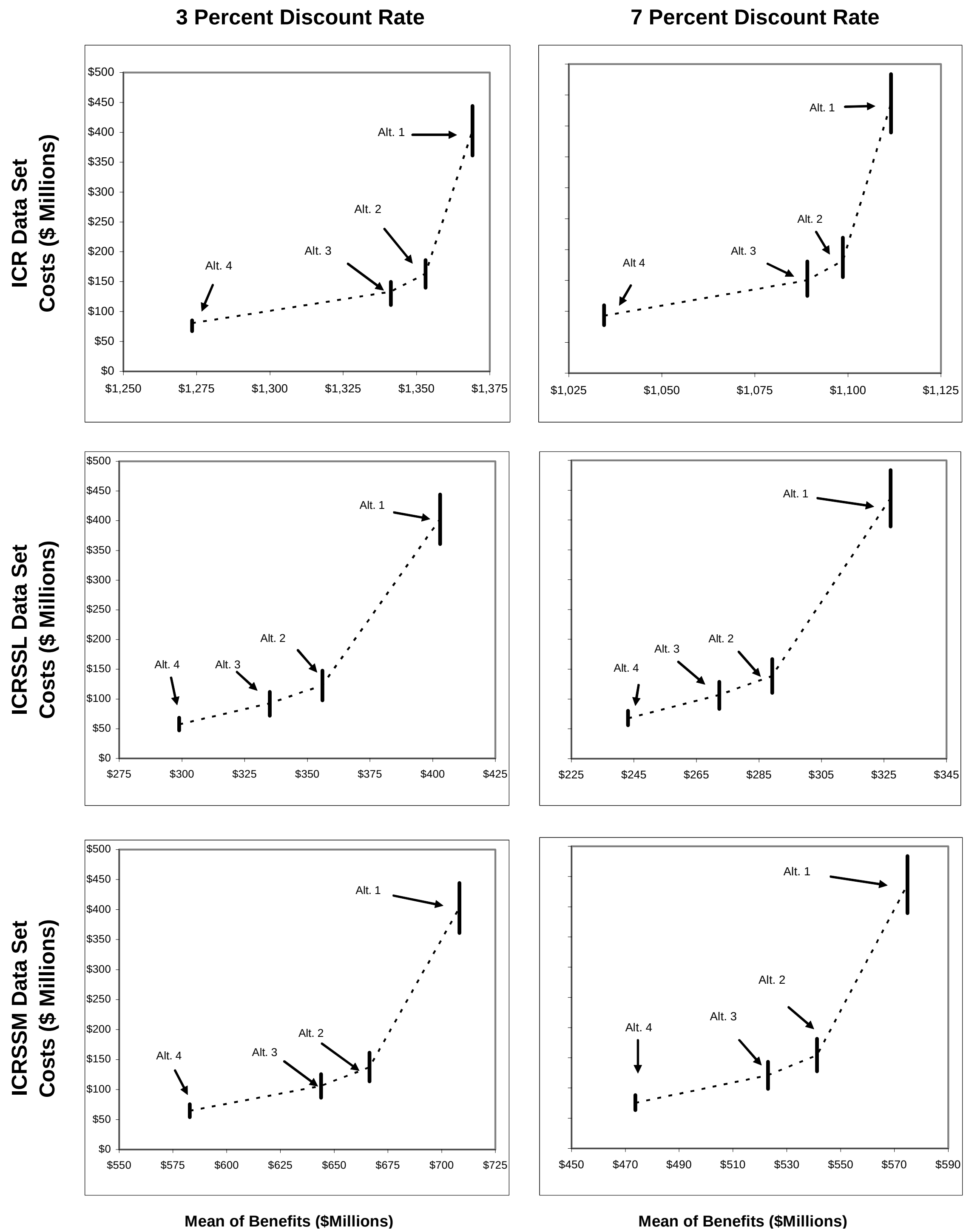


Exhibit ES.10b: Comparison of Mean—Traditional Cost of Illness[1]



Notes on Exhibits ES.10a and 10b: The traditional COI includes only values of medical costs and lost work time (including some portion of nonmarket household production). The enhanced COI also includes the values of lost personal (non-work) time such as child care and homemaking (to the extent not covered by the traditional COI), time with family, and recreation, and lost productivity at work on days when workers are ill but go to work anyway.

Source: Exhibit 8.7.

Cost effectiveness is generally used for determining which alternatives meet a certain criterion-a threshold for costs or minimum cases avoided. A comparison of cost effectiveness is made in Exhibit ES 11 between the cost per MILY of alternative rules (based on the various combinations of dose-response model, COI approach, Cryptosporidium occurrence data set, and discount rate) and cost thresholds found in the literature.

As expected, Exhibit ES 11 shows that the cost per MILY saved increases with regulatory cost and stringency: A4 has the lowest cost per MILY, the Preferred Alternative has the next lowest cost per MILY, etc. Alternative A4 is cost saving under most combinations of assumptions (23 of 36 combinations). Cost saving simply means the regulation is saving more in avoided costs for medical and lost time associated with avoided cases than the actual cost of the rule. The Preferred Alternative A3 is also cost saving under many of the combinations (16 of 36), as is the next more stringent alternative, A2 (12 of 36 combinations).

These cost per MILY ratios are compared to prima facie cost per MILY thresholds, with the understanding that the thresholds are arbitrary values, often derived by reference to the cost per QALY (or MILY) for interventions that public health specialists agree are justified. The Harvard Cost Utility Analysis database presents a median cost-utility ratio of $31,000 per QALY (or MILY) (2002$) for respiratory and cardiovascular interventions, while Tengs et al. (1995) report a median cost per life-year saved for life-saving interventions of $48,000 (1993$). The health economics literature often uses either $50,000 or $100,000 per QALY (or MILY) as a threshold with ratios less than these values considered prima facie cost effective. In general, EPA recommends that decisions as to whether a specific control strategy is justified should be based on a complete comparison of benefits and costs.

In the majority of combinations of assumptions, Exhibit ES 9 shows larger net benefits for the Preferred Alternative A3 than for Alternative A4 (21 of 36) and Alternative A2 (28 of 36). Therefore, only the Preferred Alternative A3 is compared to the cost-utility thresholds in this summary, however, complete results for all alternatives under all assumptions are shown in Exhibit ES 9.

The Preferred Alternative A3 is cost effective compared to the lowest of these thresholds in most combinations of assumptions. In comparison to prima facie cost-utility ratios of $31,000 per MILY and $50,000 per MILY, the Preferred Alternative A3 is cost effective in 30 of 36 and 33 of 36 possible combinations of assumptions, respectively.

Exhibit ES.11a: Cost Effectiveness Analysis Based on Low, Medium, and High Estimate Dose Response Models Using the Enhanced COI Approach, by Data Set, by Rule Alternative, 3% and 7% Discount Rates

Data Set	Rule Alternative	Cost per MILY[1] Saved ($)					
		3%, 25 Years			7%, 25 Years		
		Low	Medium	High	Low	Medium	High
ICR	A1	$ 62,646	$ 4,789	cost saving	$ 87,814	$ 14,392	cost saving
	A2	$ 6,997	cost saving	cost saving	$ 18,248	cost saving	cost saving
	A3 - Preferred	$ 226	cost saving	cost saving	$ 9,887	cost saving	cost saving
	A4	cost saving	cost saving	cost saving	cost saving	cost saving	cost saving
ICRSSL	A1	$ 263,970	$ 86,424	$ 42,135	$ 343,263	$ 117,942	$ 61,780
	A2	$ 69,348	$ 9,299	cost saving	$ 100,080	$ 21,479	$ 2,463
	A3 - Preferred	$ 48,806	$ 1,342	cost saving	$ 74,863	$ 11,648	cost saving
	A4	$ 22,705	cost saving	cost saving	$ 41,241	cost saving	cost saving
ICRSSM	A1	$ 138,642	$ 36,566	$ 13,753	$ 184,254	$ 54,711	$ 26,455
	A2	$ 29,183	cost saving	cost saving	$ 47,410	$ 996	cost saving
	A3 - Preferred	$ 16,993	cost saving	cost saving	$ 32,383	cost saving	cost saving
	A4	$ 995	cost saving	cost saving	$ 11,705	cost saving	cost saving

Footnote 1: MILYs (Morbidity Inclusive Life Years) are a combination of life years gained from avoided premature mortality plus QALYs (Quality-Adjusted Life Years) gained from avoided morbidity.

Exhibit ES.11b: Cost Effectiveness Analysis Based on Low, Medium, and High Estimate Dose Response Models Using the Traditional COI Approach, by Data Set, by Rule Alternative, 3% and 7% Discount Rates

Data Set	Rule Alternative	Cost per MILY[1] Saved ($)					
		3%, 25 Years			7%, 25 Years		
		Low	Medium	High	Low	Medium	High
ICR	A1	$ 75,165	$ 17,241	$ 5,585	$ 100,095	$ 26,608	$ 11,827
	A2	$ 19,491	cost saving	cost saving	$ 30,505	$ 795	cost saving
	A3 - Preferred	$ 12,701	cost saving	cost saving	$ 22,125	cost saving	cost saving
	A4	$ 1,260	cost saving	cost saving	$ 7,501	cost saving	cost saving
ICRSSL	A1	$ 276,517	$ 98,897	$ 54,616	$ 355,572	$ 130,177	$ 74,023
	A2	$ 81,618	$ 21,518	$ 6,980	$ 112,117	$ 33,465	$ 14,454
	A3 - Preferred	$ 60,927	$ 13,420	$ 2,050	$ 86,753	$ 23,496	$ 8,369
	A4	$ 34,520	$ 3,291	cost saving	$ 52,831	$ 10,406	$ 412
ICRSSM	A1	$ 151,183	$ 49,037	$ 27,346	$ 196,557	$ 66,945	$ 39,752
	A2	$ 41,597	$ 5,981	cost saving	$ 59,587	$ 13,112	$ 2,581
	A3 - Preferred	$ 29,323	$ 1,138	cost saving	$ 44,478	$ 7,127	cost saving
	A4	$ 13,084	cost saving	cost saving	$ 23,564	cost saving	cost saving

Footnote 1: MILYs (Morbidity Inclusive Life Years) are a combination of life years gained from avoided premature mortality plus QALYs (Quality-Adjusted Life Years) gained from avoided morbidity.

The Preferred Alternative (A3) was also evaluated against the other alternatives with respect to key uncertainty variables. EPA conducted a series of sensitivity analyses to examine the effects of exaggerating one uncertain variable while holding all others constant. These analyses tested the following uncertain variables: the assumptions regarding loss of productivity and the value of nonmarket work and leisure time in computing the cost of illness, the value of AIDS-related mortality rate, and the overall value of benefits (presented in Appendix P, Appendix R, and Chapter 8, respectively). In addition to the sensitivity analyses, the main body of the EA uses two possible values for the cost of illness. Further, uncertainty in the occurrence of *Cryptosporidium* in source water is addressed by carrying out separate analyses throughout the EA for the three possible occurrence distributions as well as confidence bounds of the occurrence distributions. The results of all tests show that benefits still exceed costs for the Preferred Alternative, it remains the favored alternative in the majority of conditions analyzed, and no other alternative performs as well across the range of possible occurrence and values for benefits.

The Stage 2 Microbial Disinfectants and Disinfection Byproducts (Stage 2 M-DBP) Advisory Committee recommended Alternative A3. Based on the recommendation, and supported by EPA's evaluations of benefits and costs, EPA selected Alternative A3 as the proposed rule.

1. Introduction

This document presents an analysis of the costs and benefits of the Long Term 2 Enhanced Surface Water Treatment Rule (LT2ESWTR). The analysis is performed in compliance with Executive Order 12866, *Regulatory Planning and Review* (58 Federal Register (FR) 51735), which requires that the U.S. Environmental Protection Agency (EPA) estimate the economic impact of rules costing more than $100 million annually and submit the analysis in conjunction with publishing the rule.

This chapter provides a summary of the LT2ESWTR in section 1.1 and describes the organization of the Economic Analysis (EA) in section 1.2.

1.1 Summary

The LT2ESWTR builds on the Interim Enhanced Surface Water Treatment Rule (IESWTR) and the Long Term 1 Enhanced Surface Water Treatment Rule (LT1ESWTR) by improving control of microbial pathogens, specifically the contaminant *Cryptosporidium*[1]. The LT2ESWTR also addresses the tradeoff between competing risks that is posed by the simultaneous control of microbial pathogens and disinfection byproducts (DBPs). The disinfectants commonly used to kill microorganisms react with naturally occurring organic and inorganic matter in source water, forming DBPs that are known to have adverse health effects, including cancer and developmental and reproductive effects. In order to balance the risks posed by DBPs and microbial pathogens, the LT2ESWTR will be promulgated concurrently with the Stage 2 Disinfection Byproducts Rule (DBPR). This will make it easier for water systems to comply with both rules. The LT2ESWTR applies to all community water systems (CWSs) and noncommunity water systems (NCWSs) that use surface water or ground water under the direct influence of surface water (GWUDI) as a source.

The intent of the LT2ESWTR is to supplement existing microbial treatment requirements for systems where additional public health protection is needed. The rule will require filtered systems to monitor their source water for *Cryptosporidium*. Based on the results, filtered systems must meet one of four levels of treatment for *Cryptosporidium* (with the first level requiring no additional treatment). All unfiltered systems, which are not currently required to provide any treatment for *Cryptosporidium*, must achieve 2 or 3 log *Cryptosporidium* inactivation, depending on their source water *Cryptosporidium* levels. The rule also requires systems with uncovered finished water reservoirs either to cover the reservoirs or to provide additional treatment to reservoir effluent. The rule's provisions are described in detail below.

1.1.1 Monitoring and Treatment Requirements for Filtered Systems

Systems must first monitor source water *Cryptosporidium* concentrations; based on those results, they are assigned to different treatment bins. Within each bin, systems will choose technologies from a toolbox of options for ensuring *Cryptosporidium* removal or inactivation from treated water. The bins for source waters with higher concentrations of *Cryptosporidium* involve treatment options that provide higher levels of inactivation and/or removal.

[1] IESWTR (63 FR 69477 December 1998), LT1ESWTR (67 FR 1811 January 2002)

Initial Monitoring for Bin Classification—Systems Serving at Least 10,000 People[2]

Medium and large filtered systems (those serving at least 10,000 people) will be required to monitor their raw water sources for *Cryptosporidium* at each plant at least once per month for a minimum of 2 years. Bin classification will be based on one of the following:

- The highest 12-month running annual average *Cryptosporidium* concentration (in oocysts per liter) if samples are taken monthly (24 samples total), or

- The 2-year mean *Cryptosporidium* concentration. The facility may conduct monitoring twice per month for 24 months (48 samples total) or perform additional sampling and include these results in the calculation of the mean, but the additional samples must be evenly distributed over the 2-year monitoring period.

Cryptosporidium analysis must be conducted in accordance with EPA Method 1622/23 using a sample volume of at least 10 liters.[3] Samples must also be analyzed for *E. coli* and turbidity. EPA and stakeholders will use the *E. coli* and turbidity data to evaluate methods for predicting *Cryptosporidium* occurrence.

Systems with at least 2 years of historical *Cryptosporidium* data that are equivalent in sample number, frequency, and quality to data required under the LT2ESWTR may use these data to determine bin classification in lieu of additional *Cryptosporidium* compliance monitoring, if the State approves the use of these data.

Monitoring for systems serving at least 100,000 people starts no later than 6 months after promulgation of the LT2ESWTR. Monitoring for systems serving at least 50,000 people and fewer than 100,000 people starts no later than 12 months after promulgation of the LT2ESWTR. Monitoring for systems serving at least 10,000 people and fewer than 50,000 people starts no later than 24 months after promulgation of the LT2ESWTR. Systems will submit monitoring data to EPA as they are generated; they will then be entered into an EPA database. At the end of the 2-year monitoring period, EPA will give the results to the States/Primacy Agencies, which will then work with their systems to determine appropriate compliance steps.

Initial Monitoring for Bin Classification—Systems Serving Fewer than 10,000 People

Source water monitoring for small systems (those serving fewer than 10,000 people) will begin 2 years after the first large systems initiate source water *Cryptosporidium* monitoring. The required monitoring is on a delayed schedule so EPA can incorporate information on *E. coli* and turbidity collected by the medium and large systems into the monitoring requirements. (EPA will examine these data and their use as indicators of *Cryptosporidium.*) In the absence of a new indicator, small systems will conduct 1 year of biweekly *E. coli* source water monitoring and will be required to conduct *Cryptosporidium* monitoring only if *E. coli* concentrations exceed the following levels:

- An annual mean concentration greater than 10 *E. coli* per 100 mL for lake and reservoir source waters; or

---

[2] The monitoring and treatment requirements for wholesale systems—i.e., those that sell water only to other systems—are dependent on the population served by the largest system in the combined distribution system.

[3] Systems must meet all requirements of the analytical methods for *Cryptosporidium*, which include analysis of two matrix spiked samples.

- An annual mean concentration greater than 50 *E. coli* per 100 mL for flowing stream source waters.

Systems that do not exceed these levels are assumed to have a *Cryptosporidium* concentration of less than 0.075 oocysts/L and are placed in Bin 1 (see Exhibit 1.1). Small systems that exceed the *E. coli* levels mentioned above will be required to conduct semimonthly *Cryptosporidium* monitoring for a 1-year period or monthly for a 2-year period, beginning 6 months after the conclusion of *E. coli* monitoring. Bin classification for small systems conducting *Cryptosporidium* monitoring is determined by the highest 12-month running annual average.

All filtered systems that provide or will provide 5.5 log treatment[4] for *Cryptosporidium* by the date they must comply with additional *Cryptosporidium* treatment requirements are exempt from monitoring and subsequent bin classification. To meet the requirement for 5.5 log treatment, systems using conventional treatment would be required to provide 2.5 log additional treatment, and systems using direct filtration would be required to provide 3 log additional treatment.

Bins and Treatment Requirements—All System Sizes

Exhibit 1.1 presents the bins for filtered systems according to the type of treatment already in place. Systems must meet *Cryptosporidium* treatment requirements by using one of the treatment options in the "microbial toolbox," or by demonstrating performance equivalent to or exceeding the required treatment. Systems have 3 years after first being assigned to a bin to meet the treatment requirements associated with the bin. States/Primacy Agencies may grant systems a 2-year extension to comply if capital investments are necessary.

---

[4]The term "log removal" is used when the contaminant is eliminated by way of filtration; "log inactivation" is used when oocysts are killed by disinfection. The term "log treatment" encompasses both removal and inactivation, and is used to reflect the fact that under the LT2ESWTR, treatment will be achieved using a combination of filtration, disinfection, and other non-traditional methods.

Exhibit 1.1: Bin Classifications and Treatment Requirements for Filtered Systems

If your source water *Cryptosporidium* concentration (oocysts/L) is . . .	Your bin classification is . . .	And if you use the following filtration treatment in full compliance with existing regulations, then your *additional* treatment requirements are . . .			
		Conventional Filtration	**Direct Filtration**	**Slow Sand or Diatomaceous Earth Filtration**	**Alternative Filtration Technologies**
< 0.075	**1**	No additional treatment	No additional treatment	No additional treatment	No additional treatment
$\geq$ 0.075 and < 1.0	**2**[1]	1 log treatment	1.5 log treatment	1 log treatment	As determined by the State[2]
$\geq$ 1.0 and < 3.0	**3**[3]	2 log treatment	2.5 log treatment	2 log treatment	As determined by the State[4]
$\geq$ 3.0	**4**[3]	2.5 log treatment	3 log treatment	2.5 log treatment	As determined by the State[5]

[1]Systems may use any technology or combination of technologies from the microbial toolbox.

[2]Total *Cryptosporidium* treatment must be at least 4.0 log.

[3]Systems must achieve at least 1 log of the required treatment using ozone, chlorine dioxide, ultraviolet light (UV), membranes, bag/cartridge filters, or bank filtration.

[4]Total *Cryptosporidium* treatment must be at least 5.0 log.

[5]Total *Cryptosporidium* treatment must be at least 5.5 log.

The total *Cryptosporidium* treatment required for Bins 2, 3, and 4 is 4.0 log, 5.0 log, and 5.5 log, respectively. The additional treatment requirements in Exhibit 1.1 are based on a determination that conventional, slow sand, and diatomaceous earth filtration plants in compliance with the IESWTR or LT1ESWTR achieve an *average* of 3 log removal of *Cryptosporidium*. (The IESWTR and LT1ESWTR require systems to achieve 2 log removal; this number is based on the *minimum* removal expected with these types of filtration.) Therefore, conventional, slow sand, and diatomaceous earth filtration plants will require an additional 1.0 to 2.5 log additional treatment to meet the total removal requirement, depending on the bin in which they are placed.

EPA has determined that direct filtration plants achieve an average 2.5 log removal of *Cryptosporidium*. (Their removal is less than in conventional filtration because they lack a sedimentation process.) Consequently, under the LT2ESWTR, direct filtration plants in Bins 2–4 must provide 0.5 log more in additional treatment than conventional plants to meet the total *Cryptosporidium* treatment requirement.

Microbial Toolbox for Meeting Additional Treatment Requirements

To meet the *Cryptosporidium* treatment requirements for the bin in which they are classified, filtered systems can select from a "toolbox" of treatment or management options. The technologies and management strategies in the microbial toolbox are presented in Exhibit 1.2. Each option in the toolbox is worth a certain amount of log treatment credit, which systems can apply toward their log treatment requirements. Systems do not get the log credit automatically when they install these technologies; they must show that they are meeting certain operational or other criteria specific to the technology. Log treatment credit under existing rules (e.g., the IESWTR and LT1ESWTR) works much the same way. Systems currently using ozone, chlorine dioxide, ultraviolet light (UV), or membranes in addition to conventional treatment may receive credit for those technologies toward meeting bin requirements if they meet the LT2ESWTR criteria for the chosen technology.

Exhibit 1.2: Microbial Toolbox Components for the LT2ESWTR (To be used in addition to existing treatment)

Toolbox Option	Log Treatment Credit
Source Toolbox Components	
Watershed control program	0.5
Alternative source/intake management	None, but conduct source water monitoring concurrently at both sources or under both intake management plans and determine the bin based on the lower mean concentration
Pre-Filtration Toolbox Components	
Presedimentation basin with coagulation	0.5
Two-stage lime softening	0.5
Bank filtration	0.5 or 1.0, depending on setback
Treatment Performance Toolbox Components	
Combined filter performance	0.5
Individual filter performance	1.0
Demonstration of performance	State approved[1]
Additional Filtration Toolbox Components	
Bag filters	2.0 as individual and 2.5 for two in series
Cartridge filters	2.0 as individual and 2.5 for two in series
Membrane filtration	As demonstrated[2]
Second stage filtration	0.5
Slow sand filters	2.5
Inactivation Toolbox Components	
Chlorine dioxide	As demonstrated[3]
Ozone	As demonstrated[3]
UV	As demonstrated[2]

[1]The State must approve the method used to demonstrate performance and must approve the log credit claimed by the system.

[2]Credit for membrane filtration and UV is based on the results of equipment-specific testing.

[3]Credit for chlorine dioxide and ozone is based on CT values achieved (CT is the product of disinfectant concentration and contact time).

Reassessment and Future Monitoring

Six years after initial bin classification, systems will be required to conduct a second round of monitoring to reassess source water conditions for bin assignments. Two years before this reassessment (4 years after initial binning), EPA plans to initiate a stakeholder process to review available analytical methods for detecting *Cryptosporidium*. If there are new, improved methods, EPA, with stakeholder input, will determine the appropriate analytical method, frequency, and locations for the second round of national assessment monitoring. If no improved *Cryptosporidium* detection method is available, monitoring will follow EPA Method 1622/23. Systems that provide a total of 5.5 log treatment for *Cryptosporidium* are not subject to future monitoring.

In addition to the reassessment and re-binning described above, the State/Primacy Agency will assess any significant changes in the watershed and source water as part of the sanitary survey process. It will then determine what follow-up action is appropriate in response to any source water changes that have taken place; responses could include actions from the microbial toolbox.

1.1.2 Monitoring and Treatment Requirements for Unfiltered Systems

Unfiltered systems that already have 3 log *Cryptosporidium* treatment in place prior to the date they would have to comply with treatment requirements are exempt from monitoring and additional *Cryptosporidium* inactivation requirements. Otherwise, large unfiltered systems must monitor *Cryptosporidium* in their source water monthly for at least 2 years, and small unfiltered systems must monitor semimonthly for 12 months or monthly for 24 months. All unfiltered systems must determine their treatment requirements based on the arithmetic mean *Cryptosporidium* concentration. If their average *Cryptosporidium* concentration is less than or equal to 0.01 oocysts/L, systems must provide 2 log *Cryptosporidium* inactivation. If their average concentration is greater than 0.01 oocysts/L, they must provide 3 log inactivation.

Monitoring for unfiltered systems will be based on the same schedule as monitoring for filtered systems, although unfiltered systems are not required to monitor *E. coli* or turbidity. As with the filtered systems, unfiltered systems must conduct a second round of *Cryptosporidium* monitoring 6 years after the initial bin assignment.

In addition to the new *Cryptosporidium* inactivation requirements, the LT2ESWTR will require unfiltered systems to continue to meet the filtration avoidance criteria under the 1989 SWTR and to continue to provide inactivation for *Giardia* and viruses. The overall inactivation requirements (i.e., 4 log virus, 3 log *Giardia*, and 2 or 3 log *Cryptosporidium*) must be met using a minimum of two disinfectants. Additionally, each of two disinfectants must meet the total inactivation for one of the three pathogens. For example, a system could use UV to inactivate 2 log of *Cryptosporidium* and *Giardia* and use chlorine to inactivate 4 log of viruses and 1 log of *Giardia.*

1.1.3 Requirements for Existing Uncovered Finished Water Reservoirs

The LT2ESWTR builds on the IESWTR and LT1ESWTR, which require covers only for *new* finished water reservoirs. The LT2ESWTR will establish requirements for all systems with *existing* uncovered finished water reservoirs. Systems must either cover the reservoir or treat reservoir discharge to the distribution system to achieve 2 log *Cryptosporidium*, 3 log *Giardia*, and 4 log virus inactivation.

1.1.4 Disinfection Profiling and Benchmarking Requirements

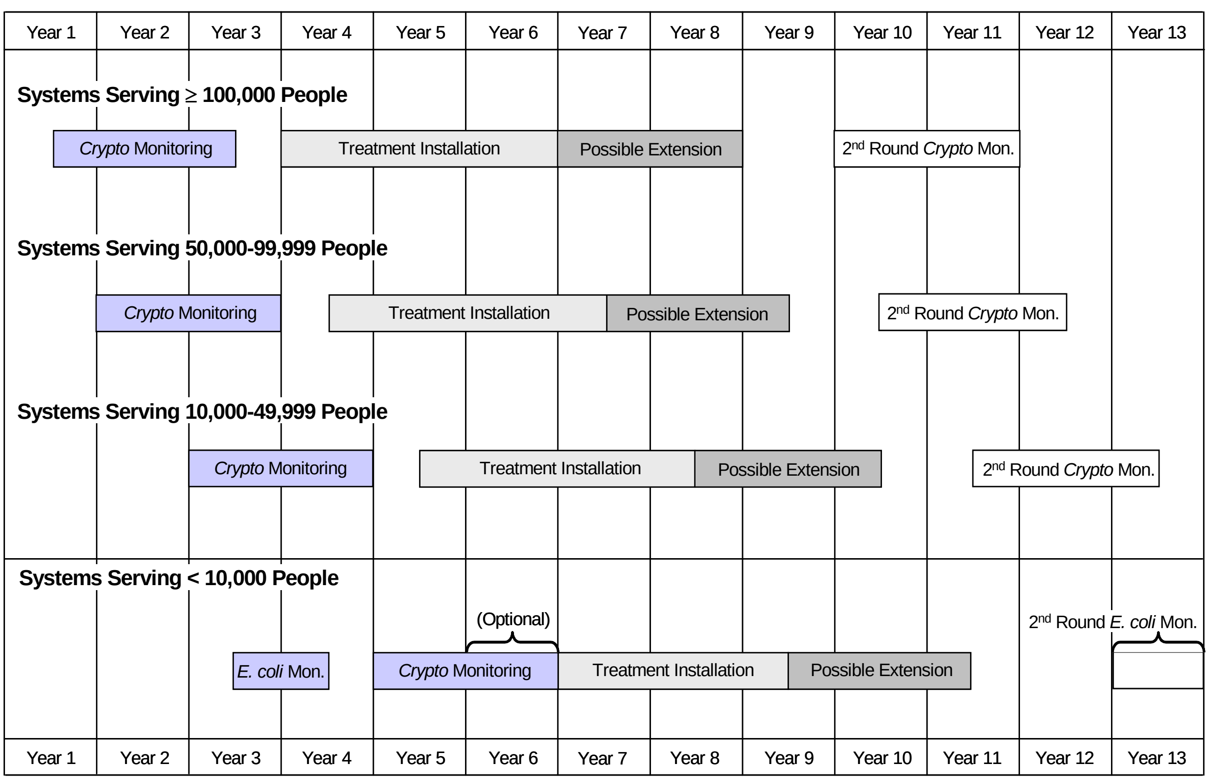
The LT2ESWTR includes a disinfection profile and benchmark requirement to ensure that any significant change in disinfection, whether for byproduct control under the Stage 2 DBPR, improved *Cryptosporidium* control under the LT2ESWTR, or both, does not significantly compromise existing *Giardia* and virus protection. A disinfection profile is a graphical representation of a system's level of *Giardia* and viral inactivation measured during the course of 1 or more year(s). A benchmark is the lowest monthly average of microbial inactivation during the disinfection profile period.

The profiling and benchmarking requirements under the LT2ESWTR are similar to those promulgated under the IESWTR and LT1ESWTR and are applicable to systems making a significant change to their disinfection practice. The LT2ESWTR requires these systems to prepare a disinfection profile that characterizes current levels of *Giardia lamblia* and virus inactivation throughout the plant over the course of 1 year. The profile may be developed using equivalent historical data. Prior to making the change, the system must calculate a benchmark and consult with the State regarding how the proposed change will affect the current disinfection level.

1.1.5 Implementation Timeline

Exhibit 1.3 shows the timeline of LT2ESWTR activities for filtered systems. The schedule for monitoring and compliance with treatment requirements differs by population served.

Exhibit 1.3: Implementation Time Line for LT2ESWTR for Filtered Systems



1.2 Document Organization

This EA is organized into the following chapters:

- Chapter 2 identifies the public health concerns addressed by the rule and provides a 20-year regulatory history that includes a description of relevant National Primary Drinking Water Regulations (NPDWRs). It also explains the statutory authority for promulgating the LT2ESWTR and the economic rationale for choosing a regulatory approach.

- Chapter 3 describes the regulatory alternatives considered for the LT2ESWTR and the process for developing them.

- Chapter 4 characterizes the baseline conditions that EPA expects to exist (including system inventory, treatment, and water quality data) before systems complete the monitoring and begin making treatment changes to meet the LT2ESWTR requirements. Because of the timing of the IESWTR, LT1ESWTR, and Stage 1 DBPR[5], EPA had to predict the changes in treatment and water quality made by systems as a result of these rules to characterize pre-LT2ESWTR baseline conditions.

- Chapter 5 reviews available toxicological and epidemiological data related to *Cryptosporidium* and presents the public health and economic benefits (both quantifiable and unquantifiable) of this rule. It compares the benefits of the four regulatory alternatives and presents several sensitivity analyses.

- Chapter 6 presents an estimate of the costs of implementing the rule to the drinking water industry, households, and States/Primacy Agencies. It also compares the costs of the four regulatory alternatives.

- Chapter 7 discusses analyses performed to evaluate the effects of the rule on different segments of the population. It also considers various executive orders and other requirements, including the Regulatory Flexibility Act (RFA) and Unfunded Mandates Reform Act (UMRA).

- Chapter 8 summarizes and analyzes the rule's benefit and cost estimates. It also compares the results of the Preferred Regulatory Alternative to the other alternatives considered.

---

[5] The compliance deadlines for the IESWTR and Stage 1 DBPR were January 2002 for large and medium surface water systems and January 2004 for small systems. The compliance deadline for the LT1ESWTR was January 2005.

2. Statement of Need for the Rule

2.1 Introduction

This chapter presents the need for the LT2ESWTR by identifying the public health concerns that this rule will address. Included is a discussion of related regulations that shows that these public health concerns are not adequately addressed by other rules. This chapter concludes with a discussion of the economic rationale for the rule. The remaining sections are organized as follows:

- 2.2 Description of the Issue
- 2.3 Risk Balancing
- 2.4 Public Health Concerns to be Addressed
  - 2.4.1 *Cryptosporidium*
  - 2.4.2 Uncovered Finished Water Reservoirs
- 2.5 Regulatory History
  - 2.5.1 Statutory Authority for Promulgating the Rule
  - 2.5.2 1979 Total Trihalomethane Rule
  - 2.5.3 1989 Total Coliform Rule
  - 2.5.4 1989 Surface Water Treatment Rule
  - 2.5.5 1996 Information Collection Rule
  - 2.5.6 1998 Interim Enhanced Surface Water Treatment Rule
  - 2.5.7 1998 Stage 1 Disinfectants and Disinfection Byproducts Rule
  - 2.5.8 2000 Proposed Ground Water Rule
  - 2.5.9 2001 Filter Backwash Recycling Rule
  - 2.5.10 2002 Long Term 1 Enhanced Surface Water Treatment Rule
  - 2.5.11 2003 Proposed Stage 2 Disinfectants and Disinfection Byproducts Rule
- 2.6 Economic Rationale for Regulation

2.2 Description of the Issue

More than 14,000 public water systems (PWSs), serving approximately 180 million people in the United States and its territories, use surface water or ground water under the direct influence of surface water (GWUDI) as their source. These sources carry microbial contaminants, some of which pose significant risks to public health. The U.S. Environmental Protection Agency (EPA or the Agency) is particularly concerned about *Cryptosporidium* because it is resistant to many commonly used drinking water disinfectants, such as chlorine, and it poses significant health risks, including death. Moreover, there is no effective drug available to cure cryptosporidiosis, the health condition caused by *Cryptosporidium* infection (Framm and Soave 1997). The primary issue of concern addressed by this rule is the risk to public health in water supplies with inadequate *Cryptosporidium* treatment.

The 1989 SWTR requires most surface water and GWUDI systems to remove microbial contaminants physically through filtration. (Exemptions to this filtration requirement are granted to systems that meet specified avoidance criteria.) Types of filtration systems include the following:

- Conventional treatment—coagulation, flocculation, and sedimentation of particles, followed by granular media filtration.

- Direct filtration—coagulation and flocculation followed by rapid sand filtration, but no sedimentation basin. This type of filtration system is designed for low-turbidity waters.

- Slow sand and diatomaceous earth filtration—filters that work at very low flow rates without the use of a coagulant in pretreatment.

- Alternative filtration—other technologies, including membranes and bag and cartridge filters.

Current regulations specify the performance of filtration systems in terms of filtered water turbidity limits. Turbidity is a measure of the clarity of water and is quantified in nephelometric turbidity units (NTU). The 1989 SWTR required all surface water and GWUDI systems using rapid sand filtration technologies to meet combined filter effluent turbidity limits of 0.5 NTU 95 percent of the time. The 1998 Interim Enhanced Surface Water Treatment Rule (IESWTR) requires improved filtration performance by lowering the turbidity standard to 0.3 NTU 95 percent of the time (with a maximum of 1 NTU at any time) for large systems using rapid sand filtration. The 2002 LT1ESWTR extended this requirement to small systems. At this lower limit, EPA believes that systems are generally achieving a minimum of 2 log (99 percent) removal of *Cryptosporidium*. Slow sand and diatomaceous earth filtration systems can achieve at least 2 log removal at a higher effluent turbidity of 1 NTU 95 percent of the time because of differences in their removal mechanisms. While the degree of *Cryptosporidium* reduction achieved under these standards may provide adequate public health protection for some source waters, EPA recognizes that some systems may have higher levels of contamination against which additional protection is warranted. Methods such as additional filtration, the use of alternative disinfectants such as ozone or ultraviolet light (UV), improved source water protection, or other treatment and management initiatives can help systems achieve additional protection against *Cryptosporidium*.

The LT2ESWTR also addresses the risk of microbial pathogen contamination in unfiltered systems, which lack the protective barriers from *Cryptosporidium* that filtered systems provide. The rule requires unfiltered systems to provide at least 2 log inactivation of *Cryptosporidium* by disinfection; the amount of disinfection will depend on the results of source water *Cryptosporidium* monitoring. The rule also requires the use of two disinfectants to meet *Cryptosporidium* and existing inactivation requirements (i.e., those for *Giardia* and viruses).

Lastly, the LT2ESWTR addresses health risks posed by uncovered finished water reservoirs. There are approximately 81 uncovered reservoirs that hold finished water, not including those that are scheduled to be covered or taken off-line, ranging in size from a few thousand to more than 3 billion gallons. While the IESWTR and LT1ESWTR require systems to cover all *new* finished water reservoirs, the LT2ESWTR builds on these rules by addressing *existing* uncovered finished water reservoirs.

2.3 Risk Balancing

EPA expects some systems to change treatment practices in response to the Stage 2 Disinfectants and Disinfection Byproducts Rule (DBPR) requirements. These changes have the potential to increase the occurrence of microbial pathogens in drinking water as systems alter the use of disinfectants to comply with the new disinfection byproduct (DBP) requirements. DBPs result from chemical reactions between disinfectants and organic and inorganic compounds in the water. Some DBPs are associated with health risks, including adverse developmental and reproductive health effects and cancer. The LT2ESTWR, therefore, has additional disinfection profiling and benchmarking provisions to help ensure that systems maintain control of microbial risks as they take steps to reduce the formation of DBPs.

EPA is making a concerted effort to understand and balance risks from DBPs and microbes, and the costs and benefits of addressing those risks in its rulemaking efforts. To allow for simultaneous compliance and balancing of risks between microbial pathogens and DBPs, EPA is promulgating the LT2ESWTR concurrently with the Stage 2 DBPR. For detailed information regarding the Stage 2 DBPR, see the draft *Economic Analysis for the Stage 2 Disinfectants and Disinfection Byproducts Rule* (USEPA 2003d).

2.4 Public Health Concerns to Be Addressed

In 1990, EPA's Science Advisory Board (SAB), an independent panel of experts established by Congressional mandate, cited drinking water contamination as one of the most important environmental risks and indicated that disease-causing microbial contaminants (i.e., bacteria, protozoa, and viruses) pose a particularly high health risk due to the large populations that are directly exposed to them (SAB and USEPA 1990). Information on waterborne disease outbreaks from the U.S. Centers for Disease Control and Prevention (CDC) underscores this concern. Data collected by CDC indicate that between 1971 and 2002, 757 waterborne disease outbreaks, caused by various types of contamination, were reported (Craun and Calderon 1996, Levy et al. 1998, Barwick et al. 2000, Lee et al. 2002, Blackburn et al. 2004).

The effects of waterborne disease are usually acute, resulting from a single or small number of exposures. Most waterborne pathogens cause gastrointestinal illness with diarrhea, abdominal discomfort, nausea, vomiting, or other symptoms. Most such cases involve a sudden onset and generally are of short duration in healthy people. Some pathogens (e.g., *Giardia* and *Cryptosporidium*), however, may cause extended illness, lasting weeks or longer in otherwise healthy individuals. The infection can prove fatal for members of sensitive populations, such as the immunocompromised or the elderly. Other waterborne pathogens cause, or at least are associated with, more serious disorders such as hepatitis, particularly hepatitis A (Moore et al. 1993), peptic ulcers and gastric cancer (*Helicobacter pylori*) (Park et al. 2001, Sepulveda and Graham 2002), myocarditis (group B coxsackievirus) (Kim et al. 2001), meningitis (group B coxsackievirus and echoviruses) (Lee and Kim 2002, Amvrosieva et al. 2001), and other diseases.

2.4.1 *Cryptosporidium*

Cryptosporidium is of particular concern to EPA because, unlike pathogens such as viruses and bacteria, *Cryptosporidium* oocysts are resistant to inactivation by many common disinfection methods. Since the oocyst is especially resistant to chlorine disinfection, simply increasing existing chlorination dosage levels or contact time above those most commonly practiced in the United States is not effective. Other emerging disinfectant-resistant pathogens, such as *Microsporidia*, *Cyclospora*, and *Toxoplasma*, are also a concern for similar reasons.

Cryptosporidiosis is a protozoal infection that usually causes 7 to14 days of diarrhea, possibly accompanied by low-grade fever, nausea, and abdominal cramps in individuals with healthy immune systems (Juranek 1998). It is caused by the ingestion of infectious oocysts, which are readily carried in water. The most common source of oocysts in water is the feces of infected hosts (Perz et al. 1998; Rose 1997). Although cryptosporidiosis often occurs through ingestion of contaminated food or water, it may also result from direct or indirect contact with infected people or animals (Casemore 1990; Juranek 1998; Rose 1997). Infected humans and other animals excrete oocysts, which can then be transmitted to others. Okhuysen et al. (1998) and Dupont et al. (1995) found through human volunteer feeding studies that a low dose of *Cryptosporidium parvum* (or *C. parvum)* is sufficient to cause infection in healthy adults.

Some subpopulations are at greater risk of serious illness or death from waterborne disease than the general population (Frost et al. 1997). These include children (especially the very young), the elderly, pregnant women, and the immunocompromised. These sensitive groups account for almost 20 percent of the population in the United States (Gerba et al. 1996; USEPA 1998a). The severity and duration of illness are often greater in immunocompromised people than in healthy individuals, and death may result. For instance, of the people who died in the 1993 Milwaukee cryptosporidiosis outbreak, 85 percent had AIDS as the underlying cause of death (Hoxie et al. 1997).

Cryptosporidium has caused a number of documented waterborne disease outbreaks. However, it is important to note that *C. parvum* was not identified as a human pathogen until 1976, and outbreaks attributed to cryptosporidiosis were not reported in the United States prior to 1984. The first report of an outbreak caused by *Cryptosporidium* was published during the development of the SWTR (D'Antonio et al. 1985). EPA, CDC, and the Council of State and Territorial Epidemiologists have maintained a collaborative surveillance program for collection and periodic reporting of data on waterborne disease outbreaks since 1971. The CDC database and biennial CDC–EPA surveillance summaries include data reported voluntarily by the States on the incidence and prevalence of waterborne illnesses.

Between 1991, the first year the SWTR and Total Coliform Rule were in effect, and 2002, the most recent year for which data are available, 106 drinking water-related outbreaks associated with confirmed or suspected microbiological causes occurred in PWSs. Twenty-one outbreaks occurred in PWSs with surface water sources; the rest were in systems using wells or springs. The etiology of outbreaks included *Cryptosporidium*; *Giardia*; bacteria such as *Campylobacter jejuni*, *Shigella sonnei*, and *E. coli* O157:H7; Norwalk-like viruses and small round-structured viruses; and acute gastrointestinal illness of unknown etiology (AGI). These outbreaks are listed individually in Appendix A of the *Occurrence and Exposure Assessment for the Long Term 2 Enhanced Surface Water Treatment Rule* and are based on CDC surveillance summaries (Moore et al. 1993, Kramer et al. 1996a, Levy et al. 1998, Barwick et al. 2000, Lee et al. 2002, Blackburn et al. 2004).

From 1984 to 2002, there were 10 reported outbreaks of cryptosporidiosis associated with drinking water in PWSs in the United States (Moore et al. 1993; Kramer et al. 1996a; Craun 1996; Levy et al. 1998; Barwick et al. 2000, Lee et al. 2002, Blackburn et al. 2004). Two additional outbreaks occurred in private wells, and another 52 outbreaks occurred in recreational waters. Exhibit 2.1 summarizes the cryptosporidiosis outbreaks associated with drinking water.

Exhibit 2.1: Reported Cryptosporidiosis Outbreaks in U.S. Drinking Water Systems

Year	Location and System Type	Cases of Illness	Source Water	Treatment	Suspected Cause
1984	Braun Station, TX, CWS	117 (confirmed) 2,000 (estimated)	Well	Chlorination	Sewage-contaminated well
1987	Carrollton, GA, CWS	13,000 (estimated)	River	Conventional filtration/ chlorination; inadequate backwashing of some filters	Treatment deficiencies
1991	Berks County, PA, NCWS	551 (estimated)	Well	Chlorination	Ground water under the influence of contaminated surface water
1992	Medford (Jackson County and Talent), OR, CWS	3,000 (estimated); combined total for Jackson County and Talent	Spring/River	Chlorination/package filtration plant	Source not identified for Jackson County; treatment deficiencies at water treatment plant in Talent
1993	Milwaukee, WI, CWS	403,000 (estimated)	Lake	Conventional filtration	High source water contamination and treatment deficiencies
1993	Cook County, MN, NCWS	27 (confirmed)	Lake	Filtered, chlorinated	Possible sewage backflow from toilet/septic tank
1994	Clark County, NV, CWS	103 (confirmed); many were HIV positive	River/Lake	Prechlorination, filtration and post-filtration chlorination	Source not identified
1994	Walla Walla, WA, CWS	134 (confirmed)	Well	None reported	Sewage contamination
1998	Williamson County, TX, CWS	1,400 (confirmed)	Well	Chlorinated	Sewage contamination
2000	Florida, CWS	5	Well	Chlorinated	Broken well, treatment deficiencies

Source: Craun et al. (1998), Barwick et al. (2000), and Lee et al. (2002).

Five of the 10 outbreaks in Exhibit 2.1 originated from surface water or possibly GWUDI supplied by PWSs serving fewer than 10,000 people. In total, the 10 outbreaks caused an estimated 421,337 cases of illness, the majority occurring in Milwaukee in 1993. These outbreaks demonstrate that when treatment is not operating optimally or when source water is highly contaminated, *Cryptosporidium* can be present in the finished drinking water and infect consumers, ultimately resulting in disease outbreaks.

The National Research Council concluded that the number of identified and reported outbreaks in the CDC database (both for surface and ground waters) represents a small percentage of actual waterborne disease outbreaks (National Research Council 1997). Most outbreaks in CWSs are not recognized until a sizable proportion of the population is ill (Perz et al. 1998, Craun 1996). In addition to the complications involved in identifying waterborne disease outbreaks, some States do not have active outbreak surveillance programs. Those that do exist are based on voluntary and confidential responses by State and local public health officials. Even when outbreaks are recognized, few are successfully traced to the drinking water source. Physicians, for instance, may not have sufficient community-wide information to attribute gastrointestinal illness to any specific origin, such as a drinking water source. Many people who experience gastrointestinal illness (predominantly manifested as diarrhea) do not seek medical attention, and some healthy adults with cryptosporidiosis may not suffer severe symptoms from the disease. Even if infected individuals consult a physician, *Cryptosporidium* is not identified by routine diagnostic tests for gastroenteritis and, therefore, tends to be under-reported in the general population (Craun 1996).

The limited number of reported cases of waterborne disease such as cryptosporidiosis may be due to the fact that a significant portion of these illnesses may be endemic (i.e., not associated with an outbreak), and thus are even more difficult to recognize. One study, for example, found that 14 to 40 percent of the normal gastrointestinal illness in a community in Quebec was associated with treated drinking water from a surface water source (Payment et al. 1997).

2.4.2 Uncovered Finished Water Reservoirs

Many PWSs store treated drinking water in some type of reservoir before delivering it to their customers. Although good engineering practice dictates that such reservoirs be covered to prevent recontamination, there are currently no regulations that require existing reservoirs to be covered. (The IESWTR and LT1ESWTR require *new* reservoirs to be covered.) The use of uncovered finished water reservoirs has been questioned since 1930 because of their susceptibility to contamination and subsequent threats to public health. Many sources of contamination can lead to the degradation of water quality in uncovered finished water reservoirs. These include, but are not limited to, surface water runoff, algal growth, insects and fish, bird and animal waste, airborne deposition, and human activity. Algal blooms are the most common problem in open reservoirs and can become a public health risk. Algae growth leads to the formation of DBPs and causes taste and odor problems. Algae also provide a food source for bacteria that decompose plant matter. Some blue-green algae (actually a type of bacterium called cyanobacteria) contain toxins that can induce headaches, fever, diarrhea, abdominal pain, nausea, and vomiting. Bird and animal wastes are other common and significant sources of contamination. These wastes may carry microbial contaminants such as coliform bacteria, viruses, and human pathogens, including *Vibrio cholera*, *Salmonella*, *Mycobacteria*, bacteria that cause typhoid fever, and *Giardia*, in addition to *Cryptosporidium* (USEPA 1999c). Microbial pathogens can also be found in surface water runoff along with agricultural chemicals, automotive wastes, turbidity, metals, and organic matter (USEPA 1999c; LeChevallier et al. 1997b). In an effort to minimize contamination, systems have implemented controls such as reservoir covers and liners, regular draining and washing, proper security and monitoring, bird and insect control programs, and drainage designed to prevent surface runoff from entering the reservoir (USEPA 1999c).

Few studies quantitatively evaluate the impacts of uncovered finished water reservoirs on public health. LeChevallier et al. (1997b) compared the influent and the effluent water quality from six New Jersey reservoirs for a 1-year period to determine the impact of uncovered finished water storage reservoirs on water quality. There were significant increases in turbidity, particle counts, total coliform, fecal coliform, and heterotrophic plate count bacteria in the effluent compared to the influent. There was also a significant decrease in the chlorine residual in the effluent samples, meaning little chlorine would be left to provide continued disinfection in the distribution system.

2.5 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 standards by identifying which contaminants should be regulated and by establishing the maximum levels of the contaminants allowed in drinking water, specifying treatment techniques to reduce contaminant levels.

2.5.1 Statutory Authority for Promulgating the Rule

Section 1412(b)(1) of the 1996 SDWA reauthorization mandated new drinking water requirements. EPA's general authority to set Maximum Contaminant Level Goals (MCLGs) and develop National Primary Drinking Water Regulations (NPDWRs) 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 PWSs 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" (SDWA 1412(b)(1)(A)).

To regulate a contaminant, EPA first sets an MCLG at a level at which no known or anticipated adverse health effects occur. MCLGs are established solely on the basis of protecting public health and are not enforceable. EPA simultaneously sets an enforceable Maximum Contaminant Level (MCL) as close as technologically feasible to the MCLG, while taking costs into consideration. If it is not feasible to measure the contaminant at levels presumed to have impacts on health, a treatment technique can be specified in place of an MCL. Water systems comply with a drinking water regulation by not exceeding the MCL or by meeting treatment technique requirements.

In addition to the general authorities cited above, SDWA Section 1412(b)(2)(C) requires specifically that EPA promulgate the Final Enhanced Surface Water Treatment Rule (ESWTR).

> The Administrator shall promulgate an Interim Enhanced Surface Water Treatment Rule, a Final Enhanced Surface Water Treatment Rule, a Stage 1 Disinfectants and Disinfection Byproducts Rule, and a Stage 2 Disinfectants and Disinfection Byproducts Rule in accordance with the schedule published in volume 29, Federal Register, Page 6361 (February 10, 1994), in Table III.13 of the proposed Information Collection Rule.

The promulgation of the IESWTR and LT1ESWTR satisfied the statutory requirement for an interim rule, and the LT2ESWTR satisfies the requirement for a final rule and the Congressional intent to review and revise the IESWTR and LT1ESWTR based on data available from the Information Collection Rule (ICR) and Information Collection Rule Supplemental Survey (ICRSSs) (see section 2.5.5). Also, to achieve the goals of the Stage 2 DBPR, the LT2ESWTR must be promulgated to achieve a balance between the risks of microbial pathogens and DBPs.

The following sections summarize the development of NPDWRs over the past 20 years.

2.5.2 1979 Total Trihalomethane Rule

Under the Total Trihalomethane Rule (44 FR 68624 November 1979), EPA set an MCL for total trihalomethanes (TTHM), the sum of chloroform, bromoform, bromodichloromethane, dibromochloromethane, of 0.10 mg/L as a running annual average (RAA) of quarterly samples. This standard applied to CWSs using surface or ground water that served at least 10,000 people and that added a disinfectant to the drinking water during any part of the treatment process. This 1979 rule was superseded by the 1998 Stage 1 DBPR (section 2.5.7).

2.5.3 1989 Total Coliform Rule

The Total Coliform Rule (TCR) (54 FR 27544 June 1989) applies to all PWSs. Because monitoring PWSs for every possible pathogenic organism is not feasible, coliform organisms are used as indicators of possible distribution system contamination. Coliforms are easily detected in water and are used to indicate a system's vulnerability to pathogens. In the TCR, EPA set an MCLG of zero for total coliforms. EPA also set a monthly MCL for total coliforms and required testing of total-coliform-positive cultures for the presence of *E. coli* or fecal coliforms. *E. coli* and fecal coliforms indicate more immediate health risks from sewage or fecal contamination, and their presence is an acute MCL violation, which requires immediate public notification. Coliform monitoring frequency is determined by the size of the population served, the type of system (community or noncommunity) and the type of source water (surface water, GWUDI, or ground water). In addition, the TCR required sanitary surveys every 5 years (or 10 years for NCWSs using disinfected ground water) for systems that collect fewer than five routine total coliform samples per month (typically serving fewer than 4,100 people).

2.5.4 1989 Surface Water Treatment Rule

Under the SWTR (54 FR 27486 June 1989), EPA set MCLGs of zero for *Giardia lamblia*, viruses, and *Legionella*, and established treatment requirements for all PWSs using surface water or GWUDI as a source. The SWTR includes treatment technique requirements for filtered and unfiltered systems that are intended to protect against the adverse health effects associated with *Giardia lamblia*, viruses, and *Legionella*, as well as many other pathogenic organisms. These requirements include:

- Maintenance of a disinfectant residual in water entering and within the distribution system.

- Removal/inactivation of at least 99.9 percent (3 log) of *Giardia* and 99.99 percent (4 log) of viruses.

- Filtration, unless systems meet specified avoidance criteria.

- For filtered systems, a turbidity performance standard for the combined filter effluent consisting of a 5-NTU maximum and 95 percent of measurements in 1 month not to exceed 0.5 NTU, based on 4-hour monitoring for treatment plants using conventional treatment or direct filtration (with separate standards for other filtration technologies). The 1998 IESWTR and the 2002 LT1ESWTR superseded these particular requirements.

- Watershed control programs and water quality requirements for unfiltered systems.

2.5.5 1996 Information Collection Rule

The ICR (61 FR 24354 May 1996) applied to PWSs serving more than 100,000 people. A more limited set of ICR requirements pertained to ground water systems serving 50,000 to 100,000 people.

The ICR authorized EPA to collect occurrence and treatment information to help evaluate the need for possible changes to the microbial treatment practices and to help evaluate the need for future regulation of disinfectants and DBPs. The ICR provided EPA with additional information on the national occurrence in drinking water of (1) chemical byproducts that form when disinfectants used for microbial control react with naturally occurring compounds present in source water; and (2) disease-causing microorganisms, including *Cryptosporidium*, *Giardia*, viruses, and coliform bacteria. The ICR also required water systems to collect plant configuration data showing the type of treatment provided. The ICR monthly sampling data provided a total of 18 months of influent and treated water quality data including pH, alkalinity, turbidity, temperature, calcium and total hardness, total organic carbon, UV_{254}, bromide, ammonia, and disinfectant residual. These data provided an indication of the "treatability" of the water, the occurrence of contaminants, and the potential for DBP formation. The data collected under the ICR were used in analyses supporting development of the LT2ESWTR and Stage 2 DBPR.

2.5.6 1998 Interim Enhanced Surface Water Treatment Rule

The IESWTR (63 FR 69478 December 1998) updated the 1989 SWTR for large systems. It applies to PWSs serving at least 10,000 people and using surface water or GWUDI as a source. These systems were to comply with the IESWTR by January 2002. The primary purpose of the IESWTR is to improve control of *Cryptosporidium* and to address tradeoffs between the risks from microbial pathogens and those from DBPs. The requirements and guidelines include:

- An MCLG of zero for *Cryptosporidium*;
- Removal of 99 percent (2 log) of *Cryptosporidium* for systems that provide filtration;
- For treatment plants using conventional treatment or direct filtration, a turbidity performance standard for the combined filter effluent consisting of a 1 NTU maximum and 95 percent of measurements in 1 month not to exceed 0.3 NTU, based on 4-hour monitoring;
- Continuous monitoring of individual filter effluent turbidity in conventional and direct filtration plants and recording turbidity readings every 15 minutes when these filters are on-line;
- A disinfection benchmark to assess the level of microbial protection provided before facilities change their disinfection practices to meet the requirements of the Stage 1 DBPR;
- Inclusion of *Cryptosporidium* in the definition of GWUDI and in the watershed control requirements for unfiltered PWSs;
- Covers for all new finished water storage facilities; and
- A primacy provision that requires States to conduct sanitary surveys with a minimum frequency for all surface water systems, including those serving fewer than 10,000 people.

EPA promulgated the IESWTR concurrently with the Stage 1 DBPR so that systems could coordinate their response to the risks posed by DBPs and microbial pathogens.

2.5.7 1998 Stage 1 Disinfectants and Disinfection Byproducts Rule

The Stage 1 DBPR (63 FR 69390 December 1998) applies to all CWSs and NTNCWSs that add a chemical disinfectant to their water. Certain requirements designed to provide protection against acute health effects from chlorine dioxide also apply to transient noncommunity water systems (TNCWSs). Surface water and GWUDI systems serving at least 10,000 people were required to comply with the rule by January 2002. Surface water and GWUDI systems serving fewer than 10,000 people and all ground water systems must comply by January 2004.

The Stage 1 DBPR sets maximum residual disinfectant level goals (MRDLGs) for chlorine (4 mg/L as Cl_2), chloramines (4 mg/L as Cl_2), and chlorine dioxide (0.8 mg/L as ClO_2); and MCLGs for bromodichloromethane (0 mg/L), bromoform (0 mg/L), dibromochloromethane (0.06 mg/L), dichloroacetic acid (0 mg/L), trichloroacetic acid (0.3 mg/L), bromate (0 mg/L), and chlorite (0.8 mg/L). The rule sets MRDLs for chlorine (4 mg/L as Cl_2), chloramines (4 mg/L as Cl_2), and chlorine dioxide (0.8 mg/L as ClO_2); and MCLs for TTHM (0.080 mg/L), HAA5 (0.060 mg/L), bromate (0.010 mg/L), and chlorite (1.0 mg/L). The MRDLs and MCLs, except those for chlorite and chlorine dioxide, are calculated as RAAs. For conventional surface water and GWUDI systems, a treatment technique—enhanced coagulation/softening—is specified for the removal of DBP precursors.

As noted in section 2.5.6, the Stage 1 DBPR was promulgated concurrently with the IESWTR to coordinate the control of DBPs and microbial contaminants.

2.5.8 2000 Proposed Ground Water Rule

The proposed Ground Water Rule (65 FR 30194 May 2000) addresses fecal contamination in ground water systems. The rule also builds on the TCR through provisions based on further evaluation of *E. coli* monitoring results measured under the TCR. Key components of the multibarrier approach for protection of ground water included in the proposed rule are:

- Sanitary surveys for all ground water systems conducted at the same frequency as in surface water systems;

- Hydrogeologic sensitivity assessments to identify ground water sources that are susceptible to fecal contamination;

- Source water monitoring for an indicator of fecal contamination for systems drawing from susceptible ground water sources;

- Correction of significant deficiencies and fecal contamination by eliminating the source of contamination, correcting the deficiency, providing an alternative source of water, or providing inactivation and/or removal of 99.99 percent (4 log) of viruses; and

- Compliance monitoring to ensure that disinfection treatment is reliably operated when it is used.

2.5.9 2001 Filter Backwash Recycling Rule

The Filter Backwash Recycling Rule (FBRR) (66 FR 31086 June 2001) regulates systems where filter backwash is returned to the treatment process. The rule applies to surface water and GWUDI systems that use direct or conventional filtration and recycle spent filter backwash water, sludge thickener supernatant, or liquids from dewatering processes. The rule requires that these recycled liquids be returned to a location such that all steps of a system's conventional or direct filtration are employed. The rule also requires systems to notify the State that they practice recycling. Finally, systems must collect and maintain information for review by the State.

2.5.10 2002 Long Term 1 Enhanced Surface Water Treatment Rule

The LT1ESWTR (67 FR 1812 January 2002) is an extension of the 1998 IESWTR to small systems. LT1ESWTR extends control of *Cryptosporidium* and other disease-causing microbes to surface water and GWUDI systems that serve fewer than 10,000 people. Key provisions in the LT1ESWTR are very similar to those for the IESWTR, but provide additional flexibility for small systems.

2.5.11 2003 Proposed Stage 2 Disinfectants and Disinfection Byproducts Rule

The requirements of the Stage 2 DBPR apply to all CWSs and NTNCWSs that add a disinfectant other than UV or that deliver water that has been treated with a disinfectant other than UV. The Stage 2 DBPR builds on the 1979 Total Trihalomethane Rule and the 1998 Stage 1 DBPR by requiring reduced levels of DBPs in distribution systems. Each rule activity for the Preferred Regulatory Alternative and the associated rule schedule are described below.

The Stage 2 DBPR is designed to reduce DBP occurrence peaks in the distribution system by changing compliance monitoring requirements. Compliance monitoring will be preceded by an initial distribution system evaluation (IDSE) to identify distribution system locations that represent high total trihalomethane (TTHM) and haloacetic acids (HAA5) levels. Systems may perform an IDSE by completing either a system-specific study (SSS) or a standard monitoring program (SMP). NTNCWSs serving fewer than 10,000 people are not required to conduct an IDSE, and other systems may receive waivers from the IDSE requirement.

The Stage 2 DBPR changes the way sampling results are averaged to determine compliance. The compliance determination for the Stage 2 DBPR is based on a locational running annual average (LRAA) instead of the system-wide RAA used under the Stage 1 DBPR. LRAAs are RAAs calculated separately for each sample location in the distribution system. With the Stage 2 LRAA requirement, the TTHM and HAA5 MCLs must be met at each monitoring location, while the Stage 1 RAA requires a system to average results over all monitoring locations.

2.6 Economic Rationale for Regulation

This section addresses the economic rationale for choosing a regulatory approach. Such a rationale is required by Executive Order Number 12866, *Regulatory Planning and Review* (The White House 1993), which states the following:

> ...[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, Office of Management and Budget (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" (USEPA 1996b).

In a perfectly competitive market, prices and quantities are determined solely by the aggregated decisions of buyers and sellers. Such a market occurs when many producers of a product are selling to many buyers, and both producers and consumers have perfect information on the characteristics and prices of each firm's products. Barriers to entry in the industry cannot exist, and individual buyers and sellers must be "price takers": i.e., their decisions cannot affect the price. Several properties of the public water supply do not satisfy the conditions for a perfectly competitive market and, thus, lead to market failures that require regulation.

First, many water systems are natural monopolies. A natural monopoly exists when it is impossible for more than one firm in each area to recover the costs of production and survive. There are high fixed costs associated with reservoirs and wells, transmission and distribution systems, treatment plants, and other facilities. For other potential suppliers to enter the market, they would have to provide the same extensive infrastructure to realize similar economies of scale and be competitive. A splitting of the market with increased fixed costs (for example, two supplier networks in a single market) usually makes this situation unprofitable for one or both suppliers. The result is a market suitable for a single supplier and one that is hostile to alternative suppliers. In such natural monopolies, suppliers have fewer incentives for providing high quality service or maintaining competitive prices. In these situations, governments often intervene to help protect the public interest.

Because PWSs are legal as well as natural monopolies, they are often subject to price controls, if not outright public ownership. While customers may demand improvements in water quality, the regulatory regime may not transmit that demand to the water supplier or allow the supplier to raise its price to recover the cost of the improvements. If consumers do not believe that their drinking water is safe enough, they cannot simply switch to another water utility. Other options for obtaining safe drinking water (e.g., buying bottled water or installing point-of-use filtration) often cost consumers more than water purchased from public water supplies. Therefore, the water supplier may have little incentive to improve water quality.

Second, the public may not understand the health and safety issues associated with drinking water quality. Understanding the health risks posed by trace quantities of drinking water contaminants involves analysis and synthesis of complex toxicological and health sciences data. Therefore, the public may not be aware of the risks it faces. For example, cases of waterborne disease are likely to be under-reported since a significant portion may be endemic, making them more difficult to recognize. There is, therefore, a lack of occurrence data and related cost information on endemic waterborne disease available to the public. EPA has implemented a Consumer Confidence Report (CCR) Rule (USEPA 1998) that makes water quality information more readily available to consumers. This rule requires CWSs to publish an annual report on Local drinking water quality. Consumers, however, still have to analyze this information for its health risk implications. Even if informed consumers are able to engage water systems in a dialogue about health issues, the costs of such interaction (measured in personal time and monetary outlays) present a significant impediment to consumer expression of risk reduction preferences. Moreover, these reports typically contain no information about the risk associated with *Cryptosporidium* and most other microbial pathogens, because PWSs are not required to analyze for them.

SDWA regulations are intended to provide a level of protection from exposure to drinking water contaminants by setting minimum performance requirements. These regulations are intended neither to restructure market mechanisms nor to establish competition in supply; rather, they establish the level of service to be provided that best reflects public preference for safety. The Federal regulations reduce the high information and transaction costs by acting on behalf of consumers in balancing risk reduction and the social costs of achieving this risk reduction.

3. Consideration of Regulatory Alternatives

3.1 Introduction

The U.S. Environmental Protection Agency (EPA or the Agency) evaluated a number of regulatory alternatives that could mitigate the health concerns addressed by the Long Term 2 Enhanced Surface Water Treatment Rule (LT2ESWTR). These evaluations took place during a regulatory negotiation process that began in the Spring of 1999, and included consultation with the Stage 2 Microbial and Disinfection Byproducts (Stage 2 M-DBP) Advisory Committee that was convened under the Federal Advisory Committees Act (FACA). This chapter summarizes the alternatives considered and develops a context for the regulatory approach taken. The remainder of the chapter is organized as follows:

- 3.2 Development Process for Regulatory Alternatives
- 3.3 Specific Regulatory Alternatives Considered in this EA
  - 3.3.1 Summary of Bin Classification and Treatment Requirements for Regulatory Alternatives
  - 3.3.2 Additional Treatment for Direct Filtration Systems
- 3.4 Alternative Monitoring Approaches Considered
  - 3.4.1 Indicators of Microbial Contamination
  - 3.4.2 *Cryptosporidium* Monitoring Strategies for Bin Classification

3.2 Development Process for Regulatory Alternatives

Two efforts in the regulatory development process for the LT2ESWTR are particularly relevant to evaluation of alternatives discussed in the Economic Analysis (EA): (1) the data synthesis and analysis resulting from the Information Collection Rule (ICR) and ICR Supplementary Surveys (ICRSSs), and (2) the deliberations and recommendations of the Stage 2 M-DBP Advisory Committee.[1] EPA held 14 formal negotiation meetings of the Stage 2 M-DBP Advisory Committee between March 1999 and September 2000. Before convening the committee, EPA also held three preparatory stakeholder meetings on pathogen and disinfection byproduct (DBP) health effects, occurrence, and treatment. The objective of the committee meetings was to reach a consensus regarding recommended provisions for the two rules (Stage 2 Disinfectants and Disinfection Byproducts Rule (DBPR) and LT2ESWTR).

Technical support for the Stage 2 M-DBP negotiation meetings was provided by the Technical Work Group (TWG), which the committee established at its first meeting and comprised EPA and drinking water industry experts. The TWG's activities resulted in the collection, development, evaluation, and presentation of key data related to the LT2ESWTR, including new data on pathogenicity, occurrence, and treatment of microbial contaminants, specifically *Cryptosporidium*.

The ICR database provided much of the information evaluated for the LT2ESWTR. EPA promulgated the ICR in 1996 pursuant to the Safe Drinking Water Act (SDWA) requirements. The ICR required approximately 300 large public water systems (PWSs) with approximately 500 separate water treatment plants to conduct 18 months of sampling for water quality and treatment parameters related to

[1] The Stage 2 M-DBP Advisory Committee comprised representatives from a variety of stakeholder organizations. A complete list of participating members (as well as a summary of committee findings) is included in the docket for the LT2ESWTR.

DBP formation and the occurrence of microbial pathogens. After the ICR data collection, EPA obtained additional data on pathogen occurrence through the ICRSSs. These involved 127 water treatment systems, including 40 small systems. Large and medium systems collected semi-monthly samples for *Cryptosporidium*, *Giardia*, and other water quality parameters for 1 year. Small systems (those serving fewer than 10,000 people) collected monthly water quality data, but did not sample for protozoa.

EPA, in consultation with nationally recognized experts in statistics, evaluated ICR and ICRSS data to generate estimates of national occurrence of *Cryptosporidium* in surface water and finished water. These data were evaluated under various regulatory scenarios to estimate the reduction of *Cryptosporidium* reaching consumers.

3.3 Specific Regulatory Alternatives Considered in this EA

The recommendations of the Advisory Committee are described in a document called the Agreement in Principle (USEPA 2000e). The Advisory Committee reached consensus on the issues of uncovered finished water reservoirs and treatment of unfiltered water without formally identifying regulatory alternatives other than the proposed approaches. Consequently, no formal alternatives were presented for these requirements. The committee's recommendations to address these issues are reflected in the LT2ESWTR. For control of *Cryptosporidium* in filtered systems, however, several alternatives were considered. The committee discussed, but quickly found impractical, alternatives based on monitoring for *Cryptosporidium* in finished water. The occurrence of *Cryptosporidium* in finished water is so low that the volume of water required for analysis would make monitoring costs prohibitive. Thus, all the alternatives based on monitoring directed that monitoring be performed on the source water.

The following subsections detail the differences between the alternatives and explain the rationale behind EPA's selection of the Preferred Alternative. Section 3.3.2 also describes the additional treatment requirements proposed for direct filtration systems.

3.3.1 Summary of Bin Classification and Treatment Requirements for Regulatory Alternatives

In considering different approaches for filtered systems under the LT2ESWTR, the M-DBP Advisory Committee focused on four regulatory alternatives (hereafter referred to as Alternatives A1 through A4). Alternative A1 requires the same amount of reduction of *Cryptosporidium* for all systems, while the other three base their treatment requirements on the amount of *Cryptosporidium* found in a system's source water through monitoring. These measurements place a system in one of several bins, ranging from "no action" to an additional 2.5 log *Cryptosporidium* treatment. Further, all alternatives allow systems to select treatment technologies based on the amount of *Cryptosporidium* treatment needed to meet requirements and the effectiveness of each technology.

In evaluating each binning scenario, the committee asked the following questions:

- Do the treatment requirements adequately reduce *Cryptosporidium* concentrations in finished water?
- How many systems would be required to add treatment?
- What is the likelihood of bin misclassification?

- What are the chances that systems with high source water concentrations would be placed in the bin requiring no action?

The predicted finished water *Cryptosporidium* concentrations and percentages of plants adding treatment are shown for the Preferred Regulatory Alternative in Chapter 4. The likelihood of classification in a certain bin for a given concentration and the predicted percentages of plants in each bin for all the regulatory alternatives are shown in Appendix B.

Exhibit 3.1 summarizes binning and treatment scenarios for each regulatory alternative. These alternatives were defined by two criteria: (1) bin boundaries, as defined by the results of *Cryptosporidium* monitoring, and (2) the treatment scenarios (log reduction requirements for *Cryptosporidium*) required for each bin. The alternatives were compared within the context of the economic analysis to assist EPA in selecting a Preferred Regulatory Alternative.

On the basis of preliminary cost-benefit analyses, the Advisory Committee chose Alternative A3 as the Preferred Alternative. This EA continues to support Alternative A3 as the best choice and EPA is promulgating Alternative A3 for this reason. Alternative A3 was shown to be the most cost effective and to deliver the best value. Comparisons of the net benefits of each alternative are summarized in the executive summary and described in more detail in Chapter 8.

Exhibit 3.1: Summary of Bin Requirements for Filtered Systems

Source Water *Cryptosporidium* Monitoring Results (oocysts/L)	**Additional Treatment Requirements**
Alternative A1	
2.0 log inactivation required for all systems	
Alternative A2	
< 0.03	No action
≥ 0.03 and < 0.1	0.5 log
≥ 0.1 and < 1.0	1.5 log
≥ 1.0	2.5 log
Alternative A3 - Preferred Alternative	
< 0.075	No action
≥ 0.075 and < 1.0	1 log
≥ 1.0 and < 3.0	2 log
≥ 3.0	2.5 log
Alternative A4	
< 0.1	No action
≥ 0.1 and < 1.0	0.5- log
≥1.0	1.0 log

Note: "Additional treatment requirements" are for systems that have conventional treatment in full compliance with existing rules (the IESWTR and LT1ESWTR).

3.3.2 Additional Treatment for Direct Filtration Systems

The Agreement in Principle (USEPA 2000e) recommended that EPA address direct filtration systems in connection with Bins 2-4 of Alternative A3 in the LT2ESWTR. Direct filtration plants lack sedimentation basins; their treatment processes move directly from addition of coagulant and mixing to filtration. Conventional filtration plants use coagulation, sedimentation, and filtration. Sedimentation reduces the *Cryptosporidium* load on the filters and helps plants respond to sudden changes in influent water quality.

EPA considered the effectiveness of direct filtration in removing *Cryptosporidium* when determining how to apply the Advisory Committee's treatment technique recommendations for conventional plants to direct filtration plants. EPA has consistently recognized the value of employing multiple barriers for pathogen removal to provide redundancy and reliability. Studies have shown that a well-operated sedimentation basin can reduce *Cryptosporidium* levels by 0.5 log or more (Dugan et al. 1999; Edzwald and Kelley 1998; and Patania et al. 1995). The SWTR Guidance Manual (USEPA 1991) also supports giving less credit to direct filtration systems; these systems are eligible for 0.5 log less credit for *Giardia* than conventional filtration systems.

Based on these studies, EPA's prior consideration of the effectiveness of direct filtration systems for *Giardia*, and the Agency's confidence in the multiple barrier approach, EPA concluded that direct filtration plants should provide an additional 0.5 log treatment beyond that required for conventional treatment plants. A more detailed discussion of *Cryptosporidium* removal by conventional and direct filtration can be found in the EPA document, *Occurrence and Exposure Assessment for the Long Term 2 Enhanced Surface Water Treatment Rule* (USEPA 2003c).

3.4 Alternative Monitoring Approaches Considered

EPA considered a variety of monitoring approaches while developing LT2ESWTR regulatory alternatives. These include evaluating other water quality parameters as surrogates for *Cryptosporidium* and alternative monitoring strategies to minimize monitoring costs, especially for small drinking water systems. These issues are described in the subsections below.

3.4.1 Indicators of Microbial Contamination

Due to the cost associated with *Cryptosporidium* monitoring, the Stage 2 M-DBP Advisory Committee evaluated alternative source water quality parameters to determine if they could be used to identify water sources with high *Cryptosporidium* levels. The committee assessed the 12-month means of monitoring data for turbidity, total organic carbon (TOC), *E. coli*, fecal coliform, and total coliform bacteria as surrogates for *Cryptosporidium*. Specifically, the committee evaluated whether these potential surrogates could accurately assign plants to LT2ESWTR microbial framework bins. None of these parameters correlated well with *Cryptosporidium* levels at all concentrations. Evidence indicated that *E. coli* would be somewhat effective in identifying plants with *Cryptosporidium* levels above or below 0.075 oocysts/L in reservoirs, lakes, and flowing streams (USEPA 2003c). Under the Preferred Alternative, this level is the cutoff between the no-action and the action bins (Bins 2, 3, and 4). Thus, the committee recommended that *E. coli* be used as a screening test for small systems under the Preferred Alternative, A3.

The selection of the *E. coli* level for determining when additional *Cryptosporidium* monitoring in small systems should be conducted was based on limited data. Therefore, the Advisory Committee agreed that additional data should be collected to evaluate the *E. coli* indicator criteria and to develop alternative criteria, if appropriate. Accordingly, the Advisory Committee agreed that large systems would measure *E. coli* and turbidity in their source water when they sample for *Cryptosporidium*. The composite data will be submitted to EPA. This will give EPA time to develop possible alternative indicator levels or indicator parameters (e.g., turbidity in combination with *E. coli*) prior to the date when small systems are required to begin source water monitoring for *E. coli*. Following the completion of 1 year of monitoring under the LT2ESWTR, EPA will determine if alternative indicators (to the *E. coli* levels prescribed in the rule) are appropriate for determining classification into bins. Depending upon its findings, EPA will issue guidance for States to consider prescribing alternative indicator requirements for small systems. Therefore, the LT2ESWTR allows for alternative indicators to be considered by the Primacy Agency.

The use of *E. coli* as a screen for *Cryptosporidium* monitoring is applicable only to Alternatives A3 and A4. Using *E. coli* levels to predict a mean *Cryptosporidium* concentration of less than 0.03 oocysts per liter—the action cutoff level for Alternative A2—was less reliable (USEPA 2003c). Thus, under Alternative A2, no screening test is available, and all small systems must monitor for *Cryptosporidium*. Since Alternative A1 requires the same level of treatment for all systems, no monitoring provisions for large or small systems are included for Alternative A1.

3.4.2 *Cryptosporidium* Monitoring Strategies for Bin Classification

EPA and the Advisory Committee also evaluated alternative monitoring strategies to ensure that levels of source water contamination would be adequately characterized, while minimizing the monitoring burden. Approaches considered included taking 24, 48, or 72 source water samples to determine bin classification using the bin boundaries in Alternative A3.

EPA chose to allow systems serving at least 10,000 people to collect and analyze 24 monthly samples over a 2-year period and base the bin assignment on the maximum running annual average (RAA). (The first RAA will be the average of the results of the first 12 months of monitoring; the second RAA will be the average of results from months 2–13; the third will be the average of concentrations from months 3–14; and so forth.) Alternatively, systems may collect two or more samples per month over the 2-year period, at regular intervals, and use the simple average (the average of all 48 samples) to determine bin placement. The following paragraphs discuss the methodology for choosing these monitoring frequencies.

EPA knew that the measured amount of *Cryptosporidium* in each sample might be different from the actual or “true” concentration because of error inherent in sampling and analytical methods. For example, method error can be introduced by inefficiencies in oocyst recovery, false detections, and analyst error. Sampling error is affected by the sample size and the fact that the concentration in a given sample may misrepresent the concentration in the larger water body. EPA was primarily concerned that high-occurrence sources could possibly be placed in either the no-action bin (Bin 1, for mean occurrence below 0.075 oocysts/L) or bins that provided insufficient remedies. This could result in insufficient protection of public health. A secondary concern was that systems could be assigned to a higher bin than was warranted by their true concentration, resulting in unnecessary costs for systems.

EPA performed a Monte Carlo analysis to determine the probabilities of misclassification based on different monitoring scenarios (see Appendix B for details). The analysis accounted for the volume assayed, variation in source water *Cryptosporidium* occurrence, and variable method recovery.

The analysis specifically considered the likelihood that a system with a true mean *Cryptosporidium* concentration a factor of 3.16 (0.5 log) above or below a bin boundary would be assigned to the wrong bin. Probabilities were assessed for two cases:

- Misclassification low: a system with a mean concentration of 0.24 oocysts/L (i.e., factor of 3.16 above the Bin 1 boundary of 0.075 oocysts/L) is misclassified low in Bin 1.

- Misclassification high: a system with a mean concentration of 0.024 oocysts/L (i.e., factor of 3.16 below the Bin 1 boundary of 0.075 oocysts/L) is misclassified high in Bin 2.

Exhibit 3.2 shows the error rates the model predicts at concentrations of 0.24 oocysts/L and 0.024 oocysts/L (a factor of 3.16 above and below the Bin 1 boundary of 0.075 oocysts/L) under different monitoring scenarios.

Exhibit 3.2: Probability of Misclassification for Monitoring and Binning Strategies Considered for the LT2ESWTR

Monitoring Strategy	Probability of Misclassification High	Probability of Misclassification Low
48-sample simple mean	1.7%	1.4%
24-sample maximum RAA	5.3%	1.7%
24-sample simple mean	2.8%	6.2%
12-sample second highest value	47%	1.1%
8-sample maximum value	66%	1.0%

Note: Probability of misclassification high into Bin 2 was calculated for systems with true *Cryptosporidium* concentrations of 0.024 oocysts/L, or 0.5 log below the Bin 1 boundary of 0.075 oocysts/L. Probability of misclassification low into Bin 1 was calculated for systems with *Cryptosporidium* concentrations of 0.24 oocysts/L, or 0.5 log above the Bin 1 boundary.

Source: Appendix B.

The first two approaches shown in Exhibit 3.2—the 48-sample simple mean and 24-sample maximum RAA—were recommended by the Advisory Committee and are proposed for bin classification under the LT2ESWTR because they have low misclassification rates. As shown in Exhibit 3.2, these strategies have misclassification low rates of 1 to 2 percent, meaning there is a 98 to 99 percent likelihood that a plant with an oocyst concentration 0.5 log above the Bin 1 boundary would be correctly assigned to Bin 2. The misclassification high rate is near 2 percent for the 48-sample simple mean and 5 percent for the 24-sample maximum RAA. These rates indicate that a plant with an oocyst concentration 0.5 log below the Bin 1 boundary would have a 95 to 98 percent probability of being correctly assigned to Bin 1. Bin misclassification rates across a wide range of concentrations are shown in Appendix B.

The 24-sample simple mean had a slightly lower misclassification high rate than the 24-sample maximum RAA (2.8 vs. 5.3 percent) but the misclassification low rate of the simple mean was almost 4 times greater. Consequently, a plant with a mean *Cryptosporidium* level above the Bin 1 boundary would be much more likely to be misclassified in Bin 1 using a 24-sample simple mean than with a 24-sample maximum RAA. To increase the probability that systems with mean *Cryptosporidium* concentrations above 0.075 oocysts/L will provide additional treatment, EPA is proposing that if only 24 samples are taken, the maximum RAA be used to determine bin assignment.

EPA evaluated monitoring strategies involving only 12 and 8 samples to determine if less frequent monitoring could provide satisfactory bin classification; these lower numbers of samples are not adequate. For example, Exhibit 3.2 shows that if plants were classified in bins based on the second highest concentration of 12 samples or the highest concentration of eight samples, then low misclassification low rates could be achieved. A system with a mean *Cryptosporidium* level 0.5 log above the Bin 1 boundary would have a 99 percent chance of being appropriately classified in a bin requiring additional treatment under either strategy. However, a system with a mean oocyst concentration 0.5 log below the Bin 1 boundary would have a 47 percent chance of being incorrectly classified in Bin 2 using the second highest result among 12 samples, or a 66 percent likelihood of being misclassified in Bin 2 using the maximum result among 8 samples. Therefore, these strategies were not proposed.

Increasing the number of samples used to compute the maximum RAA above 24 also increased the number of annual averages computed, so it did not reduce the likelihood of misclassification high. Computing a simple mean based on more than 48 samples did reduce bin misclassification rates, but the rates were already very small (1 to 2 percent for plants with levels 0.5 log above or below bin boundaries). For sources with *Cryptosporidium* concentrations very near or at bin boundaries, increasing the number of samples did not markedly improve the error rates, which remained near 50 percent at the bin boundaries.

In summary, EPA believes that the prescribed sampling designs in the Preferred Alternative perform well for the purpose of accurately assigning source waters to bins. More costly designs, involving more frequent sampling and analysis, provide only marginally improved performance, while placing a greater burden on limited laboratory capacity.

4. Baseline Conditions

4.1 Introduction

To estimate the impact of the LT2ESWTR regulatory alternatives on the water supply industry, it is first necessary to establish the conditions that exist within the industry just before the regulatory requirements take effect. This baseline allows a consistent comparison of public health impacts (developed in Chapter 5) and the economic and financial impacts (developed in Chapters 6 and 7) across regulatory alternatives.

Because the compliance deadlines of recently promulgated and proposed rules will occur after the date EPA is required to promulgate the LT2ESWTR, many of the baseline conditions must be estimated rather than directly measured. Thus, data on existing conditions are combined with projections of changes to those conditions to estimate the baseline for the LT2ESWTR. The steps required to determine the baseline conditions are as follows:

- Compile an industry profile—identify and collect information on the segments of the water supply industry subject to the rule.

- Characterize influent water quality—summarize the relevant characteristics of the raw water treated by the industry.

- Characterize treatment for other rules—predict what the industry will do to comply with the provisions of rules that may precede the LT2ESWTR and that may generate changes relevant to this rule, specifically the IESWTR, LT1ESWTR, Stage 1 DBPR, and Stage 2 DBPR.

- Predict occurrence following implementation of other rules—estimate what the treated water quality will be after the rules preceding the LT2ESWTR are implemented.

This chapter presents an analysis that is at a level of detail and precision appropriate to support subsequent analyses and regulatory decisions for the LT2ESWTR. An exhaustive review of the water supply industry, source waters, or industry practices was not needed to conduct the analysis. The remainder of this chapter is organized as follows:

4.2 Data, Tools, and Processes Used in Baseline Development
 4.2.1 ICR and ICRSS Observed Data
 4.2.2 ICR and ICRSS Modeled Data and Method for Predicting Source Water Occurrence
 4.2.3 Surface Water Analytical Tool (SWAT)
4.3 Industry Profile
 4.3.1 Public Water System Characterization
 4.3.2 Systems, Plants, and Population Subject to the LT2ESWTR
 4.3.3 Water Treatment Plant Design and Average Daily Flows
4.4 Baseline for Unfiltered Plants (Pre-LT2ESWTR)
 4.4.1 Treatment Characterization for Unfiltered Plants
 4.4.2 Number of Unfiltered Systems, Plants, and Population Served
 4.4.3 Source Water *Cryptosporidium* Occurrence for Unfiltered Plants
 4.4.4 Finished Water *Cryptosporidium* Occurrence for Unfiltered Plants
4.5 Baselines for Filtered Plants (Pre-LT2ESWTR)
 4.5.1 Treatment Characterization for Filtered Plants
 4.5.2 Number of Filtered Plants and Population Served

4.2 Data, Tools, and Processes Used in Baseline Development

Several data sources were used to characterize the baseline and to predict changes in treatment technologies and water quality for different regulatory alternatives. The Safe Drinking Water Information System–Federal Version (SDWIS[1]) (4th Quarter Freeze Year 2003 data[2]) is used to create system and population baselines (USEPA 2003e). SDWIS is EPA's national regulatory compliance database for the drinking water program. It includes information on the nation's 170,000 public water systems (PWSs) and on violations of drinking water regulations. EPA's Web site provides more information on SDWIS (http://www.epa.gov/safewater/sdwisfed/sdwis.htm).

EPA also used *Geometries and Characteristics of Water Systems* (also called the Model Systems Report) (USEPA 2000a). In this document, EPA used 1995 Community Water System Survey (CWSS) data to develop equations to predict flows based on system populations. The 1995 CWSS was a mail survey covering over 3,000 surface and ground water systems, to which 1,980 systems responded. The data gathered included treatment practices, water demand, and financial information. See *Community Water System Survey* (USEPA 1997c), for more information.

To characterize the influent water quality, treatment processes, and finished water quality, EPA primarily used data from the 1996 Information Collection Rule (ICR), for which *Cryptosporidium* monitoring requirements applied to all PWSs serving at least 100,000 people and using surface water or ground water under the direct influence of surface water (GWUDI) as a source. The purpose of the ICR was to collect DBP and microbial occurrence and treatment information to help evaluate the need for further microbial and disinfection byproduct (DBP) rules. The ICR gathered plant-level data from about 300 water systems over 18 months (July 1997-December 1998). These data characterize the source water occurrence of *Cryptosporidium*, *Giardia*, viruses, and indicators of microbial contamination, along with types of treatment in place. The data used in this economic analysis (EA) are from the Auxiliary 1 (AUX1) database (USEPA 2000h).

The Information Collection Rule Supplemental Surveys were voluntary surveys, for which 40 medium (serving 10,000–99,999) and 40 large plants (serving 100,000 or more) collected *Cryptosporidium* and *Giardia* source water occurrence data. These data are presented in the *Occurrence and Exposure Assessment for the Long Term 2 Enhanced Surface Water Treatment Rule* (USEPA 2003c). Treatment characterization and other information were obtained from industry and State sources.

Several analytical tools (models) also were used to estimate the following:

- Source water *Cryptosporidium* occurrence;

---

[1] Throughout this document, the acronym "SDWIS" represents "SDWIS–Federal Version."

[2] All industry baseline data reflect revisions to SDWIS 4th Quarter Year 2000 Freeze to account for reporting errors in Massachusetts and Montana.

- Treatment changes due to the Stage 1 and Stage 2 DBPRs;
- Number of plants falling into various treatment bins, based on predicted source water occurrence; and
- Occurrence of *Cryptosporidium* in finished water under Pre-LT2ESWTR and LT2ESWTR conditions.

4.2.1 ICR and ICRSS Observed Data

Three sets of monitoring data are used to characterize *Cryptosporidium* source water occurrence: the ICR data set and the ICRSS data sets for medium and large systems. Microbial analyses for the ICR were conducted according to the ICR Method (USEPA 1996a). The ICRSSs evaluated source water for *Cryptosporidium*, *Giardia*, and coliforms at a sample of medium surface water systems (those serving 10,000 to 99,999 people) as well as a sample of large surface water systems. EPA Methods 1622 (USEPA 1999a) and 1623[3] (USEPA 1999b), summarized in the Occurrence and Exposure Assessment, were used for *Cryptosporidium* and *Giardia* analyses. With Methods 1622 and 1623, the volume of water analyzed was on the average larger than the volume analyzed with the ICR Method, yielding better estimates of *Cryptosporidium* occurrence on a per-sample basis (the volume analyzed with the ICR Method depended on the sample pellet volume after centrifugation and was based on the volume needed to meet detection limits). The ICRSS data consist of semi-monthly observations taken over a 12-month period at 40 randomly selected large plants and 40 randomly selected medium plants[4]. Exhibit 4.1 summarizes the differences between the ICR and ICRSS data collection methods.

[3] Method 1622 was used for the first 4 months of data collection, at which time Method 1623 replaced Method 1622. The primary difference between Method 1622 and Method 1623 is that the Method 1622 immunomagnetic separation (IMS) kit includes only reagents for *Cryptosporidium* purification, whereas Method 1623 uses the *Giardia*/*Cryptosporidium*-combination kit, which includes reagents for both *Cryptosporidium* and *Giardia* purification.

[4] Forty small plants also were included in the survey, but they did not monitor protozoa concentrations.

Exhibit 4.1: Comparison of ICR and ICRSS Data Collection Methods

	ICR	ICRSSM	ICRSSL
System size of plants participating (population served)	≥100,000	10,000-99,999	≥100,000
Number of surface water plants participating	350	40	40
Sample frequency	Monthly	Semi-monthly	Semi-monthly
Sampling period	July 1997-December 1998	March 1999-February 2000	March 1999-February 2000
Required sample volume	100 L	10 L	10 L
Median sample volume analyzed	3.2 L	10 L	10 L
Average recovery rates for lab method	12%	43%	
Percentage of samples where *Cryptosporidium* was not detected	93%	83%	87%
Percentage of plants with at least one positive *Cryptosporidium* sample	44%	85%	85%

Source: USEPA 2003c, USEPA 2000h, and USEPA 2000i.

The ICR monitoring program resulted in nearly 6,000 *Cryptosporidium* measurements from 350 water sources (USEPA 2000h). The ICRSS monitoring produced approximately 1,900 measurements from 80 source waters. *Cryptosporidium* was not detected in most of the samples (93 percent of ICR samples and 86 percent of ICRSS samples). Approximately 44 percent of plants participating in the ICR program had at least one positive sample, while the increased sensitivity of the methods under the ICRSS led to a much higher percentage of plants (approximately 85 percent) having at least one positive sample.

The detection of *Cryptosporidium* oocysts is complex. Because of the low occurrence of *Cryptosporidium* in source waters, a sample may not contain any oocysts even though the source water does. Thus, a non-detection in a test volume is not definitive evidence against occurrence in the source. In addition, the laboratory method is inefficient and may not recover all the oocysts that were in a sample. While underestimation is much more likely, when detections do occur, sample concentrations also may overestimate influent concentrations because of the small volume of sample involved (i.e., one oocyst identified in a 10-liter sample may not represent the true proportion of oocysts in the much larger source water volume).

During the ICR collection period, EPA implemented the ICR Laboratory Spiking Program (LSP) to assess the recovery of *Cryptosporidium* oocysts from field samples analyzed with the ICR Method. At the time of the ICR sample collection, duplicate 100-liter samples were collected and spiked with a known quantity of *Cryptosporidium* oocysts. Recovery of the oocysts (i.e., the detection of known oocysts) by laboratories was very low, with an average of 12 percent of the known quantity being recovered per sample. The ICRSS Matrix Spike Program was used to assess the recovery of oocysts from field samples using Methods 1622/1623 during the ICRSS. Duplicate samples were spiked with a known quantity of *Cryptosporidium* oocysts, filtered, and analyzed using Methods 1622/1623. The average recovery for the ICRSS was 43 percent. These spiking programs are further described in the LT2ESWTR Occurrence and Exposure Assessment (USEPA 2003c).

Each set of data has its advantages; for instance, the ICR data set contains data from more plants than the ICRSS data sets do, but the ICR data set does not include data for plants in medium-sized systems. The ICRSS data set does not include enough data for unfiltered plants to be useful for modeling, while the ICR set does. The ICRSS sets, on average, had higher recovery rates and larger sample volumes than the ICR set. The ICR collected data for a longer time period, but the ICRSS data were collected more frequently. In considering which data set best represents the national distribution of *Cryptosporidium* occurrence, none was judged superior to the others; that is, no one set was considered to have a greater likelihood of representing "true" occurrence. In view of this, each data set was kept separate, and a weighting of their relative values to allow them to be combined was not attempted.

Cryptosporidium observations were characterized according to oocyst structure as observed under a microscope, as defined below:

- **Empty:** Oocyst-type walls, but not containing internal material.

- **Non-Empty:** Includes oocysts with internal structure and with amorphous structures. Oocysts with amorphous structures have walls and internal material characteristic of *Cryptosporidium*, but the material cannot be confirmed as *Cryptosporidium*.

    - **With Internal Structures:** Oocysts that have a cell wall and recognizable internal structures consistent with *Cryptosporidium*; subset of non-empty category.

    - **With Amorphous Structures:** Oocysts that have a cell wall and internal material but no recognizable internal structures; subset of non-empty category.

- **Total:** The combined count of empty oocysts and non-empty oocysts (those with either internal or amorphous structures).

At meetings of the Technical Working Group of the Microbial-Disinfection Byproducts Advisory Committee, participants agreed that the type of oocyst observed gives information about the level of confidence that the oocyst is actually *Cryptosporidium*. The presence of internal structures may increase the confidence that the observed object is indeed a *Cryptosporidium* oocyst, and not some other item or organism with similar gross morphology. While oocysts that are empty are unlikely to be viable or infectious at the time of the laboratory analysis, they are still indicators of the possible presence of *Cryptosporidium*. Oocysts with amorphous structures give a level of confidence between that of empty oocysts and those with internal structures. A detailed presentation of observed *Cryptosporidium* occurrence and evaluation of results from the ICR and ICRSS is provided in the Occurrence and Exposure Assessment (USEPA 2003c).

The analysis presented in this document assumes that total *Cryptosporidium* counts are the most representative of the presence of *Cryptosporidium* in source waters. While some of these oocysts may not have been infectious at the time of analysis, they likely represent *Cryptosporidium* that was present in the water. The probability of oocyst infectivity is addressed in the risk assessment model in section 5.2.3.

To account for the limitations in observed data in the three data sets, modeled estimates of the range of underlying total "true" *Cryptosporidium* occurrence, consistent with the observed occurrence, were developed.

4.2.2 ICR and ICRSS Modeled Data and Method for Estimating Source Water Occurrence

An accurate representation of *Cryptosporidium* concentrations in source water is important for estimating both costs and benefits. The LT2ESWTR treatment requirements are based on the results of source water *Cryptosporidium* monitoring. Consequently, this EA predicts the number of plants requiring treatment, as well as level of treatment, based on estimates of *Cryptosporidium* occurrence in the source water. The cost associated with increased levels of treatment and estimated reduction in illness of the affected population is also derived from those same occurrence estimates. This section provides the rationale for using estimates modeled from observed data and summarizes the modeled results.

The ICR and ICRSS provide source water quality data for developing this estimated national occurrence distribution. The raw data include the number of oocysts detected and the associated sample volume analyzed. A straightforward approach to modeling is first to divide the counts by the volumes to obtain concentrations and then to model the distribution of estimated concentrations. However, there are limitations in the data that negate the usefulness of this approach.

First, sample volumes are low relative to the volume needed to calculate representative concentrations of *Cryptosporidium* in source water consistently. The volumes collected also are inconsistent from location to location or even month to month at a given location. For example, the majority of sample counts in the ICR and ICRSS were zeros (no *Cryptosporidium* detected), but these zero counts are based on widely varying sample volumes. Common sense suggests that a zero count from a 10-liter sample should be weighted more heavily than a zero count from a 1-liter sample. Based on a straightforward sample concentration calculation, however, both concentrations would be considered the same.

Second, the majority of *Cryptosporidium* oocysts captured in samples likely were not detected in testing, due to a lack of precision in analytical methods. Therefore, straightforward concentration estimates would systematically under-estimate the true concentration of *Cryptosporidium* in national source waters.

Finally, there are limitations in the counts or concentrations that can be reported due to the rare occurrence of oocysts. Oocyst counts can only be whole numbers—it is impossible to detect half an oocyst—and most counts were zeros or ones. Since the volume analyzed in each sample was generally small, a limited number of concentrations could be calculated from the count and volume data. For instance, one oocyst in 10 liters gives a concentration of 0.1 oocysts/L, while one oocyst in 5 liters gives a concentration of 0.2 oocysts/L. The volume analyzed would have to be quite large or the number of oocysts present greater to enable more precise calculations of concentration.

These limitations are examples of uncertainty, or lack of knowledge, about the true *Cryptosporidium* concentrations. When the observed data are used to calculate concentrations, the data limitations result in a large number of individual sample values that may each over- or under-represent the true *Cryptosporidium* concentrations. To account for these limitations and other sources of variability in the data and to be able to estimate national occurrence, model-based occurrence estimates are chosen over observed data[5]. A more detailed discussion of this estimation procedure is provided in the Occurrence and Exposure Assessment (USEPA 2003c).

The benefits of using model-based estimates are that a model can properly account for the following conditions:

- Variability in the data, based on location, sampling technique, turbidity dependence, and other factors;

[5] Variability refers to observed differences attributable to true heterogeneity or diversity in a population or parameter, as opposed to uncertainty, which refers to lack of accuracy or precision in the measurement method.

- The low and variable recovery rates of the measurement methods;
- The small volumes assayed and their adequacy in representing the much larger volume of source water at the time of sampling; and
- The small number of samples assayed at each location and their ability to represent the average concentration in that location's water during the 18 months of the survey.

EPA developed a probability model that links the survey data (sample volumes and laboratory oocyst counts) to the unknown source water concentrations, which are the quantities of interest. The model accomplishes two tasks. First, it adjusts concentration estimates to account for varying sample volumes and test method recovery rates. Second, the assumed probability structure makes it possible to quantify uncertainty in the concentration estimates.

To account for varying sample volumes and recovery rates, the model defines an expected count for each survey sample. This is the average number of oocysts detected in repeated sampling from a given survey location, assuming a particular source water concentration, sample volume, and test method recovery rate:

Average *Count* = *Concentration* × *Volume* × *Recovery*

or, in terms of units:

oocysts detected = (oocysts present/liter) × (liters) × (oocysts detected/oocysts present)

Concentration is the unknown, and estimating it from data is the goal of the modeling. *Count* and *Volume* are known. They are measured directly and reported for each survey sample. *Recovery* is the ratio of oocysts detected in laboratory testing to oocysts present in the sample. Since *Recovery* cannot be measured directly for an individual test, there are no sample-by-sample data available for it. For a particular test method, however, the typical range of recovery values can be estimated from designed experiments using "spiked" samples with known concentrations (see Chapter 3). This was done for each of the *Cryptosporidium* lab methods used in the ICR and ICRSS, and recovery rate probability distributions were fit to the results. Simulated *Recovery* values were drawn from these probability distributions. Because *Count*, *Volume*, and *Recovery* are either known or simulated, fitting the data to the above formula results in estimates for the unknown *Concentration* that account for the variation in these other variables.

To estimate the uncertainty in the occurrence results derived from the above formula, we next define a probability structure for the observed sample counts. Each observed count is assumed to come from a Poisson probability distribution, a fundamental probability model for counting rare events (this is the distribution that results from the fact that only zero or one oocyst is usually present in a sample). The mean of each distribution is the average count as defined above. Incorporating these probability distributions in the model allows for the calculation of uncertainty bounds for the concentration estimates.

A Markov Chain Monte Carlo (MCMC) approach was employed to fit this model to the data. MCMC is an iterative technique for fitting statistical models to data. The Markov Chain is a sequence of joint probability distributions that converges to a stable distribution for likely model parameter values. Monte Carlo is a computational technique for solving intractable integrals through extensive, simulated sampling.

The benefit and cost analyses use plant-mean estimates of source water concentrations. The model not only predicts individual concentrations, but average concentrations for each plant over the time period covered by the observed data. For each primary data set (ICR, ICRSSM, and ICRSSL) the model generates multiple log-normal distributions of plant-mean estimates. (EPA believes the distribution of plant-mean concentrations is log-normal; this is described in section 3.3.3.2 of the Occurrence and Exposure Assessment.) Both the benefits and cost analyses draw samples from these distributions to reflect both variability and uncertainty.

The results of the occurrence models employed in this EA are documented in sections 4.4.3 and 4.5.3 for unfiltered and filtered plants. As described above, there was no single occurrence distribution that served as input but, instead, a collection of plausible occurrence distributions. Summary plots in these sections, then, show both the mean occurrence distribution—which represents the "middle" distribution—and confidence bounds that capture the range of occurrence distributions in a given collection.

4.2.3 Surface Water Analytical Tool (SWAT)

SWAT uses source water and treatment data collected under the ICR to estimate the percentage of large surface water plants that would require advanced technologies to meet Stage 1 and Stage 2 DBPR limits for disinfection byproducts (DBPs). Several advanced technologies, namely chlorine dioxide, ozone, ultraviolet light (UV) disinfection, and membrane processes, not only produce fewer byproducts than chlorine, but also provide varying degrees of *Cryptosporidium* removal or inactivation. The characteristics, costs, and effectiveness of these technologies are taken into account in developing the baselines for this EA.

A more detailed description of SWAT and how it was used to predict changes in treatment technologies under the Stage 2 DBPR is provided in the *Economic Analysis for the Stage 2 Disinfectants and Disinfection Byproducts Rule* (USEPA 2003d). In addition, a detailed description of the SWAT components and its operation can be found in the document *Surface Water Analytical Tool (SWAT) Version 1.1—Program Descriptions and Assumptions* (USEPA 2000b).

4.3 Industry Profile

This section identifies the PWSs subject to the LT2ESWTR. Subsequent sections identify the subset of systems subject to specific provisions of the rule (e.g., baselines for unfiltered and filtered systems). The water system baseline characterizations presented here are key inputs to the cost and benefit assessments described in this EA.

EPA's categorization scheme for water systems is summarized, followed by a presentation of systems, plants, and populations subject to the LT2ESWTR. A summary of water treatment plant design flows and average daily flows concludes the industry profile section.

4.3.1 Public Water System Characterization

Categorizing water systems allows EPA to determine the impacts of this rule on different types of systems. For this EA, EPA sorted systems on the basis of size, ownership, and retail/wholesale relationships provided in SDWIS. This section explains the classifications used.

PWS Type

As defined by the Safe Drinking Water Act (SDWA), a PWS is a water system that provides piped water for human consumption and has at least 15 service connections or regularly serves an average of at least 25 individuals per day for at least 60 days per year. EPA classifies PWSs into two broad groups:

- ***Community Water Systems*** (CWSs) have at least 15 service connections used by year-round residents or regularly serve at least 25 year-round residents.

- ***Noncommunity Water Systems*** (NCWSs) are PWSs that are not classified as CWSs.

EPA further classifies NCWSs into two types:

- ***Nontransient Noncommunity Water Systems*** (NTNCWSs) regularly serve at least 25 of the same people more than 6 months per year.

- ***Transient Noncommunity Water System***s (TNCWSs) do not regularly serve at least 25 of the same people more than 6 months per year.

Population Served

Under the LT2ESWTR, as with some previous rules, small systems (those serving fewer than 10,000 people, as defined in the rule) will face somewhat different requirements than larger systems. System size is important in the regulatory analysis as well. Costs are estimated using the size of systems as a factor, household costs are derived in part from the number of households in a system size category, and separate technology decision trees are used for different sizes of systems.

Both the benefits and cost models use the following nine size categories:

- Small systems are broken down into five subcategories based on the number of people served:
  - <25
  - 25–<100
  - 100–<500
  - 500–<3,300
  - 3,300–<10,000

- Medium systems are broken down into two subcategories:
  - 10,000–<50,000
  - 50,000–<100,000

- Large systems are broken down into two subcategories:
  - 100,000–<1 million
  - ≥1 million

In some parts of the benefits and cost models (e.g., applying assumptions about existing treatment practices) and in other analyses, four sizes are used—very small (<500), small (500–<10,000), medium, and large. Other parts use two categories—small (<10,000) and large (≥10,000).

Source Water

Systems are classified by the source water from which they draw. Surface water systems typically draw from reservoirs, natural lakes, or flowing streams. Ground water systems draw from wells. Some ground water sources are under the direct influence of surface water sources. These systems, called GWUDI systems, are considered directly influenced if surface water microorganisms are present. This category is important to the extent that pathogens, such as *Giardia* cysts and *Cryptosporidium* oocysts, can contaminate the ground water source. Some systems may have multiple source types and are referred to as "mixed systems." In SDWIS and the Baseline Handbook, a mixed system is categorized as a surface water system if it gets any portion of its flow from surface water. Based on the analysis in the Model Systems Report (USEPA 2000a), it is estimated that 21 percent of surface water systems obtain some of their water from ground water sources. Of these systems, one-third (8 percent of all surface water systems) get the majority of their flow from ground water. Mixed systems may either be systems that have some plants that are solely supplied by ground water and other plants that are solely supplied by surface water, or they may have one or more plants in which both types of source waters are mixed.

Ownership

Systems are also categorized by ownership. Private systems are owned by private corporations, associations, or individuals. Private systems are still PWSs. Public systems are owned by public entities, such as a municipality, county, or special district. Ownership distinctions are important to the analysis since differences exist between public and private systems in their access to capital and other means of financing. This distinction becomes important in calculating household costs in Chapter 6 and the Unfunded Mandates analysis presented in Chapter 7.

Purchased and Nonpurchased systems

Systems are categorized according to whether they provide or treat water themselves or whether they purchase it from other systems. Purchased systems are not expected to make treatment modifications under the LT2ESWTR; instead, purchased systems will absorb (through rate increases) the costs of additional treatment installed by the sellers. On the other hand, nonpurchased systems collect and treat the water themselves and distribute it to their retail and wholesale customers. These systems are subject to most of the provisions of the LT2ESWTR.

4.3.2 Systems, Plants, and Population Subject to the LT2ESWTR

This section estimates the baseline number of systems subject to the LT2ESWTR. The LT2ESWTR applies to all PWSs, regardless of type or size, that use surface water or GWUDI.

The baseline presented in this section is used to estimate implementation costs, such as those for training and becoming familiar with the rule (see Appendix D). Not all of the systems incurring implementation costs will incur costs for other provisions of the rule. Depending on existing treatment technology, size, and other factors, only subsets of the systems presented in this section are subject to specific provisions of the rule. The numbers of unfiltered plants, filtered plants, and uncovered finished water reservoirs subject to specific rule provisions are presented in sections 4.4 through 4.6.

Number of Systems

Systems in SDWIS are listed according to their retail population served. The advantage of classifying them this way is that it appropriately accounts for both the total number of individual PWSs in the United States and the total population served by all of those systems. However, a disadvantage of this method (especially for surface water CWSs) when estimating national costs of regulations is that it does not directly account for the fact that the water delivered by purchased systems to their retail customers is actually treated by other, upstream systems. It is important to recognize that the total flow for systems supplying surface water is actually treated by fewer than half of the surface water systems accounted for in SDWIS. Because of economies of scale, the unit cost of treatment (in cents per gallon) is lower for systems treating larger flows than it is for systems treating smaller flows. For example, it is typically more expensive to build and operate two treatment plants serving 5,000 people than one treatment plant serving 10,000 people. Failing to account for the fact that surface water is actually treated in larger quantities at a smaller number of systems than SDWIS suggests could result in an upward bias in national cost estimates of rules that affect a substantial portion of surface water systems.[6]

To compensate for this bias, an analysis was performed to link consecutive or purchased surface water CWSs and NTNCWSs to their respective wholesale systems using SDWIS data. CWSs were only linked to other CWSs and NTNCWSs were linked only to other NTNCWSs. TNCWSs were not linked, since they usually do not purchase water from other TNCWSs. If a consecutive system could be linked to a wholesaler, that system was removed from the system count and its population was added to the population of the wholesale system. Consecutive systems that could not be definitively linked to their wholesalers were considered stand-alone purchased systems. Although consecutive systems do not treat their water, these systems are included in the treatment baseline because their populations and flows must be accounted for in estimating treatment costs. EPA recognizes that including them as separate plants overestimates treatment costs. The decision process for this analysis is summarized in Exhibit 4.2

The number of surface water systems (including mixed systems) and GWUDI systems per size category in SDWIS (pre-linking) is shown on the left side of Exhibit 4.3. Systems whose ownership category was listed as "other" in SDWIS were reallocated to private and public and purchased and nonpurchased categories based on the existing proportion of each category to the total number of systems. Note that the *total* number of nonpurchased systems in columns H and I is the same as the total number of nonpurchased systems before linking in columns C and D. However, the numbers of public and private nonpurchased systems changed slightly because of how the systems with "other" ownership types are allocated within each size category. The inventory of nonpurchased systems, unlinked or pre-linking, is used as the baseline for determining implementation costs. Purchased systems are not included in this baseline because they do not have their own source water, so they will not be subject to monitoring or treatment requirements and do not need to conduct implementation activities. This baseline is also used with minor modifications to determine the number of systems (and plants) subject to monitoring costs.

[6] Many purchased systems do no treatment themselves; the supplying system treats their water. In fact, fewer than half of the surface water systems in SDWIS treat the total flow from systems that supply surface water.

Exhibit 4.2: Methodology for "Linking" Consecutive Surface Water CWSs and NTNCWSs to Their Selling Systems

- If a system has multiple sources, (e.g., a system has a primary source of surface water in addition to a purchased surface water source), it was assumed to be adequately represented as a nonpurchased surface water system, and was not linked to its seller (i.e., only 100-percent purchased surface water systems were linked).
- If a purchased surface water system (System P) purchases all of its water from *one* nonpurchased surface water system (System S), its population was added to that of System S, and it was removed from the inventory of purchased-water systems.
- If the purchased surface water system buys water from *multiple* nonpurchased-water systems, it was assigned to the most directly related nonpurchased seller with the largest population. For example, a purchased system (System C) purchases from a nonpurchased system (System B1) and a purchased system (System B2), which in turn purchases from a nonpurchased system (System A). In this case, System C was linked to System B1, and the population of System C was added to that of System B1.
- When the purchased system and its seller were not of the same type (e.g., a CWS purchasing from a NTNCWS), they were not linked. Systems purchasing from sellers of a different system type were counted as separate, unlinked purchased-water systems.
- If the PWS identification number of the seller did not correspond to an active water system, the purchased system was counted as a separate, unlinked, purchased system.
- Some purchased-water systems have what is referred to as "cascading provider relationships." For instance, a purchased system (System C) may purchase water from another system (System B). This system (System B) does not treat its own water, but instead purchases water from another system (System A). For this analysis, the populations of both Systems B and C were added to the population of System A, and Systems B and C were removed from the inventory of purchased-water systems.
- In a few cases, the seller could not be found, i.e., a purchased system (e.g., System C) could not be linked to a nonpurchased system (e.g., System A). These purchased-water systems were counted as separate, unlinked, purchased-water systems.

Exhibit 4.3a: Inventory of Unlinked and Linked Surface Water and GWUDI CWSs

Population Served	System Inventory Before Linking: Number of Systems: Purchased: Public	Purchased: Private	Nonpurchased: Public	Nonpurchased: Private	Total No. of Systems	Linked System Inventory: Number of Systems: Purchased: Public	Purchased: Private	Nonpurchased: Public	Nonpurchased: Private	Total No. of Systems	Plants per System	Total Plants	Population Served	Percent of Total Population
	A	B	C	D	E = A+B+C+D	F	G	H	I	J=F+G+H+I	K	L=J*K	M	N
<100	420	302	188	235	1,145	23	8	109	232	372	1.0	376	20,526	0.01%
100-499	843	641	409	314	2,207	40	25	391	311	767	1.0	767	199,595	0.11%
500-999	648	391	324	102	1,465	21	11	301	103	436	1.1	459	317,910	0.17%
1,000-3,299	1,186	303	925	158	2,572	53	23	846	155	1,077	1.0	1113	2,175,624	1.20%
3,300-9,999	858	140	940	85	2,023	48	15	934	89	1,086	1.0	1128	6,655,716	3.66%
10,000-49,999	682	91	863	99	1,735	32	2	955	102	1,091	1.1	1184	25,903,789	14.25%
50,000-99,999	103	18	169	31	321	7	0	218	36	261	1.2	325	18,249,527	10.04%
100,000-999,999	58	9	184	25	276	7	0	234	28	269	1.4	384	76,010,534	41.80%
1,000,000+	0	0	14	2	16	0	0	17	2	19	3.4	64	52,305,188	28.76%
Total	**4,798**	**1,895**	**4,016**	**1,051**	**11,760**	**231**	**84**	**4,007**	**1,056**	**5,378**		**5,799**	**181,838,409**	**100%**

Exhibit 4.3b: Inventory of Unlinked and Linked Surface Water and GWUDI NTNCWSs

Population Served	System Inventory Before Linking: Number of Systems: Purchased: Public	Purchased: Private	Nonpurchased: Public	Nonpurchased: Private	Total No. of Systems	Linked System Inventory: Number of Systems: Purchased: Public	Purchased: Private	Nonpurchased: Public	Nonpurchased: Private	Total No. of Systems	Plants per System	Total Plants	Population Served	Percent of Total Population
	A	B	C	D	E = A+B+C+D	F	G	H	I	J=F+G+H+I	K	L=J*K	M	N
<100	14	37	67	114	232	14	32	66	114	226	1.0	226	11,101	1.52%
100-499	29	46	84	158	317	29	44	83	156	312	1.0	312	72,127	9.88%
500-999	10	16	23	57	106	10	14	24	58	106	1.0	106	70,321	9.63%
1,000-3,299	17	12	18	45	92	16	12	17	46	91	1.0	91	153,287	20.99%
3,300-9,999	8	3	1	12	24	8	3	3	11	25	1.0	25	125,413	17.18%
10,000-49,999	2	2	0	1	5	2	2	0	1	5	1.0	5	128,055	17.54%
50,000-99,999	0	0	0	0	0	0	0	0	0	0	0.0	0	0	0.00%
100,000-999,999	1	0	0	0	1	1	0	0	0	1	1.0	1	169,846	23.26%
1,000,000+	0	0	0	0	0	0	0	0	0	0	0.0	0	0	0.00%
Total	**81**	**116**	**194**	**386**	**777**	**81**	**106**	**193**	**386**	**766**		**766**	**730,150**	**100%**

Exhibit 4.3c: Inventory of Surface Water and GWUDI TNCWSs

Population Served	System Inventory									
	Number of Systems					Plants per System	Total Plants	Population Served	Percent of Total Population
	Purchased		Nonpurchased		Total No. of Systems				
	Public	Private	Public	Private					
	F	G	H	I	J=F+G+H+I	K	L=J*K	M	N
<100	83	397	224	569	1,273	1.0	1273	47,620	0.37%
100-499	25	76	175	334	610	1.0	610	119,980	0.94%
500-999	11	17	48	31	107	1.0	107	68,762	0.54%
1,000-3,299	14	4	36	13	67	1.0	67	117,455	0.92%
3,300-9,999	3	0	14	2	19	1.0	19	89,020	0.70%
10,000-49,999	3	0	7	2	12	1.0	12	221,299	1.73%
50,000-99,999	0	0	0	0	0	0.0	0	0	0.00%
100,000-999,999	0	0	1	0	1	1.0	1	144,000	1.12%
1,000,000+	2	0	0	0	2	1.0	2	12,000,000	93.69%
Total	**141**	**494**	**504**	**952**	**2,091**		**2,091**	**12,808,136**	**100%**

Notes: TNCWSs were not included in the linking exercise, and therefore only one inventory is presented in Exhibit 4.3c, compared to Exhibits 4.3a and 4.3b.
For TNCWSs, "population served" is actually the population served at a given time. These numbers are used for calculating treatment costs. The total number of people served over 1 year (or whatever length of time the TNCWSs is in operation) is generally much larger. To calculate benefits, EPA adjusted the population to account for the total number of people served per year and for the fact that each customer would be served by the system for a shorter period of time than 1 year. These adjustments are described in Chapter 5.

The total number of nonpurchased systems remains the same before and after linking; however, the number of such systems in a size category may change. This is because a nonpurchased system's population changes if a purchased system is linked to the nonpurchased system, and the population may change enough to move the system to the next size category.

The number of purchased systems left after the linking process and the population associated with these systems are included in the baseline for plants subject to treatment requirements because their population must be accounted for in determining treatment costs (EPA realizes that including the systems themselves does result in an over-estimate of the number of systems requiring treatment under LT2ESWTR).

Sources: [A]-[D] SDWIS September 2003 (USEPA 2003e); excludes Massachusetts Regional Water Authority and their consecutive systems.
Systems not categorized as "public" or "private" in SDWIS were redistributed among public and private purchased and nonpurchased water systems according to the proportions of systems in these categories.
[F]-[I] Data from Columns A-D modified using linking methodology described in Exhibit 4.2, except for TNCWSs, which were not linked.
[K] Derived from CWSS data (USEPA 1997c) and Model Systems Report (USEPA 2000a), modified to exclude ground water plants and weighted for representativeness of each system to all CWSs.
[M] Includes SDWIS population served by surface water and GWUDI systems for nonpurchased and purchased systems in columns F–I based on SDWIS (USEPA 2003e). Original SDWIS population distribution was modified using linking methodology described in Exhibit 4.2, except for TNCWSs, which were not linked.

The right side of Exhibit 4.3 shows the baseline number of systems, after the linking process, that are subject to the treatment requirements of the LT2ESWTR. (Actual treatment requirements will be determined by results of *Cryptosporidium* monitoring.) This baseline includes both purchased and nonpurchased systems. The baseline number of systems was converted to plants as described below.

Number of Plants

Water systems can have one treatment plant supplying all of the water distributed to the population, or multiple plants treating water. The water may come from different sources, or even different source types such as surface and ground water sources. Many of the costs in Chapter 6 are developed by estimating the costs of installing additional treatment at existing plants. Therefore, for this baseline analysis, EPA needed to calculate the number of plants represented by the systems reported in existing databases.

EPA used the 2000 CWSS data to estimate the number of plants per system. The survey requested information on the number of treatment plants per system, the source of water treated at each plant, and the type of treatment in place. The analysis excluded systems whose responses to the treatment questions were incomplete. (Some reported no treatment for surface water sources, which indicates the source was likely purchased treated water.) The analysis also excluded systems whose flow rates per person were unusually high or low. (These systems were identified as outliers in a separate analysis of average daily flow and design capacity.) Ninety of the 1,246 systems in the sample were dropped from the analysis, and of the remainder, 587 systems use surface water for at least a portion of their supply. The number of plants that treat surface water or GWUDI was counted for each system; plants that treated ground or purchased water only were not included in the count. The mean ratios by size category incorporated sample weights for survey non-response and specific question non-response. (See *The 2000 Community Water System Survey, Volume II* for details on sample weight calculations.)

The ratios of plants to systems are shown in Exhibit 4.3. For surface water and GWUDI CWSs, the average number of surface water treatment plants per system varies from 1.0 to 3.4.

Plant information is not available for noncommunity water systems. Because they typically serve a single building or are located in a small area, this analysis assumes that the ratio of plants per system is 1:1 for all size categories. Exhibit 4.3 summarizes the total number of plants for CWSs, NTNCWSs, and TNCWSs. The total number of plants displayed in Exhibit 4.3 is the baseline from which regulatory impacts are estimated.

Population

The total population that the LT2ESWTR affects is derived from SDWIS data (USEPA 2003e). As described in Exhibit 4.2, the linking process redistributes the population served by purchased systems to the seller. This analysis also corrects for double-counted populations between wholesale and consecutive systems. The breakdown of population by size category is shown in Exhibit 4.3a; this breakdown includes adjustments made to populations during the linking process (see Exhibit 4.2).

One method for determining the impact of the rule involves a cost analysis on a per household basis. Only the population served by CWSs is considered in the household cost analysis. People served by NTNCWSs and TNCWSs when working, attending school, or traveling are also served on a regular basis by another source, such as a private well or a CWS. Their consumption from a NCWS is an incidental use in addition to their regular service. Adding the population served by NCWSs to that served by CWSs would lead to double counting in cases where both types of systems served the same person. If some people served by private wells receive water from NTNCWSs for part of the year, the error introduced by ignoring this consumption from this source is less than it would be if the population served by NCWSs were included in the baseline.

The population served is affected differently depending on the service type, in that people experience different durations of exposure. This, in turn, affects water demand on the system, as well as risk of exposure to contaminated water.

Uncertainty in Baseline Input Data

EPA recognizes that there is uncertainty in the data sources used to define the system inventory for the LT2ESWTR. The uncertainty is not quantified in this EA; however, a qualitative discussion of the identified uncertainties is provided below.

As noted above, SDWIS and the 2000 CWSS are the primary sources of system inventory data. SDWIS is EPA's primary drinking water database. It stores State-reported information on each water system, including name, ID number, number of people served, type of system (year-round or seasonal), and source of water (ground or surface). These data are required fields of entry; additional data, such as buying and selling information, are not required. In 1998, EPA began a major effort to assess the quality of the data in SDWIS. The results, published in *Data Reliability Analysis of the EPA SDWIS/FED*, found that the quality of the required inventory data was high (USEPA 2000c). Thus, EPA believes that uncertainty in the system inventory data from SDWIS with respect to numbers of systems, source information, and size classification is low, and need not be further accounted for in the analysis.

The 2000 CWSS was the primary data source used to develop estimates of the number of treatment plants per system. It was developed to gather data on CWSs in the United States. Of the 1,870 systems statistically selected to receive the main survey questionnaire, 1,246 responded. These responses were weighted and adjusted for item nonresponse to maintain statistical representation of the total universe of CWSs (USEPA 2003f). For the surface-water-plant-per-system analysis, 587 systems were included. This represents slightly more than 10 percent of the nonpurchased CWS systems in the baseline. EPA believes that extrapolating mean estimates from these data to the CWS baseline is appropriate, and that the error this procedure introduces is negligible.

4.3.3 Water Treatment Plant Design and Average Daily Flows

Treatment technology costs are based on the volume of water treated per day. The cost analysis described in Chapter 6 uses two types of treatment plant flow:

- Design flow—the maximum capacity at which the plant was intended to operate, expressed in millions of gallons per day (mgd).

- Average daily flow—the flow a treatment plant produces, averaged over 365 days, expressed in mgd.

Design flows are used to estimate the capital costs of the technology that will be installed to meet the requirements of the LT2ESWTR. Average daily flows are used to estimate the annual cost of ongoing operations and maintenance (O&M). Average daily flows give a better indication of chemical usage and operational costs than do design flows. The flows presented in this section are used to estimate costs for both unfiltered and filtered plants.

To derive flow information for different-sized plants, EPA developed the following regression equations relating design and average daily flow to population served for surface water systems using data from the 1995 CWSS:

$$\text{Design Flow (MGD)} = 0.36971\, X^{0.97757}/1{,}000$$
$$\text{Average Daily Flow (MGD)} = 0.10540\, X^{1.02058}/1{,}000$$

Where X = mean population served.

The derivation of these equations is presented in detail in the Model Systems Report (USEPA 2000a) and summarized in the Baseline Handbook (USEPA 2001c). EPA used these equations to estimate mean flows per system, based on the population per system shown in column A of Exhibit 4.4, and then divided by the number of plants per system to determine the flow per plant.

Exhibit 4.4a summarizes populations served and design and average daily flows for filtered plants at CWSs. Exhibit 4.4b shows the flows and populations for unfiltered plants (all unfiltered plants are CWSs except for one TNCWS, which was grouped with the CWSs). EPA recognizes that there is a range of design and average daily flows within each category, but believes that using mean flow values is adequate for the cost and benefit analyses in this EA.

An equivalent regression analysis relating NCWS flows to population served was not done in the Model Systems Report. Therefore, average daily and design flows for NCWSs were estimated using mean population served per plant for NCWSs substituted into the CWS regression equations. Flows are summarized in Exhibit 4.4a for filtered NTNCWSs and TNCWSs. Plant flows for filtered CWSs, NTNCWSs, and TNCWSs differ from each other because of the difference in mean population per plant for each of the three categories, and the volume of water delivered to commercial and industrial customers. Use of CWS equations to determine NCWS flows may result in an overestimation of flows because NCWSs often serve people for only part of the day. This may lead to an overestimation of costs for NCWSs. This overestimation is addressed as part of the uncertainties summarized in section 4.8.

For this rulemaking, EPA considered estimating flows for NCWSs according to service category (e.g., schools, restaurants, hotels, industry), as has been done in some other rules, instead of size. EPA decided against such an approach for the following reasons:

- Service category flows are based on mean population served for all systems in that category, regardless of source water type. EPA expects that surface water and GWUDI sources would be more prevalent in larger noncommunity systems, but has no basis for developing revised population estimates for each service category by source.

- More critical to the LT2ESWTR, the method used to predict technology selection in Chapter 6 is a function of population served, and does not directly apply to service categories that may include a wide range of water system sizes (e.g., schools can be very small local buildings or large universities).

Exhibit 4.4a: Average Daily and Design Flow by System Size for Filtered Plants

System Size	Population per System	Plants per System	Average Daily Flow (MGD) per Plant	Design Flow (MGD) per Plant
	A	B	$C = (0.10540*A^{1.02058})/(B*1{,}000)$	$(0.36971*A^{0.97757})/(B*1{,}000)$
CWSs				
<100	55	1.0	0.01	0.02
100-499	259	1.0	0.03	0.08
500-999	723	1.1	0.08	0.22
1,000-3,299	2,000	1.0	0.24	0.60
3,300-9,999	6,027	1.0	0.73	1.76
10,000-49,999	23,481	1.1	2.81	6.38
50,000-99,999	68,891	1.2	7.34	15.95
100,000-999,999	277,100	1.4	26.49	54.21
1,000,000+	2,320,282	3.4	98.62	184.16
NTNCWSs				
<100	49	1.0	0.01	0.02
100-499	231	1.0	0.03	0.08
500-999	663	1.0	0.08	0.21
1,000-3,299	1,652	1.0	0.20	0.52
3,300-9,999	5,017	1.0	0.63	1.53
10,000-49,999	25,611	1.0	3.33	7.54
50,000-99,999	0	-	-	-
100,000-999,999	169,846	1.0	22.94	47.93
1,000,000+	0	-	-	-
TNCWSs				
<100	37	1.0	0.004	0.01
100-499	197	1.0	0.02	0.06
500-999	643	1.0	0.08	0.21
1,000-3,299	1,753	1.0	0.22	0.55
3,300-9,999	4,685	1.0	0.59	1.43
10,000-49,999	18,442	1.0	2.38	5.47
50,000-99,999	0	-	-	-
100,000-999,999	144,000	1.0	19.38	40.79
1,000,000+	6,000,000	1.0	871.95	1,563.07

Source: [A] Population served for each size category (Exhibit 4.12, Column E) divided by number of systems in each category (Exhibit 4.12 Column C), based on the treatment baseline.
[B] 2000 CWSS.
[C] USEPA 2000a.

Exhibit 4.4b: Average Daily and Design Flow by System Size for Unfiltered Plants

System Size	Population per System	Plants per System	Average Daily Flow (MGD) per Plant	Design Flow (MGD) per Plant
	A	B	$C = (0.10540*A^{1.02058})/(B*1,000)$	$D = (0.36971*A^{0.97757})/(B*1,000)$
CWS				
<100	78	1.0	0.01	0.03
100-499	298	1.0	0.04	0.10
500-999	822	1.1	0.09	0.25
1,000-3,299	1,663	1.0	0.20	0.50
3,300-9,999	7,861	1.0	0.96	2.29
10,000-49,999	21,979	1.1	2.62	5.98
50,000-99,999	67,277	1.2	7.17	15.58
100,000-999,999	367,684	1.0	50.45	101.98
1,000,000+	4,109,917	1.0	592.64	1,079.81

Source: [A] Population served for each size category (Exhibit 4.5, Column D) divided by number of systems in each category (Exhibit 4.5, Column A), based on the treatment baseline.
[B], [C] USEPA 2000a; plant per system ratios for systems serving over one million based on system-specific data supplied by States.

4.4 Baseline for Unfiltered Plants (Pre-LT2ESWTR)

Unfiltered plants are subject to different LT2ESWTR provisions than filtered plants. (For example, all unfiltered plants must achieve some inactivation of *Cryptosporidium*; bin assignments only determine the degree of inactivation required.) Therefore, the baselines for unfiltered and filtered plants must be developed separately. The following sections summarize the existing treatment; system, plant, and population data; source water *Cryptosporidium* occurrence; and predicted finished water *Cryptosporidium* occurrence for unfiltered plants.

4.4.1 Treatment Characterization for Unfiltered Plants

EPA estimates that a number of plants that currently are not required to filter will need to install an advanced disinfectant technology to meet the 2 log or 3 log *Cryptosporidium* inactivation requirement for LT2ESWTR. Some treatment data collected over time by EPA regional offices are available on these plants. Most of these plants are not predicted to add treatment to meet the Stage 1 or Stage 2 DBPR requirements, because they generally have low-turbidity source water and, thus, low levels of precursors for DBP formation. Unfiltered plants are not subject to IESWTR or LT1ESWTR filtration requirements. EPA therefore used the existing regional data to develop the treatment characterization for these unfiltered plants.

A review of these data reveals that unfiltered plants use a variety of treatments to disinfect or control other water quality problems. Plants serving 3,300 or fewer people generally use chlorine as the primary disinfectant, although at least one plant serving 501 to 1,000 people uses ozone. Some of these plants may also employ corrosion control, as well as manganese and iron removal. Plants serving 3,301 or more people mainly use chlorination for disinfection, and at least one plant serving 3,301 to 10,000 people uses chlorine dioxide. Other treatment processes used in medium and large unfiltered plants include corrosion control, softening, fluoridation, DBP control, taste and odor control, as well as organics and iron removal. Some plants avoiding filtration may have already installed treatment equivalent to filtration, and some systems may filter water from some but not all of their sources.

The unfiltered plant database contains treatment data for less than 50 percent of unfiltered plants. The ICR database was also examined. Only one unfiltered plant participating in the ICR was found to use ozone (USEPA 2000h), and its dose levels were not high enough to meet the LT2ESWTR requirements. No ICR unfiltered plants used chlorine dioxide. Because of the high doses of ozone or chlorine dioxide required to inactivate *Cryptosporidium*, it appears unlikely that any unfiltered plants are currently meeting the requirements of the LT2ESWTR. Therefore, for this EA, EPA estimates with a high degree of confidence that all unfiltered systems will have to add advanced disinfection to achieve the 2 log *Cryptosporidium* inactivation minimum requirement.

4.4.2 Number of Unfiltered Systems, Plants, and Population Served

Systems that operate unfiltered plants can be placed in one of two categories:

- Those with plants that are now unfiltered but are required to filter under the 1989 Surface Water Treatment Rule (SWTR); and

- Those that meet the filtration avoidance criteria of the SWTR.

Three of the 12 unfiltered plants in the ICR are currently unfiltered, but will be changing to filtration in the future. These systems are subject to requirements of the proposed LT2ESWTR for filtered systems because they do not meet the avoidance criteria under the SWTR; they are therefore included in the baseline for filtered systems (section 4.5). In addition, a fourth plant, the Massachusetts Water Resources Authority, was omitted from the unfiltered baseline (and *not* moved to filtered baseline) because of the uncertainties regarding its filtration avoidance status due to ongoing litigation at the time this calculation was done. The purchased systems associated with this plant were also removed from the baseline presented in Exhibit 4.3.

The baseline for unfiltered plants, therefore, includes only systems that meet the SWTR avoidance criteria. The criteria include that the plants:

- Disinfect to achieve 3 and 4 log reduction of *Giardia* and viruses, respectively;

- Have watershed control measures in place; and

- Are below source water limits on fecal coliform occurrence (20/100 ml) and turbidity (5 nephelometric turbidity units (NTU)).

Exhibit 4.5 presents the baseline for unfiltered systems and plants that is used for estimating costs and benefits in this EA. Data on populations served and the number of systems are derived from SDWIS and from the ICR for large systems (USEPA 2003e, 2000h). The number of plants is calculated using the plant-per-system ratios given earlier. There is only one TNCWS unfiltered system, and there are no unfiltered NTNCWSs. Maintaining a separate category in subsequent analyses for one system was judged unlikely to add precision, so this TNCWS was grouped with CWSs in all subsequent analyses. These baseline values, in conjunction with flows presented in section 4.3.3, are used to estimate costs for unfiltered systems (see Chapter 6).

Exhibit 4.5: Treatment Baseline for Unfiltered Plants by System Size

System Size (Population Served)	Number of Systems	Plants per System	Number of Plants	Population Served	Percent of Total Population Served by Surface and GWUDI CWSs
	A	B	C=A*B	D	E
<100	1	1.0	1	78	0.38%
100-499	4	1.0	4	1,192	0.59%
500-999	3	1.1	3	2,467	0.77%
1,000-3,299	15	1.0	15	24,947	1.13%
3,300-9,999	14	1.0	15	110,056	1.63%
10,000-49,999	13	1.1	14	285,732	1.09%
50,000-99,999	4	1.2	5	269,106	1.45%
100,000-999,999	4	1.0	4	1,470,734	1.90%
1,000,000+	2	1.0	2	8,219,833	13.58%
Total	**60**		**63**	**10,384,145**	**5.40%**

Notes: All systems are CWSs except one TNCWS, which was grouped with the CWSs for analysis.

Sources: [A] SDWIS (USEPA 2003e) data adjusted by EPA to exclude systems that do not meet filtration avoidance criteria.
[B] Exhibit 4.3, Column K.
[D] SDWIS data for the systems in Column A (2000h), modified to include populations added in the linking process (see Exhibit 4.1).
[E] Population served (Column D) divided by total population served by surface water and GWUDI CWSs (Exhibit 4.3a, Column M).

4.4.3 Source Water *Cryptosporidium* Occurrence for Unfiltered Plants

ICR data from 12 plants that are classified as unfiltered surface water are used to characterize *Cryptosporidium* occurrence (USEPA 2000h). The results of the ICR *Cryptosporidium* monitoring were evaluated using the model described in section 4.2.2. Because a few of these plants do not meet the filtration avoidance criteria, a sensitivity analysis was performed to see if results would be significantly different if they were excluded. The occurrence distributions with and without the affected systems were nearly identical; therefore, the original results were used in the analysis.

Observed *Cryptosporidium* Occurrence

Observed results for ICR unfiltered plants are shown in Exhibit 4.6. A comparison with those for filtered plants in the ICR (Exhibit 4.13) shows both a lower rate of positive samples and a lower average concentration of *Cryptosporidium* for unfiltered plants. While too few unfiltered plants were sampled in the ICRSS to carry out a meaningful analysis, the few that were sampled also were on the low side of the ICR unfiltered occurrence distribution.

Exhibit 4.6: Observed ICR Total Oocyst Occurrence in Source Water for Unfiltered Plants

Total Number of Plants	Number of Plants with at Least One Positive Sample (Percent)	Observed Plant-Mean Data (oocysts/L)		
		Mean	Median	90th Percentile
12	7 (58%)	0.002	0.001	0.005

Notes: Total *Cryptosporidium* includes non-empty and empty oocysts. Non-empty includes oocysts with internal structures and with amorphous structures. For each plant, all monthly observations were averaged over the sampling period (18 months) to produce plant-mean data. The mean, median, and 90th percentile shown summarize plant-mean *Cryptosporidium* for all unfiltered plants.

Source: USEPA 2000h.

Modeled *Cryptosporidium* Occurrence

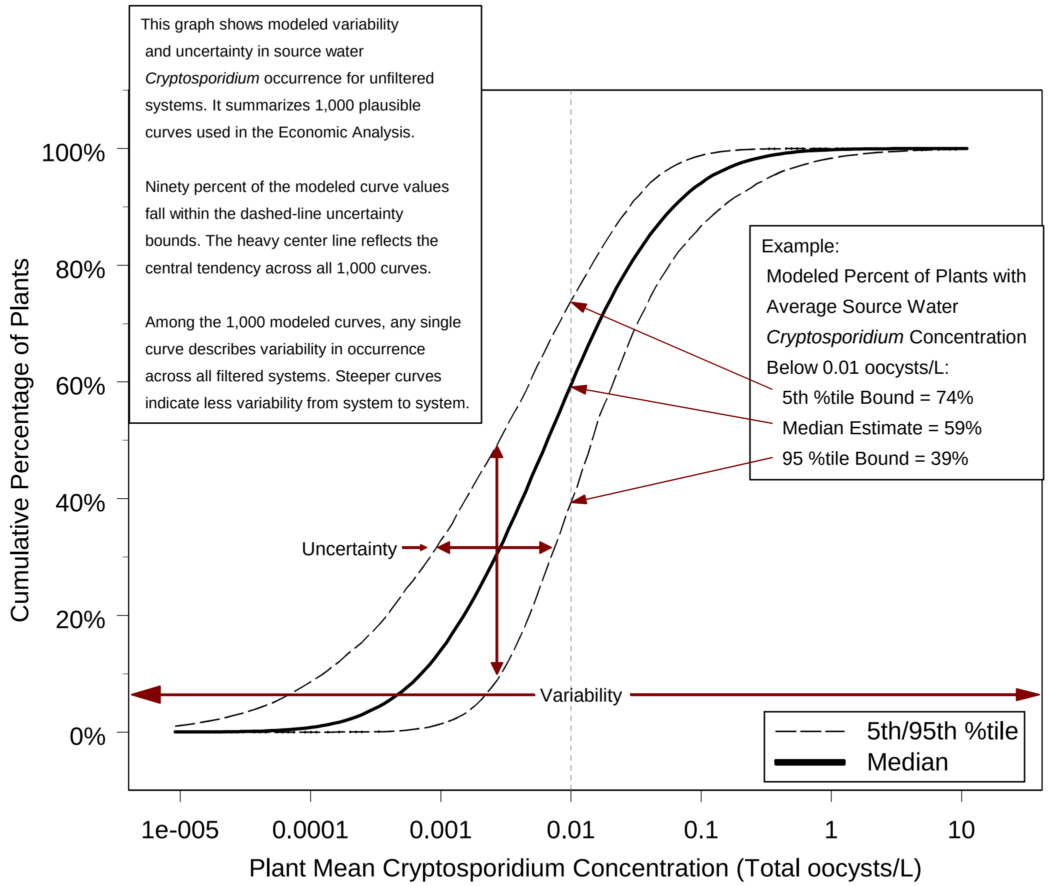
The data from these 12 plants are used to fit the unfiltered plants occurrence model, which serves as input to the EA. The modeling was carried out using the approach outlined in section 4.2.2. As explained in that section, the modeling produces a collection of plausible occurrence distributions. Exhibit 4.7 summarizes this collection of distributions. The solid center curve represents the mean distribution across the collection, and the dotted lines give a 90-percent confidence bound for the unfiltered occurrence distribution.

4.4.4 Finished Water *Cryptosporidium* Occurrence for Unfiltered Plants

As mentioned in section 4.4.1, because unfiltered plants do not have advanced treatment technologies in place that are capable of meeting 2.0 log *Cryptosporidium* removal or inactivation, they are not expected to remove or inactivate any *Cryptosporidium* from their source water. Although most unfiltered systems chlorinate their water (a few may use other disinfectants besides chlorine), chlorination is ineffective for inactivation of *Cryptosporidium*. Therefore, the finished water occurrence of *Cryptosporidium* for unfiltered plants is assumed to be the same as the source water occurrence shown in Exhibit 4.7.

The occurrence distribution in Exhibit 4.7 is derived from the ICR data set (USEPA 2000h). Although there were unfiltered plants in the ICRSS data sets, they were too few to use successfully in the model to derive national distributions. Thus, there are no explicit estimated occurrence distributions for the unfiltered ICRSS data sets. In order to develop national benefit estimates for the ICRSS data sets, EPA estimated unfiltered results based on the ratios between ICR and ICRSSM and between ICR and ICRSSL for filtered plants. Thus, although no explicit occurrence distributions were estimated for the ICRSS data sets, the likely differences in *Cryptosporidium* occurrence between the ICR and ICRSS unfiltered data sets are reflected in later analyses.

Exhibit 4.7: Modeled *Cryptosporidium* Occurrence in Source Water: ICR Data for Unfiltered Systems



Source: USEPA 2003c.

Under the LT2ESWTR, *all* unfiltered systems must provide treatment for *Cryptosporidium*. Systems with *Cryptosporidium* concentrations less than or equal to 0.01 oocysts/L must provide 2 log treatment, while systems with concentrations greater than 0.01 oocysts/L must provide 3 log treatment. The predicted bin assignments for unfiltered systems, derived from the occurrence distribution in Exhibit 4.7, are shown in Exhibit 4.8. The percentages shown represent averages over 250 simulated assignments of unfiltered systems to 2 or 3 log treatment bins. In the case of systems serving fewer than 100,000 people, the simulated assignments were based on 1,000 values drawn from the modeled unfiltered occurrence distribution. For the small number of systems serving 100,000 or more, the simulation drew *Cryptosporidium* concentrations directly from ICR survey results. In both cases, recovery was simulated to match recovery rates expected in *Cryptosporidium* monitoring employing EPA Methods 1622/1623.

Exhibit 4.8: Predicted System Bin Assignments for Unfiltered Systems, Based on Central Tendency of *Cryptosporidium* Occurrence

System Size (Population Served)	2.0 Log Treatment	3.0 Log Treatment
<100,000	79.2%	20.8%
$\geq$100,000	81.2%	18.8%

Source: Monte Carlo simulation (Appendix B). For systems serving fewer than 100,000, percentages based on modeled occurrence distribution and lab method recovery rate distribution. For systems serving 100,000 or more, percentages are based on actual ICR results and modeled lab method recovery distribution.

The percentages in Exhibit 4.8 were used to determine treatment costs each unfiltered system incurred.

4.5 Baselines for Filtered Plants (Pre-LT2ESWTR)

This section presents the Pre-LT2ESWTR treatment characterization for filtered plants. It includes estimates of the number of systems, the number of plants, and the population served for filtered systems. It also contains *Cryptosporidium* occurrence in source water and finished water and predicted bin classifications.

4.5.1 Treatment Characterization for Filtered Plants

The treatment characterization for the LT2ESWTR must take into account projected treatment modifications made to comply with other existing and soon-to-be-promulgated rules. This adjustment allows treatment changes attributable only to LT2ESWTR requirements to be isolated for the purpose of benefit and cost analysis. In addition, systems with certain treatments already in place prior to the implementation of the LT2ESWTR may qualify for pre-LT2ESWTR credit, meaning they can get credit towards the log treatment requirements of the LT2ESWTR. The rest of this subsection explains how treatment changes attributable to the IESWTR, LT1ESWTR, Stage 1 DBPR, and Stage 2 DBPR have been accounted for in developing the LT2ESWTR baseline. Although other rules have been promulgated recently or are scheduled to be promulgated before this rule, they either do not affect surface water supplies or do not involve installation of treatment that is expected to remove significantly or to inactivate *Cryptosporidium*. Therefore, such rules were not considered further.

Post-IESWTR and LT1ESWTR Treatment Characterization

For this EA, it is assumed that all medium and large systems (those serving at least 10,000 people) using conventional or direct filtration meet the combined effluent turbidity limit of 0.3 NTU 95 percent of the time, as required under IESWTR and LT1ESWTR. EPA assumed as part of the economic analyses for the IESWTR and LT1ESWTR that systems would achieve less than 0.2 NTU 95 percent of the time in order to operate within a margin of safety. Lower finished water turbidity, with a combined effluent turbidity level of 0.15 NTU, is one of the approaches in the microbial toolbox (described in detail in Chapter 6) available to systems for achieving an additional 0.5 log removal credit for *Cryptosporidium*. There are several other toolbox technologies that plants may already have installed that would gain them Pre-LT2ESWTR credit of 0.5 log toward *Cryptosporidium* removal requirements. These include secondary filters and two-stage softening.

To determine the number of plants that might obtain credit for already using some of these toolbox technologies, several data sources were reviewed. Data from the ICR, the American Water Works Association (AWWA) (AWWA 2000), a survey of small systems conducted by the National Rural

Water Association (NRWA) (USEPA 2001b), and the 1995 CWSS were reviewed to determine the percentage of plants that have these technologies that would qualify for removal credits. Exhibit 4.9 provides an estimate of the percentage of systems that would be capable of obtaining each of these Pre-LT2ESWTR half-log removal credits with existing equipment and operations or with equipment and operations predicted to be installed and in use prior to promulgation of this rule. Details on the derivation of these numbers are provided in Appendix A. Some of these plants may be able to obtain credit for having multiple technologies. The percentage of plants estimated to get 1.0 log removal credit is presented in Exhibit 4.9 as well. The estimates of 1.0 log credits are derived from the individual credits for plants receiving the various 0.5 log removal credits, assuming complete independence of the chance of having any one of the 0.5 log credits.

Exhibit 4.9: Percentage of Plants Qualifying for Pre-LT2ESWTR *Cryptosporidium* Log Reduction Credits for Existing Technologies

System Size (Population Served)	Plants with 0.15 NTU Finished Water Turbidity (0.5 Log)	Plants with Multiple Settling Basins (Conventional and Softening) (0.5 Log)	Plants with Multiple Filters (0.5 Log)	Plants with 1.0 Log Total Credit	Plants with 0.5 Log Total Credit
	A	**B**	**C**	**E=(A*B)+(A*C)+(B*C)**	**D=A + B + C - E**
Small (≤ 10k)	34%	3%	0%	**1%**	**36%**
Medium (10k -100k)	46%	5%	4%	**4%**	**51%**
Large (> 100k)	46%	5%	7%	**6%**	**52%**

Source: Appendix A, Exhibit A.7.

Post-Stage 2 DBPR Treatment Characterization

Under the LT2ESWTR, EPA exempts plants from monitoring, bin classification, and associated treatment requirements if they are achieving 5.5 log reduction. EPA estimates that very few plants met this requirement at the time of the ICR. A proportion of surface water plants, however, are expected to implement advanced technologies to meet the DBP requirements of the Stage 1 DBPR and Stage 2 DBPR. Several of these technologies will provide additional logs of *Cryptosporidium* removal or inactivation in addition to reducing DBPs. Advanced technologies that will provide both DBP and *Cryptosporidium* control include the following:

- Chlorine dioxide
- UV
- Ozone
- Microfiltration/ultrafiltration (MF/UF)

SWAT (see section 4.2.3) used source water and treatment data collected through the ICR to predict the percentage of large systems that would have to add treatment to meet Stage 2 DBPR requirements. SWAT was also able to predict plants' technology selection based on source water characteristics, treatment plant configurations, and other factors. SWAT results were extrapolated to medium and small systems using best professional judgment. EPA's *Economic Analysis for the Stage 2 Disinfectants and Disinfection Byproducts Rule* (USEPA 2003d) provides a detailed description of Stage 2 DBPR requirements, how SWAT modeled ICR systems, and how SWAT was used to develop the Stage 2 DBPR compliance forecast for plants of all sizes. Exhibit 4.10 presents predictions from SWAT of technology use following Stage 2 DBPR implementation for the four technologies listed above.

Exhibit 4.10: Predicted Percentage of Plants Using Advanced Technologies Following Implementation of the Stage 2 DBPR

System Size (Population Served)	Chlorine Dioxide	UV	Ozone	MF/UF
≤ 100	0 %	3.1 %	0 %	18.6 %
101-500	2.4 %	0.4 %	11.9 %	9.9 %
501-1,000	2.4 %	0.4 %	11.9 %	9.9 %
1,001-3,300	5.1 %	0.5 %	10.1 %	5.4 %
3,301-10,000	5.1 %	0.5 %	10.1 %	5.4 %
10,001-50,000	7.0 %	0.7 %	12.8 %	1.8 %
50,001-100,000	7.0 %	0.7 %	12.8 %	1.8 %
100,001-1 Million	7.0 %	0.7 %	12.8 %	1.8 %
> 1 Million	7.0 %	0.7 %	12.8 %	1.8 %

Source: *Economic Analysis for the Stage 2 Disinfectants/Disinfection Byproducts Rule* (USEPA 2003d), Exhibit 6.15a.

EPA did not adjust the baseline for plants that use chlorine dioxide or ozone. Chlorine dioxide and ozone doses required for *Cryptosporidium* inactivation are higher than SWTR requirements for inactivation of *Giardia* and viruses. To evaluate the use of these technologies at doses that could inactivate *Cryptosporidium*, both incremental costs for the increased dose and incremental benefits would need to be evaluated. However, available studies do not allow the quantitative evaluation of inactivation based on dose changes. In the absence of usable data, this analysis assumes that plants predicted to have installed chlorine dioxide or ozone would not meet the monitoring and treatment exemption requirements for the LT2ESWTR. The cost model for this EA assumes that these plants would install the entire technology again for the LT2ESWTR rather than simply increase the dose, resulting in an overestimate of costs. Uncertainties and biases affecting costs are summarized in section 4.8.

Currently, very few plants use UV. This is partly because of the need for higher doses required to inactivate viruses (compared to that needed for protozoans) and the need to maintain a disinfectant residual. These factors result in only about half a percent of plants nationwide using UV. Since this is such a small number of plants, the LT2ESWTR baseline was not adjusted to reflect plants that already have installed UV.

MF/UF is the only treatment process assumed to achieve 5.5 log removal. The LT2ESWTR baseline is adjusted in several ways to account for the percentage of plants that may already be using MF/UF. CWS and NTNCWS plants (both in small and large systems) that are predicted to have installed MF/UF prior to the Stage 2 DBPR are removed entirely from the monitoring and treatment baselines. Plants achieving greater than 5.5 log treatment of *Cryptosporidium* are meeting the highest level of treatment that could be required based on source water monitoring. These plants would not have to add treatment if they did monitor and were assigned to the most stringent treatment bin. EPA anticipates that some plants will install MF/UF to meet the requirements of the Stage 2 DBPR. These plants are included in the rule implementation and initial monitoring baselines, because they are still subject to the LT2ESWTR and because the Stage 2 DBPR schedule is such that they will not have installed MF/UF before initial *Cryptosporidium* monitoring begins. They are not, however, assigned to the future monitoring and treatment baselines. TNCWSs are unlikely to have installed advanced technologies, partly because Stage 1 and Stage 2 DBPRs do not address TNCWSs.

Treatment plants with different types of filtration systems have been regulated differently under IESWTR and LT1ESWTR and, to a small extent, under LT2ESWTR. The types of filtration included in this analysis are as follows:

- *Conventional filtration* includes coagulation, flocculation, and sedimentation of particles, followed by granular media filtration.

- *Direct filtration* involves coagulation and flocculation followed by rapid sand filtration, but no sedimentation.

- *Slow sand filtration* works at very low filtration rates without the use of coagulant in pretreatment.

- *Diatomaceous earth filtration* works at low filtration rates with the addition of diatomaceous earth.

- *Alternative filtration* systems include membrane, bag, and cartridge filters.

Plants filtering by slow sand and diatomaceous earth are not required to meet new combined filter effluent provisions under the IESWTR or LT1ESWTR because they can generally achieve higher *Cryptosporidium* removals at higher effluent turbidity levels. These treatment plants are still subject to additional treatment requirements of the LT2ESWTR based on the results of source water monitoring and, thus, are included in the filtered system baseline. Direct filtration plants also are included in this baseline; however, they have slightly different *Cryptosporidium* reduction requirements under the LT2ESWTR. The impacts of these additional requirements for direct filtration plants are addressed in Chapter 6.

4.5.2 Number of Filtered Plants and Population Served

Because the LT2ESWTR requires treatment for only certain filtered systems based on the results of their source water monitoring, two baselines are needed for filtered plants–monitoring and treatment. Source water monitoring requirements for wholesale systems are determined by the population served by the largest system in the combined distribution system of which the wholesale system is a part. During the SDWIS linking analysis that linked buyers to sellers (described in section 4.3), EPA also determined the population of the largest system in the combined distribution for use in estimating monitoring costs. Exhibit 4.11 presents the filtered plant baseline for estimating implementation and source water monitoring costs. Note that the number of plants does not include the purchased plants that could not be linked to their sellers since no additional monitoring costs will be incurred (the treatment baseline includes these systems as discussed below).

Exhibit 4.11: Implementation and Monitoring Baseline for Filtered Systems

System Size	Implementation Baseline: Number of Filtered Systems	Percent Avoiding Monitoring and Treatment Requirements	Plants per System	Monitoring Baseline: Number of Filtered Systems	Monitoring Baseline: Number of Filtered Plants
	A	B	C	D=A*(1-B)	E=D*(1-C)
CWSs					
<100	341	3.6%	1.01	329	333
100-499	708	3.6%	1.00	683	683
500-999	425	3.6%	1.05	410	432
1,000-3,299	1,076	3.6%	1.03	1,037	1,072
3,300-9,999	1,052	3.6%	1.04	1,014	1,054
10,000-49,999	1,010	0.4%	1.08	1,006	1,092
50,000-99,999	213	0.4%	1.24	212	264
100,000-999,999	220	0.4%	1.43	219	313
1,000,000+	16	0.4%	3.35	16	53
Total	5,061			4,926	5,294
NTNCWSs					
<100	180	3.6%	1.00	174	174
100-499	241	3.6%	1.00	232	232
500-999	81	3.6%	1.00	78	78
1,000-3,299	63	3.6%	1.00	61	61
3,300-9,999	13	3.6%	1.00	13	13
10,000-49,999	1	0.4%	1.00	1	1
50,000-99,999	0	0.4%	1.00	0	0
100,000-999,999	0	0.4%	1.00	0	0
1,000,000+	0	0.4%	1.00	0	0
Total	579			558	558
TNCWSs					
<100	793	0.0%	1.00	793	793
100-499	509	0.0%	1.00	509	509
500-999	79	0.0%	1.00	79	79
1,000-3,299	49	0.0%	1.00	49	49
3,300-9,999	16	0.0%	1.00	16	16
10,000-49,999	9	0.0%	1.00	9	9
50,000-99,999	0	0.0%	1.00	0	0
100,000-999,999	1	0.0%	1.00	1	1
1,000,000+	0	0.0%	1.00	0	0
Total	1,456			1,456	1,456

Sources:
[A] SDWIS September 2003 (USEPA 2003e) - Nonpurchased surface water and GWUDI systems.
[B] Percentage of plants predicted to have installed MF/UF to comply with Stage 1 DBPR, from SWAT technology results for Pre-Stage 2 DBPR (USEPA 2003d).
[C] Derived from 2000 CWSS data.

Exhibit 4.12 presents the treatment baseline for filtered plants. The plants estimated to have MF/UF installed to comply with the Stage 2 DBPR are removed from the LT2ESWTR treatment baseline as their costs and benefits are associated with the Stage 2 DBPR. The plants used to estimate benefits and treatment costs (columns G and H) include nonpurchased plants *and* the purchased plants that could not be linked with the systems from which they purchased their water. To capture the total flow that must be treated and the population affected by the LT2ESWTR, EPA includes these purchased systems in the analysis as though they are treating water themselves. This assumption places more plants in smaller size categories since most are a part of small systems. In the process of linking purchased systems to sellers, the population served by the purchased systems is added to that of the sellers. This can result in a population change large enough to bump the seller up to a higher size category, increasing the flow and consequently, unit costs for that system. Considering both effects, EPA believes that these purchased, unlinked systems cause an overestimation of cost since a complete technology is allocated to the smaller purchased system, instead of increasing the unit costs for the seller due to the increased population. Uncertainties associated with categorization of some purchased systems as retail are summarized in section 4.8.

Exhibit 4.12: Treatment Baseline for Filtered Plants

System Size	Number of Systems	Percent Avoiding Treatment Requirements	Treatment Baseline: Number of Filtered Systems	Number of Filtered Plants	Population Served
	A	B	C=A(1-B)	D	E
CWSs					
<100	372	18.64%	303	306	16,636
100-499	767	9.93%	691	691	178,702
500-999	436	9.93%	393	414	284,120
1,000-3,299	1,077	5.44%	1,018	1,052	2,036,517
3,300-9,999	1,086	5.44%	1,027	1,067	6,189,576
10,000-49,999	1,091	1.83%	1,071	1,162	25,148,862
50,000-99,999	261	1.83%	256	319	17,651,109
100,000-999,999	269	1.83%	264	377	73,174,602
1,000,000+	19	1.83%	19	63	43,277,931
Total	5,378		5,041	5,450	167,958,055
NTNCWSs					
<100	226	18.64%	184	184	9,032
100-499	312	9.93%	281	281	64,965
500-999	106	9.93%	95	95	63,338
1,000-3,299	91	5.44%	86	86	142,111
3,300-9,999	25	5.44%	24	24	118,591
10,000-49,999	5	1.83%	5	5	125,710
50,000-99,999	0	0.00%	0	0	0
100,000-999,999	1	0.00%	1	1	166,735
1,000,000+	0	0.00%	0	0	0
Total	766		676	676	690,482
TNCWSs					
<100	1,273	0.00%	1,273	1,273	47,620
100-499	610	0.00%	610	610	119,980
500-999	107	0.00%	107	107	68,762
1,000-3,299	67	0.00%	67	67	117,455
3,300-9,999	19	0.00%	19	19	89,020
10,000-49,999	12	0.00%	12	12	221,299
50,000-99,999	0	0.00%	0	0	0
100,000-999,999	1	0.00%	1	1	144,000
1,000,000+	2	0.00%	2	2	12,000,000
Total	2,091		2,091	2,091	12,808,136

Sources:
[A] Exhibit 4.3, Column J less unfiltered systems from Exhibit 4.5, Column A.
[B] Percentage of plants predicted to have installed MF/UF to comply with Stage 2 DBPR, from SWAT technology results for Post-Stage 2 DBPR (USEPA 2003d).
[C] Number of filtered systems subject to treatment = linked nonpurchased and purchased systems (Exhibit 4.3, Column J) * (1-Column F). This column includes nonpurchased systems that conducted monitoring, but excludes systems that monitored but that are predicted to install MF/UF to comply with the Stage 2 DBPR. Purchased systems are included so their populations can be used to determine benefits of treatment installed under the LT2ESWTR (customers of purchased systems will incur benefits of treatment installed at the associated nonpurchased system).
[D] Number of filtered plants = Column G * Exhibit 4.3, Column K.
[E] Population = (Pop. served by linked nonpurchased and purchased systems (Exhibit 4.3, Column M) - pop. served by unfiltered systems (Exhibit 4.5, Column A)) * (1-F).

4.5.3 Source Water *Cryptosporidium* Occurrence for Filtered Plants

For filtered plants, the results of plant-specific source water monitoring for *Cryptosporidium* will dictate the additional treatment required to meet provisions of the LT2ESWTR. This subsection summarizes observed *Cryptosporidium* data and discusses statistical modeling used to estimate from the observed data the underlying true *Cryptosporidium* concentration distributions. The true distributions are then used to project bin classifications for filtered systems.

Observed Cryptosporidium *Occurrence*

Exhibit 4.13 summarizes the observed *Cryptosporidium* occurrence of the ICR and ICRSS studies. See section 4.2.1 for a description of the study, laboratory methods, and method used to count oocysts. Additional data on observed occurrence are available in the Occurrence and Exposure Assessment (USEPA 2003c). The data shown for "total oocysts" were used to generate the modeled *Cryptosporidium* distributions shown below.

Exhibit 4.13: Summary of Observed *Cryptosporidium* Total Oocyst Occurrence in Source Water—Filtered Plant Data

Data Set	Total Number of Plants	Number of Plants with at Least One Positive Sample (Percent)	Observed Plant-Mean Data (oocysts/L)		
			Mean	Median	90^{th} Percentile
ICR	350	154 (44%)	0.066	0.000	0.190
ICRSSL	40	34 (85%)	0.040	0.020	0.100
ICRSSM	40	34 (85%)	0.080	0.020	0.110

Notes: Total oocysts include non-empty and empty oocysts. Non-empty oocysts include oocysts with internal structures and with amorphous structures. For each plant, all monthly observations were averaged over the sampling period (12 months for ICRSSM and ICRSSL and 18 months for ICR) to produce plant-mean data. The mean, median, and 90^{th} percentile shown summarize plant-mean *Cryptosporidium* for all plants.

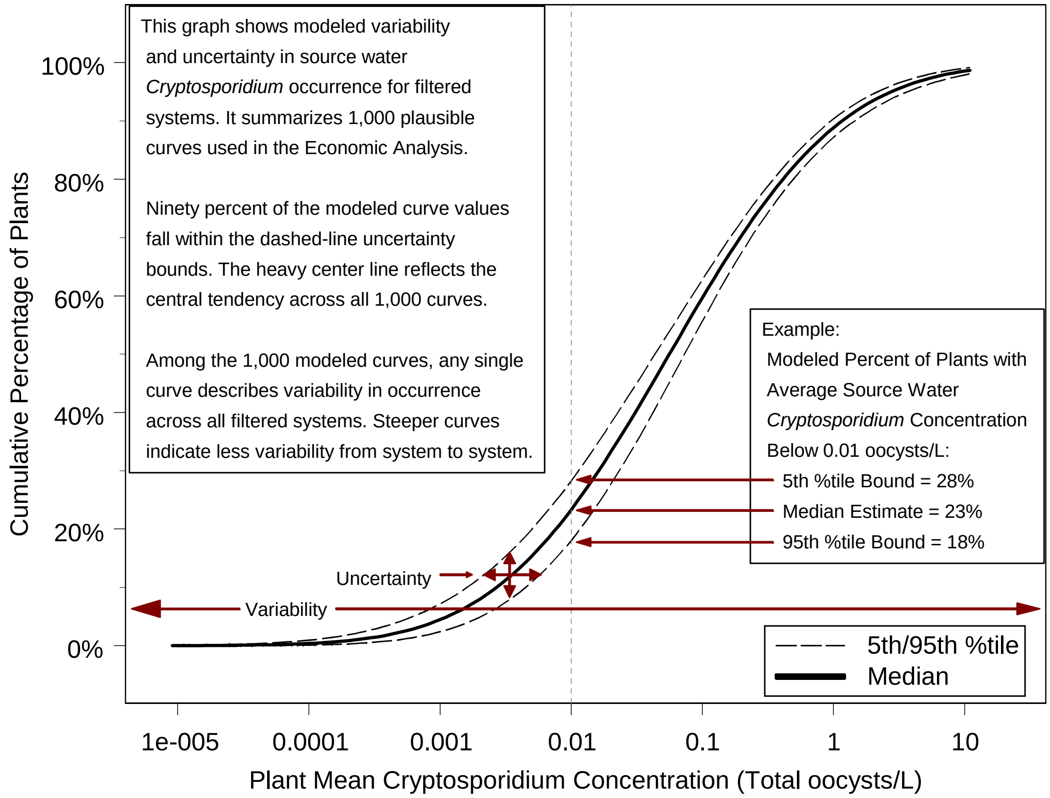
Source: USEPA 2003c.

Modeled *Cryptosporidium* Occurrence

Each of the three data sets shown in Exhibit 4.13 was used to fit an occurrence model for filtered plants using the approach outlined in section 4.2.2. As explained in that section, the modeling produces a collection of plausible occurrence distributions from each of the three data sets. Exhibits 4.13 through 4.15 summarize the resulting collection of distributions from each of the three models. The solid center curves represent the mean distribution across a given collection, and the dotted lines give a 90-percent confidence bound for the true filtered occurrence distribution based on the particular data set.

As outlined in section 5.2.4.1, all three of these models were used, independently, as input to the benefits modeling. Each model is also used, along with a distribution of lab method recovery rates, to simulate results of initial LT2ESWTR *Cryptosporidium* monitoring. The assumed recovery rate distribution is based on "spiked" sample evaluations of the lab method that will be used for initial monitoring (EPA Methods 1622/23). The overall result of this Monte Carlo simulation is a predicted distribution of systems assigned to each LT2ESWTR treatment bin; this distribution serves as input to the cost model.

Exhibit 4.14: Modeled *Cryptosporidium* Occurrence in Source Water—ICR Data for Filtered Systems



Source: USEPA 2003c.

Exhibit 4.15: Modeled *Cryptosporidium* Occurrence in Source Water—ICRSSM Data

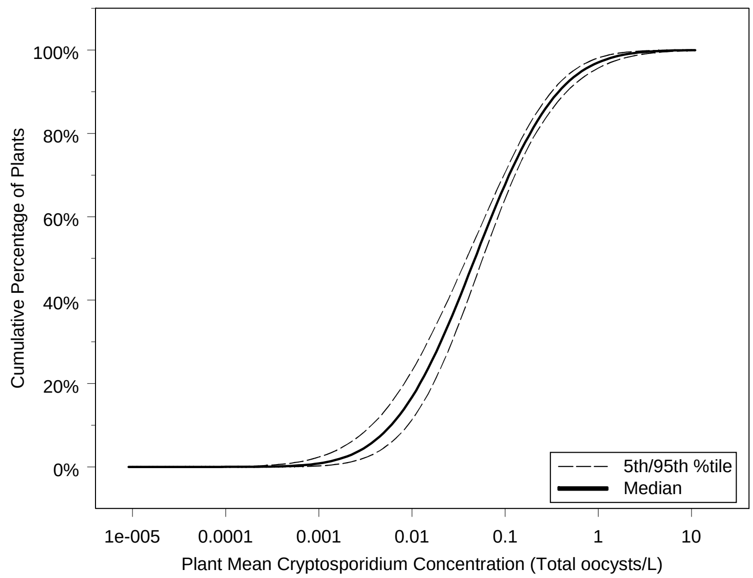
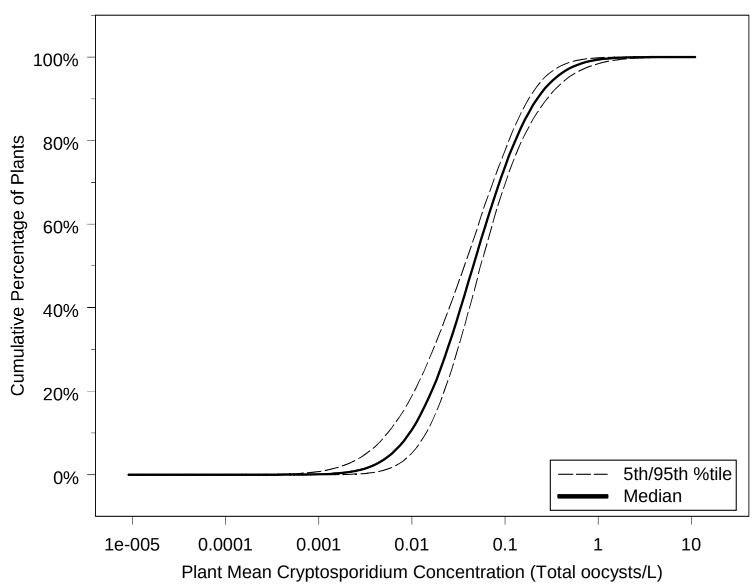
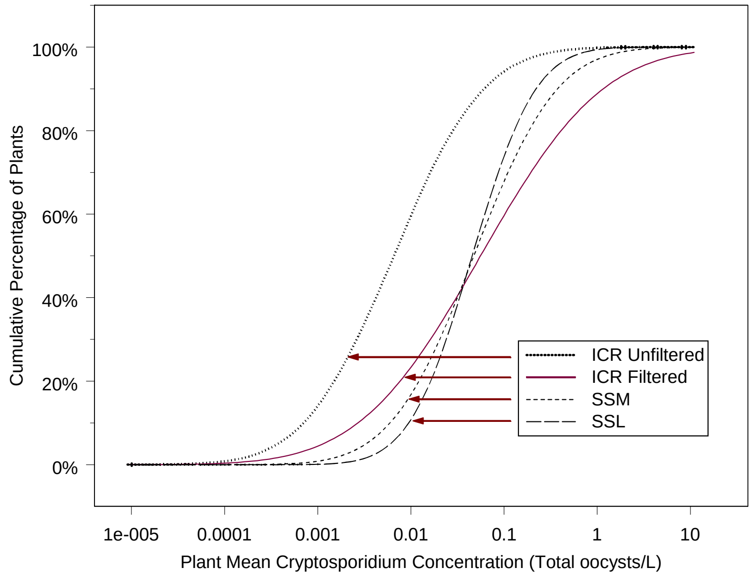


Exhibit 4.16: Modeled *Cryptosporidium* Occurrence in Source Water—ICRSSL Data



Source: USEPA 2003c.

Exhibit 4.17: Comparison of Modeled *Cryptosporidium* Occurrence in Source Water by Data Set, Median Curves Only



Source: USEPA 2003c

Exhibit 4.17 compares the central tendency of the cumulative distributions for the ICR, ICRSSM, and ICRSSL data sets. As the shape of the curves indicates, the filtered plant ICR data set describes a source water occurrence pattern with a greater frequency of high oocyst concentrations than either the ICRSSM or ICRSSL system data sets. The relatively shallower steepness of the ICR curve and the resulting lower and higher limits on the range of oocyst concentrations represented in the distribution implies more overall variability from plant to plant than the other two data sets. In other words, in addition to suggesting a greater frequency of high concentrations, the ICR data set also suggests a greater frequency of lower values than do the other two data sets. Exhibit 4.17 also shows for reference the central tendency of the cumulative distributions for unfiltered systems using the ICR data set. Exhibit 4.18 shows some of the descriptive statistics for the curves in Exhibit 4.17.

Even though the ICRSS data represent higher sample volumes and better recovery ratios, the ICR occurrence distribution includes data from more source waters. Each of these three distributions represents a plausible picture of the national occurrence of *Cryptosporidium*. It is difficult to weigh the relative importance of sample recovery versus representativeness of the sample population. Therefore, all three occurrence distributions are used in both the benefits analyses in Chapter 5 and the cost analyses in Chapter 6. The three distributions taken together encompass a range of values that help characterize the actual occurrence of *Cryptosporidium* in surface waters and the uncertainty surrounding it.

Exhibit 4.18: Summary of Modeled *Cryptosporidium* Total Oocyst Occurrence in Source Water—Median Curves Only

Data Set	Total Number of Plants	Modeled Plant-Mean Data (oocysts/L)		
		Mean	Median	90th Percentile
Filtered				
ICR	350	0.57	0.048	1.3
ICRSSL	40	0.09	0.045	0.24
ICRSSM	40	0.19	0.05	0.33
Unfiltered				
ICR	12	0.01	0.01	0.033

Notes: Total oocysts include non-empty and empty oocysts. Non-empty oocysts include oocysts with internal structures and with amorphous structures.

Source: USEPA 2003c.

4.5.4 Finished Water *Cryptosporidium* Occurrence for Filtered Plants

Pre-LT2ESWTR finished water *Cryptosporidium* concentrations (presented in this section) will be compared with predicted post-LT2ESWTR finished water levels (presented in Chapter 5) to assess the benefits of the regulatory alternatives. As with the treatment characterization presented above, the finished water *Cryptosporidium* occurrence estimates must account for improvements in finished water concentrations predicted to result from implementation of other existing rules or rules under development for implementation prior to LT2ESWTR. This section describes the methodology for predicting *Cryptosporidium* finished water occurrence based on the treatment in place following the IESWTR, LT1ESWTR, Stage 1 DBPR, and Stage 2 DPBR.

Compliance with the IESWTR, LT1ESWTR, and the Stage 1 and 2 DBPRs requires or will require some systems to modify their treatment processes to improve the removal or control the formation of DBPs. Other rules are not expected to have an appreciable impact because they affect mainly ground water systems. EPA used the EAs from the IESWTR and the LT1ESWTR, along with more recent plant performance data, to predict the number of systems in each size category that have made or will need to make treatment modifications and the effectiveness of those modifications. (These rules have not been in place long enough for all plants actually to have implemented the modifications or to have gathered information on their effectiveness.) The IESWTR and the LT1ESWTR establish filtration requirements that EPA believes provide finished water having a minimum 2 log (99 percent) reduction in *Cryptosporidium* concentrations relative to source water levels. Although systems are required to meet only the 2 log removal target, it is recognized that most systems will achieve greater levels of *Cryptosporidium* removal. For example, some systems have unit processes in addition to conventional treatment that provide higher *Cryptosporidium* removals. To capture the different levels of treatment, EPA estimated a range of *Cryptosporidium* removals in order to calculate finished water occurrence.[7]

[7] The plants with MF/UF are assumed to achieve 5.5 log *Cryptosporidium* removal. Those predicted to have it in place prior to the LT2ESWTR were subtracted from the monitoring and treatment baselines since they will be exempt from those requirements. Consequently, their high removal capabilities were not included in the finished water analysis.

Exhibit 4.19 shows the range of *Cryptosporidium* log reduction that treatment plants are expected to achieve just prior to implementation of the LT2ESWTR. To account for systems using conventional treatment and minimally meeting the IESWTR and LT1ESWTR effluent turbidity requirements, the low end of the range is set at 2.0 log. This reduction is based on the requirements of the IESWTR and LT1ESWTR (which specify 2.0 log removal) and on several studies that show that plants can achieve 2 log *Cryptosporidium* removal even under stressed conditions. These studies are described in Chapter 7 of the *LT2ESWTR Occurrence and Exposure Assessment* (USEPA 2003c). As described in section 4.5.1, many plants are expected to be eligible for 0.5 log additional treatment credits for additional unit processes or for achieving effluent turbidity below 0.15 NTU. For these systems, the range of performance was shifted up by 0.5 log to reflect the improved performance. Exhibits 4.19 and 4.20 show the triangular distributions for both the standard estimate (those minimally meeting IESWTR and LT1ESWTR effluent and turbidity requirements) and the estimate with 0.5 log reduction credit.

Based on the studies cited in the *Occurrence and Exposure Assessment*, large systems under the standard estimate are thought to achieve a maximum *Cryptosporidium* log reduction of 4.5. Many factors can negatively affect the reductions that systems are able to achieve, and these factors are thought to impact small systems more significantly. For example, smaller systems typically have fewer filters than large ones. One consequence is that a single filter performing poorly is more likely to cause poorer overall system performance. Backwashing a filter in a small system with few filters is more likely to cause hydraulic fluctuations that could result in poorer performance of the other filters. Small systems also tend to have less automated control and monitoring equipment, which makes controlling temporary aberrations more difficult. For this reason, the maximum reduction that small systems are estimated to achieve is smaller than that achieved by large systems (for the standard estimate, 3.5 log vs. 4.5 log). For systems eligible for an additional 0.5 log reduction credit, the top end of the range is increased to 4.0 log for small systems and 5.0 log for large systems.

Exhibit 4.19: Predicted Ranges of *Cryptosporidium* Reduction Pre-LT2ESWTR

System Size (Population Served)	See Exhibit	Range of Log Reduction	Mode—Lower End	Mode—Higher End
Small (<10,000) Standard Estimate	4.20a	2.0 - 3.5	2.25 log	2.75 log
Large (≥10,000) Standard Estimate	4.20b	2.0 - 4.5	2.5 log	3.0 log
Small (<10,000) Estimate w/ 0.5 Log Removal Credit	4.20c	2.5 - 4.0	2.75 log	3.25 log
Large (≥10,000) Estimate w/ 0.5 Log Removal Credit	4.20d	2.5 - 5.0	3.0 log	3.5 log

Source: Chapter 7, LT2ESWTR Occurrence Assessment (USEPA 2003c).

The log reduction values at the low and high ends of the ranges are thought to be the exception more than the rule. The studies cited in the *Occurrence and Exposure Assessment* noted median and/or average log reduction results that fall in the middle of the ranges shown in Exhibit 4.19. Although little specific information is available on how often these values occur, EPA believes, on a national scale, that the values follow central tendency. Therefore, modes of 2.5 to 3.0 log were chosen for the distribution of log reductions for large systems under the standard estimate (see second row of Exhibit 4.19). Values in between 2.5 and 3.0 log are thought to have the same possibility of being modes.

As described above, small systems are more likely to have filtration performance problems. The modes at small systems are, therefore, assumed to be lower than for large systems—2.25 and 2.75 logs under the standard estimate (first row of Exhibit 4.19). The bottom half of Exhibit 4.19 shows the estimated modes for large and small systems for systems getting a 0.5 log reduction credit, which was also applied to the modes.

This EA assumes the distribution of log reduction is triangular. (When there is little information available regarding the distribution of data, triangular distributions are commonly used.) In Exhibit 4.20, the minimum and maximum of the range define the base of the triangle and the mode defines the top. Each graph in Exhibit 4.20 corresponds to the range of one of the rows in Exhibit 4.19. Two triangles are shown for each range, illustrating the lower and upper modes. The triangles defined by all the modes in between are not shown, but are indicated by the two-way arrow on each graph. Each possible triangle, of which there is an infinite number, is considered equally likely to represent the log reduction distribution for a given system size category and treatment scenario. For example, Exhibit 4.20a shows two triangular distributions for small systems under the standard treatment estimate, which, as described in Exhibit 4.19, have a range of 2.0 to 3.5 log reduction and modes of 2.25 and 2.75 log. For the same group of systems, there are an infinite number of triangles with the same range and with modes between 2.25 and 2.75 log. Taken together, the collection of all the distributions for a given group of systems (e.g., small systems without a 0.5 log reduction credit) reflects the uncertainty about the true *Cryptosporidium* log reduction.

These triangular distributions are used in benefit and cost modeling. For a given model iteration for a given system size, the model first decides whether systems get the 0.5 log reduction credit (36 percent of small systems, 55 percent of medium systems, and 58 percent of large systems are assumed to qualify). Then it randomly selects a mode from the appropriate set of triangular distributions. From the individual distribution associated with that selected mode, the model randomly picks 100 log removal values from that distribution and uses these log reduction values to predict finished water *Cryptosporidium* concentrations. This process is repeated for 250 modes.

Exhibit 4.21 shows an example of the finished water concentration distributions generated with a modeling process similar to that described above (the curves in 4.20 were generated choosing only 250 points from each triangular distribution). These distributions were generated using the same process as the source water *Cryptosporidium* concentrations for different data sets in Exhibit 4.17 so that the differences between them would be directly comparable. Because disinfection in unfiltered systems is expected to have a negligible effect on *Cryptosporidium* concentrations, finished water concentrations in unfiltered plants are assumed to be identical to source water concentrations (compare Exhibits 4.16 and 4.20). For filtered plants, however, modeled source water concentrations were higher than those for unfiltered plants (see Exhibit 4.17); but modeled finished water concentrations were well below those same unfiltered plant concentrations.

Exhibit 4.20a: Distribution of *Cryptosporidium* Reduction in Small Systems Pre-LT2ESWTR, Standard Estimate

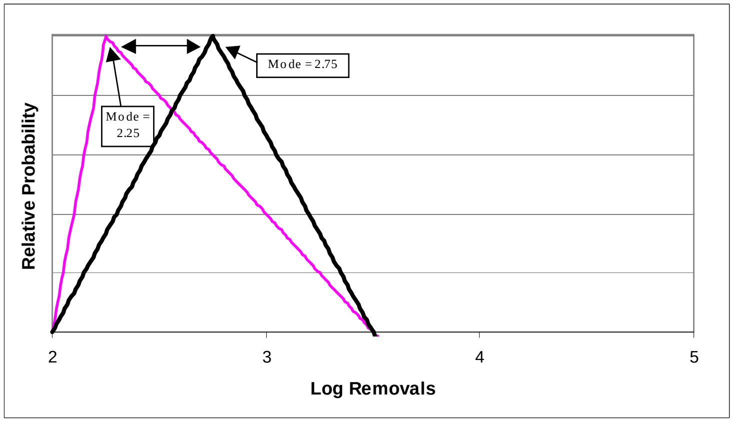


Exhibit 4.20b: Distribution of *Cryptosporidium* Reduction in Large Systems Pre-LT2ESWTR, Standard Estimate

Exhibit 4.20c: Distribution of *Cryptosporidium* Reduction in Small Systems Pre-LT2ESWTR, Estimate With 0.5 Log Reduction Credit

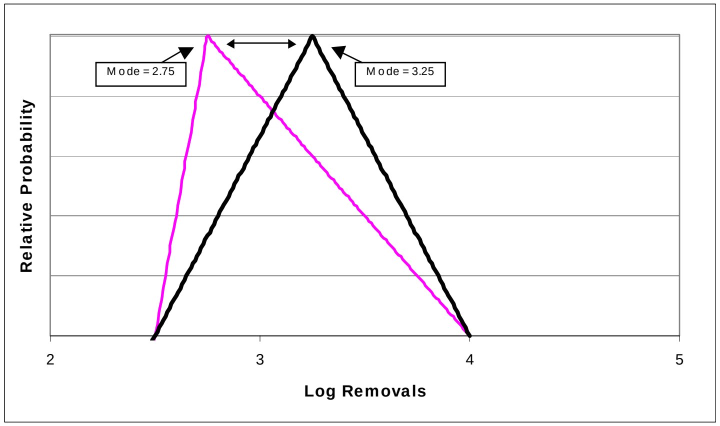
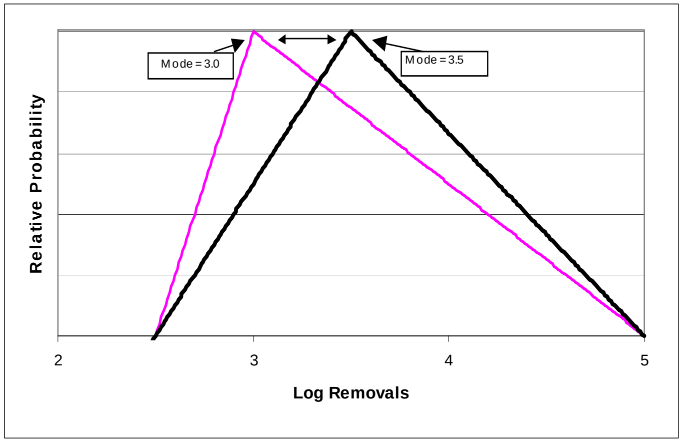


Exhibit 4.20d: Distribution of *Cryptosporidium* Reduction in Large Systems Pre-LT2ESWTR, Estimate With 0.5 Log Reduction Credit



Source: USEPA 2003c.

Exhibit 4.21a: Predicted Finished Water *Cryptosporidium* Occurrence Pre-LT2ESWTR, Small Systems

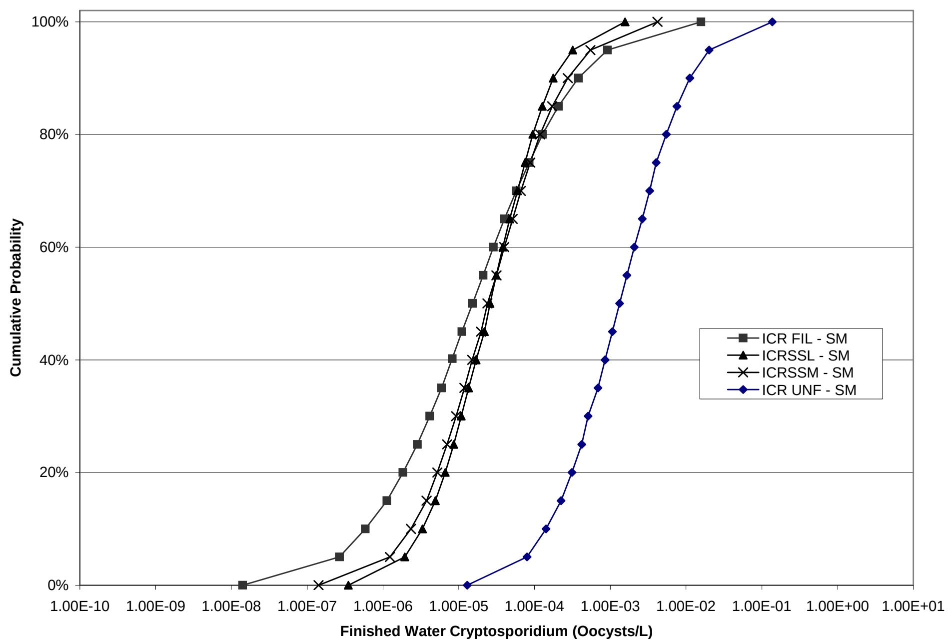
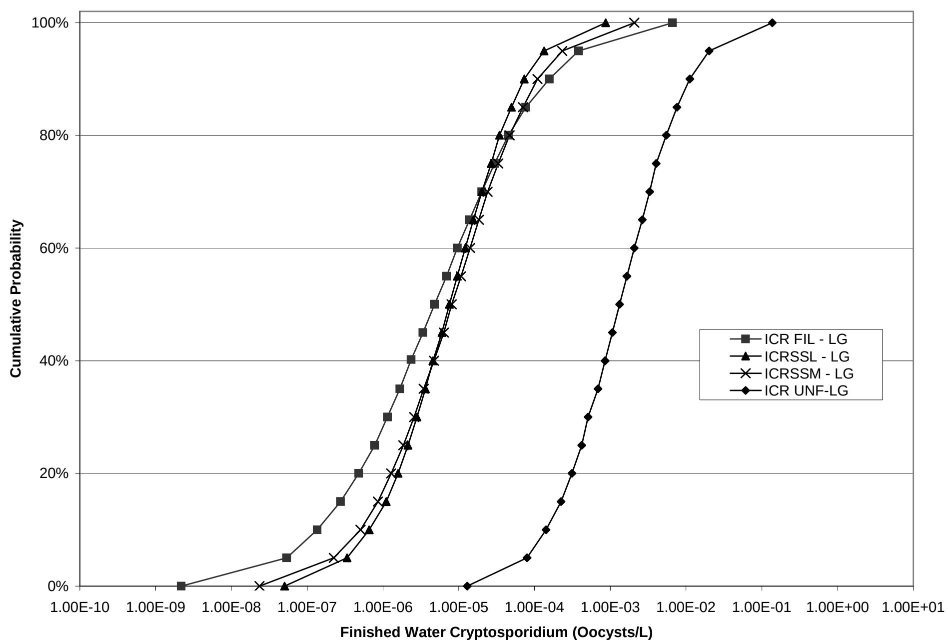


Exhibit 4.21b: Predicted Finished Water *Cryptosporidium* Occurrence Pre-LT2ESWTR, Large Systems



Source: USEPA 2003c

4.5.5 Comparison of EPA Finished Water *Cryptosporidium* Estimates with Aboytes et al. (2000)

A study by Aboytes et al. (2004) provides an alternative perspective on *Cryptosporidium* occurrence in finished drinking water and the efficacy of treatment. This study involved collecting 100-L finished water samples monthly from 82 surface water utilities. Samples were analyzed for infectious *Cryptosporidium parvum* with a cell culture-PCR method. The objective of the study was to "assess the adequacy of treatment to protect against infectious *Cryptosporidium* in drinking water." All utilities in the study were enrolled in the Partnership for Safe Water, a voluntary cooperative program that seeks to optimize treatment plant performance. Most samples had turbidities below 0.1 NTU and all were below 0.3 NTU, the standard set by the IESWTR. Their sampling detected infectious *Cryptosporidium* in 22 of the 82 plants; and in 24 of the 1,690 samples of 100 L. The authors determined an average CC-PCR recovery efficiency of 32.3 percent. Hence, if it is assumed that one infectious oocyst accounted for each positive sample, and the oocyst count is adjusted for average recovery, these results produce a mean concentration of infectious oocysts of 4.4×10^{-4} oocysts/L, or 0.044 oocysts/100 L.

To compare results from Aboytes et al. with EPA's finished water *Cryptosporidium* estimates based on results from the ICR and ICRSS, it is necessary to consider the fraction of oocysts that are infectious. Because oocysts lose viability in the environment, it is expected that infectious oocysts are only a small fraction of the total number of oocysts in a water sample. While the CC-PCR method registers only infectious oocysts, the ICR Method and EPA Methods 1622/23 count total oocysts without regard to whether they are viable and infectious. To estimate the fraction of oocysts that may be infectious, EPA evaluated a study by LeChevallier et al. (2003) that analyzed several hundred source water samples from six utilities using both the CC-PCR method and Method 1623. Oocysts were detected in 60 of 593 samples (10.1 percent) by Method 1623 and infectious oocysts were detected in 22 of 560 samples (3.9 percent) by the CC-PCR procedure. Recovery efficiencies as determined with spiked samples for the two methods were similar. According to the authors, these results suggest that approximately 37 percent of the oocysts detected by Method 1623 were viable and infectious. Based on these results, as well as consideration of the structure of counted oocysts, EPA assumes that the fraction of oocysts that is infectious may average from 15 to 25 percent for the ICR and 30 to 50 percent for the ICRSS (described in Section 5.2.4).

If the estimates of mean, large plant, finished water oocyst concentrations from Exhibit 4.21b are multiplied by 40 percent to adjust for the fraction of oocysts that are infectious, the mean finished water concentrations of infectious oocysts are as follows:

ICR Mean = 6.1×10^{-5}; ICRSSM Mean = 2.5×10^{-5}; ICRSSL = 1.4×10^{-5} (oocysts/L)

Thus, the mean finished water infectious oocyst level reported in Aboytes et al. of 4.4×10^{-4} oocysts/L is a factor of 7 greater than the EPA mean estimate based on the ICR and a factor of 30 greater than the ICRSSL estimate. While the reason for this significant discrepancy is unknown, it cannot be fully attributed to potential error in factors such as the fraction of oocysts that are infectious. Rather, it may indicate that the ICR and ICRSS underestimate source water *Cryptosporidium* occurrence and/or that EPA has overestimated treatment efficacy, as discussed below.

Unfortunately, source water data are not available for plants in the Aboytes et al. study, so it is not possible to determine directly their average treatment efficiency. However, removal efficiency may be estimated based on other survey data. The ICRSS was conducted during a time frame similar to Aboytes et al., and the filtration and separation steps used in the CC-PCR method of Aboytes et al. are similar to those in Method 1622/23 used in the ICRSS. Consequently, the ICRSS source water data may be somewhat comparable to the Aboytes et al. finished water data. The mean source water *Cryptosporidium* concentration of plants in the ICRSS, adjusted for average recovery of 43 percent, was 0.14 oocysts/L. If this value is multiplied by 40 percent as an estimate of the fraction of oocysts that are infectious, the result is a mean source water concentration of 0.056 infectious oocysts/L. If this were the mean source water concentration in the Aboytes et al. study, then the plants in that survey achieved an average removal of 1.7 log to produce the mean finished water concentration of 0.0011 oocysts/L that was measured. For the plants in the Aboytes et al. survey to have achieved a mean oocyst removal of 2.5 log, which was the lowest mean removal assumed in EPA estimates, the mean source water oocyst concentration would have to have been over twice that measured during the ICRSS. Either hypothesis indicates that EPA may have underestimated the risk from *Cryptosporidium* in drinking water by underestimating finished water oocyst concentrations.

4.5.6 Predicted Bin Classification for Filtered Plants

Under the LT2ESWTR, filtered plants will be assigned to a treatment bin based on the results of source water monitoring for *Cryptosporidium*. Each bin is defined by a range of oocyst concentrations and determines the amount of treatment each plant must provide. Using the modeled source water occurrence distributions described in section 4.5.3, EPA predicted the percentage of filtered plants that will fall into each bin. Appendix B presents the probability functions for the occurrence distributions used to evaluate bin classification. Note that the tables in Appendix B estimate the percentage of systems in each bin based on a prediction of the test measurement mean, which is the estimated underlying source water concentration adjusted for sampling and laboratory analysis error. However, bin assignments in this analysis are based on the predicted lab results, not on estimates of the "true" concentration. Exhibit 4.22 presents the plant bin assignments based on a Monte Carlo evaluation of the probability distributions for the three data sets of *Cryptosporidium* occurrence for the Preferred Regulatory Alternative. Note that the estimate based on the ICR data set is the most conservative of the three filtered plant data sets; in other words, the predicted percentage of plants requiring treatment is largest for this data set.

The percentages shown in Exhibit 4.22 were used to determine costs of installing treatment for each occurrence distribution. Plants were expected to incur different costs depending on the bin to which they were assigned.

Exhibit 4.22: Predicted System Bin Assignments for Preferred Alternative

Occurrence Dataset	Source Water Distribution	Bins and Concentrations			
		No Action <0.075 oocysts/L	Log 1.0 Removal (0.075–1 oocysts/L)	Log 2.0 Removal (1–3 oocysts/L)	Log 2.5 Removal (>3.0 oocysts/L)
ICR	5th Percentile	67.6%	26.5%	3.7%	2.1%
	Mean	65.2%	27.2%	4.4%	3.2%
	95th Percentile	61.1%	30.4%	4.8%	3.8%
ICRSSL	5th Percentile	82.3%	17.5%	0.2%	0.0%
	Mean	77.6%	21.8%	0.5%	0.1%
	95th Percentile	74.4%	24.7%	0.8%	0.1%
ICRSSM	5th Percentile	76.0%	22.9%	0.9%	0.2%
	Mean	72.8%	25.4%	1.4%	0.4%
	95th Percentile	70.1%	27.5%	1.9%	0.6%

Note: Bin assignment is based on the highest running annual average (RAA) of concentrations of 24 influent samples taken over 2 years.

Source: Appendix B, Exhibits B.8 and B.12.

4.6 Baseline for Uncovered Finished Water Reservoirs

Number of Reservoirs

The LT2ESWTR baseline for uncovered finished water reservoirs is presented in Exhibit 4.23. EPA regional offices provided data on these reservoirs based on information from States in their region; the data do not include reservoirs that are scheduled to be covered or taken off line. Most such reservoirs are located in only a few States or Territories: California, New York, New Jersey, Oregon, and Puerto Rico. The largest is in Southern California. Although there are only 81 uncovered finished water reservoirs, there is a limited amount of information on them. Most systems only reported reservoir volume. Very few reported surface area or daily flows, forcing EPA to make assumptions to estimate those parameters (both quantities are needed to estimate costs for covering the reservoirs or treating the water they discharge). Populations served by each reservoir were also often poorly documented.

For this analysis, the reservoirs are categorized according to usable volume (in millions of gallons, or MG). The mean volume, shown in the last column of Exhibit 4.23, is the average usable volume of all reservoirs in a volume category and is used to estimate costs in Chapter 6.

Exhibit 4.23: Baseline Numbers of Uncovered Finished Water Reservoirs

Size Category (MG)	Number of Uncovered Reservoirs	Mean Volume (MG)
	A	B
0 - 0.1	3	0.093
> 0.1 - 1	9	0.478
> 1 - 5	10	3.165
> 5 - 10	4	8.000
> 10 - 20	12	15.200
> 20 - 40	5	28.080
> 40 - 60	10	51.422
> 60 - 80	7	67.843
> 80 - 100	3	94.000
> 100 - 150	6	127.255
> 150 - 200	1	179.000
> 200 - 250	4	208.500
> 250 - 1000	6	694.679
> 1000	1	3,313.718
Total	81	

Source: EPA regions.

Surface Area, Average Daily Flow, and Design Flow of Uncovered Reservoirs

The cost of covering a reservoir is based largely on its surface area, while costs for disinfecting the discharge are based on flow through the reservoir. As with technologies used for *Cryptosporidium* removal, the design flow and average daily flow are used to estimate capital and O&M costs of reservoir treatment, respectively. The purpose of this section is to derive mean surface area, average daily flow, and design flow for each size category of uncovered finished water reservoir.

EPA regions provided the surface area for some individual reservoirs. Where this information was not available, engineering assumptions were necessary. To calculate surface area, a representative reservoir depth of 25 feet was assumed based on consultation with industry engineers. The mean surface area for each size category presented in Exhibit 4.24 is the average surface area of all reservoirs in the size category, whether based on actual data or based on volume with an assumed 25-foot depth.

Hydraulic residence time, defined as the time water spends inside a reservoir, can be used in conjunction with volume to estimate average daily flow through the reservoir. Hydraulic residence times in finished water storage reservoirs vary greatly across systems and seasons. The shortest times are often in the summer, while the longest may be during lower-demand periods in the winter. Because water systems strive to maintain a certain volume of storage in the distribution system for emergencies such as fire, residence times can be as great as several weeks. Within the last several years water systems have decreased average residence time to improve the quality of the water in the distribution system, striving to turn over finished water in storage facilities on a regular basis. Considering these factors, typical hydraulic residence times of 1 to 3 days were used in conjunction with volume to estimate average daily flow for reservoirs up to 100 million gallons in size, as presented in Exhibit 4.24. For the very largest reservoirs, longer hydraulic residence times are more likely; residence times as high as 21 days are assumed. (Appendix I describes the available data and provides the rationale for assumptions.)

Design flow, used to estimate capital costs, represents the maximum possible flow exiting the reservoir. Finished water storage facilities respond to daily water demand fluctuations in the distribution system in order to maintain as constant as possible a flow at the treatment plant. Therefore, maximum or design flow from a reservoir may be higher than the average flow at the treatment plant. For hydraulic modeling purposes, peak hourly flows in a distribution system have been estimated as three times the average flow (Lindeburg, 1997). Therefore, the design flow presented in Exhibit 4.24 is estimated to be three times the average daily flow.

Exhibit 4.24: Surface Area and Flows for Uncovered Finished Water Reservoirs

Size Category (MG)	Number of Uncovered Reservoirs	Mean Volume (MG)	Mean Surface Area (ft.^{2})	Estimated Average Hydraulic Residence Time (day)	Average Flow (MGD)	Design Flow (MGD)
	A	B	C	D	E = B/D	F = 3*E
0 - 0.1	3	0.093	500	1.00	0.09	0.28
> 0.1 - 1	9	0.478	2,555	1.00	0.48	1.43
> 1 - 5	10	3.165	16,924	1.00	3.17	9.50
> 5 - 10	4	8.000	42,778	2.00	4.00	12.00
> 10 - 20	12	15.200	81,278	3.00	5.07	15.20
> 20 - 40	5	28.080	150,150	3.00	9.36	28.08
> 40 - 60	10	51.422	274,964	3.00	17.14	51.42
> 60 - 80	7	67.843	362,772	3.00	22.61	67.84
> 80 - 100	3	94.000	502,641	3.00	31.33	94.00
> 100 - 150	6	127.255	680,461	4.00	31.81	95.44
> 150 - 200	1	179.000	957,156	4.00	44.75	134.25
> 200 - 250	4	208.500	1,114,900	4.00	52.13	156.38
> 250 - 1000	6	694.679	3,714,615	14.00	49.62	148.86
> 1000	1	3,313.718	17,719,245	21.00	157.80	473.39
Total	81					

Sources: [A] and [B] EPA regions.
[C] EPA regions for some reservoirs. Surface area, if not provided for an individual reservoir, is estimated based on data on volume (from EPA regions) and an assumed depth of 25 feet.
[D] Professional judgment.

System Sizes for Uncovered Reservoirs

In order to apportion the costs to a specific size PWS for the costs to the rule and household cost analyses, EPA needed to estimate a population served for each reservoir. Many reservoirs are only one of several in a system, and in such cases, there is no basis to determine what percentage of the full flow might pass through a single reservoir. Therefore, using the flow equations described in section 4.3.3, population served by each reservoir was estimated and the reservoirs were allocated to a system size based on those estimates. Exhibit 4.25 shows the distribution of uncovered filtered water reservoirs by system size. To obtain the number of households served by each reservoir for use in the household costs analysis, the number of reservoirs is multiplied by the average population per system for that size category and divided by 2.59, the number of people per household (U.S. Census Bureau 2001). Appendix I details the methodology for estimating reservoir modeling parameters.

Exhibit 4.25: Baseline Number of Uncovered Finished Water Reservoirs in Each System Size Category

System Size (Population Served)	Number of Reservoirs
<100	3
100 - 499	0
500 - 999	0
1,000 - 3,299	0
3,300 - 9,999	9
10,000 - 49,999	26
50,000 - 99,999	5
100,000 - 999,999	37
=1,000,000	1
Total	**81**

Source: Appendix I

4.7 Households Incurring Costs Due to the LT2ESWTR

Estimating the number of households served by systems affected by the LT2ESWTR is necessary to derive national per household annual costs. Exhibit 4.26 shows the possible combinations of the various rule activities that systems may conduct, and thus households may incur additional cost. For example, a filtered system may conduct monitoring and fall in a no-action bin for additional *Cryptosporidium* treatment. The costs those households incur would reflect implementation and monitoring activities. However, an filtered system with an uncovered finished water reservoir that falls into an action bin would incur costs associated with implementation, monitoring, additional *Cryptosporidium* treatment, and the uncovered reservoir.

Exhibit 4.26: Universe of Households Affected by Rule Provisions

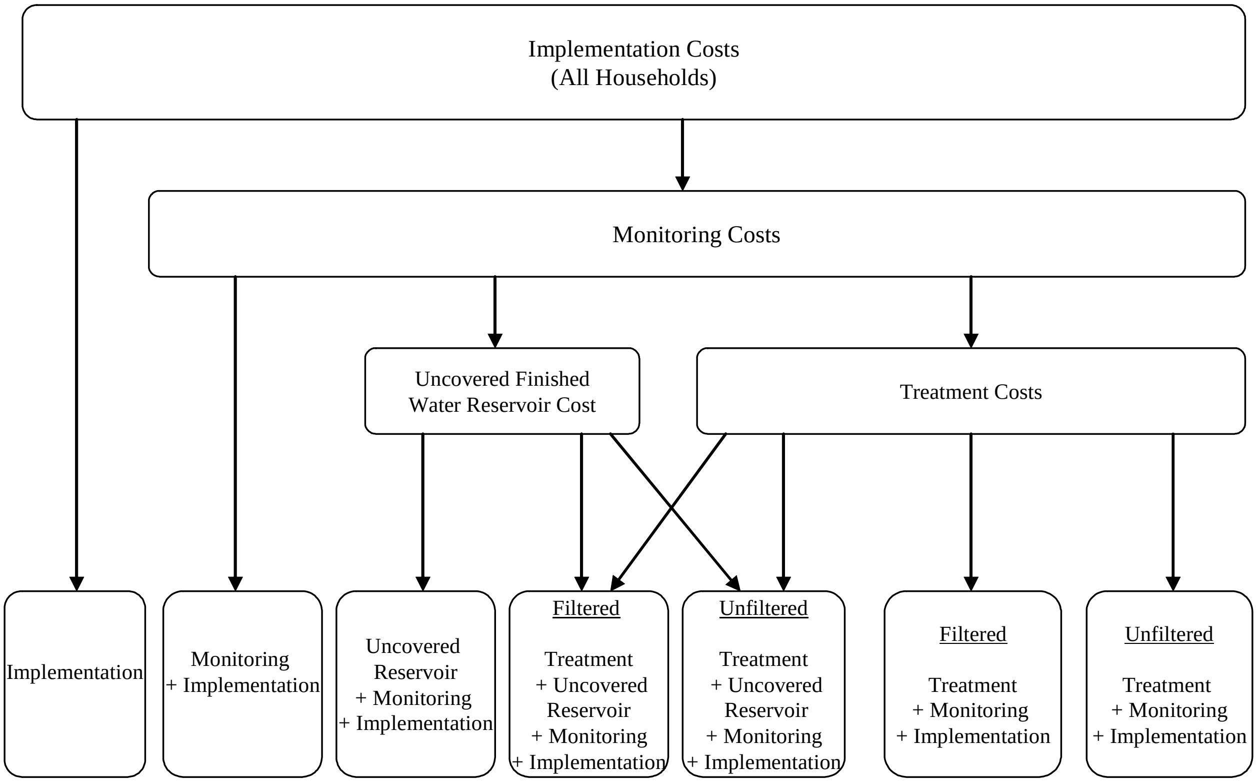


Exhibit 4.27 presents estimates of the number of households served by surface and GWUDI systems, further subdivided by those subject to the various rule provisions. The estimates were derived by dividing the total population served by CWSs subject to each rule provision within each size category by an average number of people per household of 2.59 (U.S. Census Bureau 2001). Only the CWS population is used to estimate households because it is assumed that only CWSs serve residential customers. Exhibit 4.28 shows the number of households subject to uncovered reservoir costs.

Exhibit 4.27: Baseline Numbers of Households Incurring Costs

System Size (Population Served)	Households Paying Implementation Costs	Households Paying Monitoring Costs	Households Paying Treatment Costs for Unfiltered Systems	Households Paying Treatment Costs for Filtered Systems
	A	B	C	D
<100	7,925	7,640	30	6,423
100-499	77,064	74,289	460	68,997
500-999	122,745	118,326	953	109,699
1,000-3,299	840,009	809,769	9,632	786,300
3,300-9,999	2,569,775	2,477,263	42,493	2,389,798
10,000-49,999	10,001,463	9,964,828	110,321	9,709,985
50,000-99,999	7,046,149	7,020,339	103,902	6,815,100
100,000-999,999	29,347,697	29,240,196	567,851	28,252,742
1,000,000+	20,195,053	20,121,079	3,173,681	16,709,626
Total	70,207,880	69,833,729	4,009,322	64,848,670

Notes: Includes households served by surface water or GWUDI systems only. All unfiltered systems will incur treatment costs. Not all filtered systems shown above will incur treatment costs—the households shown in Column D represent all systems that conducted monitoring less systems that are predicted to have installed MF/UF to comply the the Stage 2 DBPR. Some of these systems will be assigned to the "no action" bin and will not incur treatment costs.

Sources: [A] SDWIS population from unlinked inventory (USEPA 2003e) / 2.59 people per household (U.S. Census Bureau 2001).
[B] Implementation baseline (Column A) * percentage of systems subject to monitoring requirements (1 - Exhibit 4.11, Column C).
[C] Treatment baseline population for unfiltered systems (Exhibit 4.5, Column D) / 2.59 people per household.
[D] Treatment baseline population for filtered systems (Exhibit 4.12, Column E) / 2.59 people per household.

Exhibit 4.28: Households Paying Treatment Costs for Uncovered Reservoirs

System Size (Population Served)	Number of Households
<100	63
100 - 499	0
500 - 999	0
1,000 - 3,299	0
3,300 - 9,999	20,159
10,000 - 49,999	217,257
50,000 - 99,999	106,926
100,000 - 999,999	2,774,523
=1,000,000	267,187
Total	**3,386,115**

Source: Appendix I.

Exhibit 4.29 presents the estimated mean water usage rates (in gallons per year) per household for each system size category. These estimates are based on total residential consumption and the number of residential connections from the Baseline Handbook. The consumption in the two smallest size categories was adjusted based on analyses of 1995 CWSS data.

Exhibit 4.29: Mean Household Water Usage Rates by System Size

System Size (Population Served)	Mean Household Water Usage Rate (gal/yr)
< 100	83,000
101-500	83,000
501-1,000	104,000
1,001-3,300	87,000
3,301-10,000	97,000
10,001-50,000	109,000
50,001-100,000	119,000
100,001-1 Mil	125,000
>1 Mil	125,000

Source: USEPA 2001c, modified for systems serving 500 or fewer people based on CWSS data.

4.8 Summary of Uncertainties in Development of LT2ESWTR Baselines

Uncertainties in this baseline analysis could result in either an overestimate or an underestimate of the costs or benefits presented in Chapters 5 and 6. Exhibit 4.30 below presents an estimate of the effects that each source of uncertainty may have on subsequent analyses. Note that, in many cases, assumptions made in this baseline will overestimate both costs and benefits; however, costs are overestimated in more cases than are benefits.

Exhibit 4.30: Summary of Uncertainties Affecting LT2ESWTR Baseline Estimates

Assumption	Section with Discussion of Uncertainty	Effect on Benefit Estimates			Effect on Cost Estimates		
		Under-estimate	Over-estimate	Under- or Over-Estimate	Under-estimate	Over-estimate	Under- or Over-Estimate
Uncertainty in baseline data inputs (SDWIS, ICR, and ICRSS data)	4.3.2 4.4.2			X			X
Point estimates instead of distributions for population and flow	4.3.3			X			X
CWS flow equations for NTNCWSs	4.3.3					X	
No unfiltered plants have advanced disinfection	4.4.1		X			X	
Filtered plants do not get credit for ozone and ClO_2 from Stage 2	4.5.1		X			X	
Predicted Pre-LT2ESWTR *Cryptosporidium* removal using triangular distributions (with uncertain modes) and log reduction achieved	4.5.1			X			X
Uncertainty in baseline surface area and flows for uncovered finished water reservoirs	4.6			X			X

Note: The uncertainties associated with some assumptions are discussed in more detail in Chapters 5 and 6, and so the summaries of those assumptions are reserved until the ends of those chapters. Those key assumptions include the occurrence in source water and modeling of occurrence in finished water; risk parameters, such as infectivity and the percent of viable oocysts; and binning assignments.

5. Benefits Analysis

5.1 Introduction

The LT2ESWTR will reduce the occurrence of viable waterborne pathogens, particularly *Cryptosporidium*, in drinking water delivered by public water supplies that use surface water or ground water under the direct influence of surface water (GWUDI). The quantified health benefits estimated for this rule result from reducing the incidence of adverse health effects (illnesses and possible premature death) caused by drinking water containing *Cryptosporidium*. This rule is also expected to reduce health effects associated with other pathogens.

Section 5.2 describes the risk assessment used to estimate the number of illnesses and deaths associated with endemic cryptosporidiosis that will be avoided because of the LT2ESWTR. Section 5.3 presents the methods used to monetize these benefits. Uncertainty and variability are inherent in any risk assessment. In this EA, stochastic distributions and sensitivity analyses are used to account for uncertainty and variability. The resulting estimates are shown as mean values with 90 percent confidence bounds. Sections 5.2 and 5.3 also discuss supporting data for each variable used in the risk assessment and monetization, with citations to additional information in appendices. Section 5.4 summarizes all areas of uncertainty in the benefits analysis, noting how they are addressed and the likely effect on the national estimate.

The quantified benefits presented in this chapter are not the only benefits expected from the implementation of this rule. Other benefits, including those associated with reductions in sporadic cryptosporidiosis outbreaks, reductions in other endemic illnesses and outbreaks from other pathogens, and improved aesthetic water quality, are described in section 5.6, but are not quantified in this analysis. In addition, the benefits realized from regulating uncovered finished water reservoirs, a provision of the proposed rule, are not quantified.

The remainder of this chapter is organized as follows.

- 5.2 Quantified Health Benefits from Reduction in Exposure to *Cryptosporidium*
  - 5.2.1 Overview of Risk Assessment Methodology
  - 5.2.2 Hazard Identification
  - 5.2.3 Dose-Response Assessment
  - 5.2.4 Exposure Assessment
  - 5.2.5 Risk Model Structure
  - 5.2.6 Individual Annual Risk Distributions
  - 5.2.7 General Population Risk—Number of Cases Avoided
  - 5.2.8 Reduction in Sensitive Subpopulation Risk
- 5.3 Monetized Benefits from Reduction in Exposure to *Cryptosporidium* Resulting from the LT2ESWTR
  - 5.3.1 Value of Reduction in Cryptosporidiosis Cases
  - 5.3.2 Monetization of Benefits to Sensitive Subpopulations
- 5.4 Summary of Uncertainties
- 5.5 Comparison of Regulatory Alternatives
- 5.6 Other Benefits of LT2ESWTR Provisions
  - 5.6.1 Reduction in Outbreak Risk
  - 5.6.2 Costs to Households to Avert Infection
  - 5.6.3 Enhanced Aesthetic Water Quality
  - 5.6.4 Risk Reduction from Co-occurring and Emerging Pathogens

5.2 Quantified Health Benefits from Reduction in Exposure to *Cryptosporidium*

This section describes the risk assessment methods and assumptions used to quantify the expected health benefits of the LT2ESWTR associated with reduced exposure to *Cryptosporidium*. It also provides the results of these calculations, expressed in terms of reduced cases of illness and avoided deaths.

The quantified health benefits presented in sections 5.2 and 5.3 are derived from estimates of the Pre-LT2ESWTR annual levels of illness and death caused by endemic exposure to *Cryptosporidium* in drinking water, and the reductions expected as a result of the LT2ESWTR. Annual endemic cases are those occurring as a result of *Cryptosporidium* present in drinking water under normal operating conditions. This endemic level does not include illnesses and deaths attributable to outbreaks of cryptosporidiosis—those that are associated with events or conditions that are outside of normal treatment plant operating conditions.

Endemic levels of cryptosporidiosis cannot be measured directly because symptoms are generally underreported (relatively few seek medical attention), and because there are many potential causes of gastrointestinal illness resembling cryptosporidiosis. Usually only in an outbreak will doctors test stool samples for *Cryptosporidium*.

Even outbreaks are not always recognized, again because symptoms are underreported and not always recognized as being due to cryptosporidiosis. Data on occurrence specifically related to outbreaks were not available and dependable methods to model the future occurrence of outbreaks have not been proven. Because of these difficulties, the incidence of illness is modeled (as opposed to directly measured), and only for endemic illnesses. Thus, the illnesses estimated quantitatively in this Economic Analysis (EA) should be thought of as representing a steady, underlying level of illness unadjusted for outbreaks of the disease.

The risk assessment used to calculate the benefits of the LT2ESTWR involves a two-dimensional Monte Carlo simulation model designed to explicitly consider probability distributions describing the uncertainty in some of the model inputs, and the inherent variability in others. The structure of this model, and the basis for the characterization of the uncertainty and variability distributions used in it, are described in more detail in this chapter. The calculations for the model were carried out in SAS v8.2 (Appendix T provides details of the programming code, input data, and output results).

In addition to the use of probability distributions in the Monte Carlo simulation model, the risk assessment is designed to compare benefit estimates (reductions in risk) across several key categories: system type and size, treatment (filtered or unfiltered), and occurrence data sets of *Cryptosporidium* in source water (Exhibit 5.1). Presenting the model results across these multiple categories provides measures of variability beyond the uncertainty and variability derived through the use of probability distributions within the model. Model runs produce total national benefit estimates as well as breakouts for each of the categories listed in Exhibit 5.1.

Exhibit 5.1: Risk Assessment Model Categories

Data Set	System Size (population served)	Filtered Plants			Unfiltered Plants[1]
		CWS	NTNCWS	TNCWS[2]	CWS
ICR	<100	✓	✓	✓	✓
	100 - <500	✓	✓	✓	✓
	500 - <1,000	✓	✓	✓	✓
	1,000 - <3,300	✓	✓	✓	✓
	3,300 - <10,000	✓	✓	✓	✓
	10,000 - <50,000	✓	✓	✓	✓
	50,000 - <100,000	✓		✓	✓
	100,000 - <1 Million	✓	✓		✓
	> 1 Million	✓			✓
ICRSSM	<100	✓	✓	✓	
	100 - <500	✓	✓	✓	
	500 - <1,000	✓	✓	✓	
	1,000 - <3,300	✓	✓	✓	
	3,300 - <10,000	✓	✓	✓	
	10,000 - <50,000	✓	✓	✓	
	50,000 - <100,000	✓		✓	
	100,000 - <1 Million	✓	✓		
	> 1 Million	✓			
ICRSSL	<100	✓	✓	✓	
	100 - <500	✓	✓	✓	
	500 - <1,000	✓	✓	✓	
	1,000 - <3,300	✓	✓	✓	
	3,300 - <10,000	✓	✓	✓	
	10,000 - <50,000	✓	✓	✓	
	50,000 - <100,000	✓		✓	
	100,000 - <1 Million	✓	✓		
	> 1 Million	✓			

Note: [1]The ICRSSM and ICRSSL have no unfiltered source water occurrence data. Section 5.2.7.1 describes how unfiltered ICR data were adjusted to produce risk estimates for the ICR, ICRSSM, and ICRSSL data sets. There is only one unfiltered noncommunity water systems (NCWS); it was grouped with community water systems (CWSs) for data analysis.

[2]There are no nontransient and transient noncommunity water systems for the population categories with shaded boxes.

Sections 5.2.1 through 5.2.5 present the risk assessment methodology. Model results for the baseline and four regulatory alternatives considered in this Economic Analysis (EA) are presented and discussed in sections 5.2.6 through 5.2.8, as well as in Appendices C and O.

5.2.1 Overview of Risk Assessment Methodology

Risk assessment is an analytical tool that is used to characterize the expected incidence of adverse health effects associated with exposure to an environmental hazard, in this case *Cryptosporidium*. It is also used to estimate the benefits of actions taken to reduce exposure to that hazard.

The risk assessment used to estimate the potential benefits of the LT2ESWTR comports with a standard framework for risk assessment employed by the U.S. Environmental Protection Agency (EPA). The framework is organized in accordance with the EPA Policy for Risk Characterization (USEPA 1995a), EPA's Guidance for Risk Characterization (USEPA 1995b), and EPA's Policy for Use of Probabilistic Analysis in Risk Assessment (USEPA 1997a).

This standard framework requires the use of scientific data (or reasonable assumptions if data are not available) to produce estimates of the nature, extent, and degree of a risk. When the risks posed are not the same for all persons, that variability in risk should be described. Further, data are seldom known with certainty, and therefore, that uncertainty must be described and its impact on the risk estimates characterized. The risk assessment used here incorporates both types of information—the variability associated with the distribution of risk levels within the affected population and the uncertainty expressed by confidence bounds.

According to the 1995 EPA Policy for Risk Characterization (USEPA 1995a), health risk assessments for environmental contaminants generally involve four components:

- **Hazard Identification** addresses the nature of the potential adverse health effects associated with exposure to the contaminant.

- **Dose-Response Assessment** addresses information concerning the relationships, quantitative where possible, between the magnitude of exposure to the contaminant and the extent and severity of the adverse health effects.

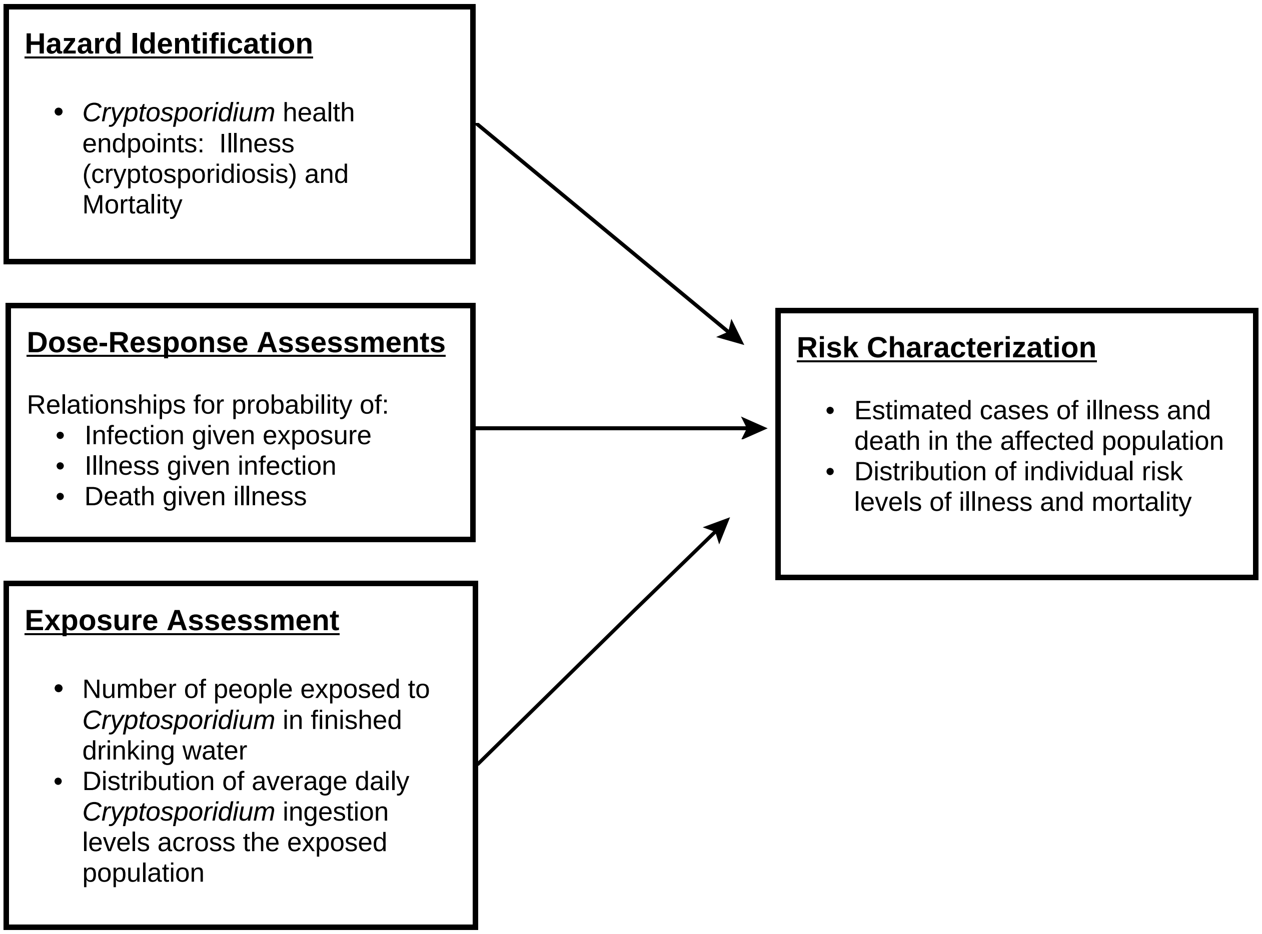
- **Exposure Assessment** estimates both the number of people in the population exposed to the contaminant and the distribution of levels of exposure within that population.

- **Risk Characterization** combines the hazard identification, dose-response assessment, and exposure assessment information to describe overall risk to the exposed population, in terms of both the distribution of risk levels in the population and the total number of cases of adverse effects expected.

Exhibit 5.2 depicts these elements of the risk assessment for characterizing the endemic risk of illness and death from exposure to *Cryptosporidium* in drinking water systems.

To derive benefit estimates of the LT2ESWTR using this risk assessment framework, the analysis calculates the difference between illness and death estimates for the baseline (Pre-LT2ESWTR) condition and illness and death estimates after implementation of the LT2ESWTR. Benefit estimates are the number of illnesses and deaths avoided because of a regulatory requirement (i.e., Pre-LT2ESWTR and the four regulatory alternatives for LT2ESWTR described in section 3.3).

Exhibit 5.2: Health Risk Assessment Framework for *Cryptosporidium*



5.2.2 Hazard Identification

This section presents summary information on the adverse health effects associated with *Cryptosporidium* ingestion from drinking water, including a discussion of cryptosporidiosis and the potential for illness. It also discusses the potential for mortality, particularly among the immunocompromised. For further information on health effects associated with *Cryptosporidium*, see Chapter 2 of this document as well as the *Occurrence and Exposure Assessment for the Long Term 2 Enhanced Surface Water Treatment Rule* (USEPA 2003c).

Ingesting *Cryptosporidium* oocysts can cause cryptosporidiosis, which typically is an acute, self-limiting illness with symptoms that include diarrhea, abdominal cramping, nausea, vomiting, and fever (Juranek 1995). Cryptosporidiosis can also cause non-gastrointestinal symptoms, such as eye and joint pain, headaches, dizziness, and fatigue (Hunter et al. 2004). There is no treatment that can eliminate a *Cryptosporidium* infection, and only a few antiparasite or antimicrobial agents have shown even a slight ability to reduce a patient's parasite load (Guerrant 1997). In some occurrences, cryptosporidiosis can be fatal, particularly among subpopulations such as Acquired Immunodeficiency Syndrome (AIDS) patients, the elderly with other underlying illnesses, and other immuno-compromised individuals.

Limited information is available on the endemic incidence of cryptosporidiosis in the United States. Mead et al. (1999) have estimated that there are approximately 15 million physician visits annually for diarrhea, and that approximately 2 percent of these, or 300,000 cases, are due to cryptosporidiosis. They also estimate that of these 300,000 cases, only about 10 percent are attributable to food-borne transmission, with the remainder due to the consumption of contaminated water (from drinking or recreational exposure) or person-to-person contact. The number of endemic cases estimated by Mead et al. is probably low because only a fraction of people who experience diarrhea visit a physician. For example, in the 1993 cryptosporidiosis outbreak in Milwaukee, Wisconsin, medical care was sought in 12 percent of cases (Corso et al., 1993). Mead et al. estimate that there are approximately 211 million episodes of gastroenteritis in the United States each year, of which only about 38 million are attributable to known pathogens. Published information does not provide estimates of cases due solely to drinking water.

Another potential indicator of endemic cryptosporidiosis is the fraction of the human population that has positive antibodies against *Cryptosporidium*. Studies of a variety of populations have found a reactivity to *C. parvum* antigens in 25 to 35 percent of adults; this number is even higher in developing countries (Chappell et al. 1999; Frost et al. 1998). While these positive reactions indicate past exposure to *Cryptosporidium*, the number of exposures, durations of illness, and individual susceptibilities to re-infection cannot be determined by simple testing. Levels of one antigen, IgG, have been observed to drop over time, so a high level of IgG antibodies in an individual can be an indicator of recent exposure or infection (van Herck et al. 2000; de Melker et al. 2000), but since the rate of decrease is not known and possibly differs for each individual, it is difficult to estimate endemic rates through immunology.

Many, probably most, infected individuals do not seek medical treatment for their symptoms. If they do seek medical treatment, primary care physicians may not be able to isolate *Cryptosporidium* as the cause of the illness. If diagnosed, physicians may not report the information to the Centers for Disease Control (CDC). These compounded effects could lead to gross underreporting and underestimating of cryptosporidiosis cases (Okun et al. 1997). Additionally, individuals can be infected with *Cryptosporidium* yet exhibit no symptoms of infection. This is seen more among people without pre-existing immunity to *Cryptosporidium*, and can further hide the true incidence of cryptosporidiosis in the United States.

Although the focus of the risk and benefits analysis conducted here is on endemic cases, most of the information available on the health hazards from exposure to *Cryptosporidium* derives from studies involving outbreaks. The 1993 Milwaukee outbreak was the largest recorded outbreak of waterborne disease in the United States. Using standard epidemiological methods, CDC estimated that over 400,000 people became ill (Craun et al. 1998). Of those, 4,000 required hospitalization (approximately 1 percent of those becoming ill), and there were 54 cryptosporidiosis-associated deaths, with at least 46 of these being immunocompromised individuals (as reported on death certificates) (Mackenzie et al. 1994; Hoxie et al. 1997).

Several subpopulations may be more sensitive to cryptosporidiosis, including the young, elderly with other underlying illnesses, malnourished, disease-impaired (especially those with diabetes), and a broad category of those with compromised immune systems (Rose 1997). There has been little research in the United States on cryptosporidiosis in children and the disease-impaired. The extent to which the elderly are more susceptible to cryptosporidiosis is not known; however, during the Milwaukee outbreak (as well as prior to the outbreak), the rate of gastroenteritis-related emergency room visits among those 65 and over was shown to increase with age. It is not known whether these patients may have had underlying illnesses or other risk factors that could have affected their immunity to *Cryptosporidium*. The elderly were also shown to have a shorter incubation period during the outbreak than the general adult population (Naumova et al. 2003). However, another study of the Milwaukee outbreak, a random telephone survey, showed that the elderly had a lower illness rate than the general population (MacKenzie et al. 1994). The possibility of increased risk of cryptosporidiosis among the elderly population is of some concern because the elderly population is projected to increase in the coming decades. In the year 2000, those 65 and over made up 12.4 percent of the U.S. population; that percentage is expected to reach 16.3 percent by 2020 (U.S. Census Bureau 2004).

Subpopulations with compromised immune systems include AIDS patients, those with lupus or cystic fibrosis, transplant recipients, and those on chemotherapy (Rose 1997). Symptoms in the immunocompromised subpopulations are much more severe, including debilitating, voluminous diarrhea that may be accompanied by severe abdominal cramps, weight loss, malaise, and low-grade fever (Juranek 1995). Symptoms may also last longer than in those with healthy immune systems. Moreover, mortality is a substantial threat to the immunocompromised infected with *Cryptosporidium*:

> The duration and severity of the disease are significant: whereas 1 percent of the immunocompetent population may be hospitalized with very little risk of mortality (< 0.001), *Cryptosporidium* infections are associated with a high rate of mortality in the immunocompromised (50 percent). (Rose 1997).

Exhibit 5.3 contains detailed information on some of the cryptosporidiosis symptoms observed during the Milwaukee outbreak.

Exhibit 5.3: Symptoms of 205 Patients with Confirmed Cases of Cryptosporidiosis During the Milwaukee Outbreak

Symptom	Percent of Patients	Mean	Range
Diarrhea	93%	~12 days duration	1–55 days duration
Abdominal Cramps	84%	N/A	N/A
Weight Loss	75%	10 pounds	1–40 pounds
Fever	57%	100.9˚F	99.0˚–104.9˚F
Vomiting	48%	N/A	N/A

N/A: Not applicable.
Source: Mackenzie et al. 1994.

Although the Milwaukee outbreak represents the largest number of cases in a single cryptosporidiosis outbreak in the United States, most identified outbreaks have occurred in small systems serving fewer than 10,000 people. Between 1991 and 1996, 6 outbreaks caused by *Cryptosporidium* in small water systems resulted in 271 reported cases of cryptosporidiosis and 3,822 estimated cases (USEPA 2003c). Three of the six outbreaks were in small surface water systems, and three occurred in GWUDI systems. During small-system outbreaks, the percent of the exposed population becoming ill ranged from 8 to 70 percent.

Again, outbreak cases are believed to represent only a portion of the total incidence of cryptosporidiosis. Only large outbreaks cases concentrated in a specific location are likely to be detected and reported. Endemic cases (which are the focus of this analysis) and smaller outbreaks are less likely to be identified.

5.2.3 Dose-Response Assessment

This section presents the dose-response model, which characterizes the relationship between ingestion of *Cryptosporidium* oocysts and the likelihood of infection, illness, and mortality. This model is the first of two steps in the overall risk assessment model. The second step, the exposure assessment, is described in the following section. The specific variables of the dose-response model include the following:

- Infectivity dose-response function
- Morbidity factor used to compute the risk of illness, given that an infection has occurred
- Mortality factor to compute the risk of death, given that an illness has occurred.

Previous *Cryptosporidium* risk assessments by Haas et al. (1996), Rose (1997), and Teunis et al. (2002) have focused on assessing the dose-response relationship and exposure risks. The risk assessment for waterborne cryptosporidiosis done by Haas et al. (1996) took existing data on *Cryptosporidium* infectivity and used an exponential dose-response model to determine the median infectious dose (ID_{50}). This information was then used to determine a dose-morbidity ratio and the finished water concentration of oocysts that would be acceptable given guidelines for annual risk of infection from any one type of pathogen. The infectivity data used were from healthy subjects and were extrapolated to the broader population.

Cryptosporidium occurs in different species and strains, with varying degrees of infectiousness to humans. *Cryptosporidium* samples from several different sources (called isolates) have been collected and cultivated for use in clinical trials. Two studies by Teunis et al. (2002) examined the dose-response variation between different isolates of *Cryptosporidium* and between hosts with varying immune responses. These studies concluded that for *Cryptosporidium*, illness and infectivity[1] vary among isolates, and that for individuals with elevated IgG levels, the probability of infection and illness decreases. The assessment by Rose (1997) added to the previous work by documenting sources of *Cryptosporidium*, those populations that are more susceptible to infection, historical cryptosporidiosis outbreaks, and the occurrence of *Cryptosporidium* in the environment.

Infectivity Dose-Response Model

The primary dose-response model used for the baseline risk assessment, as well as six alternative dose-response models that were evaluated by EPA are all based upon the same model structure referred to as the "Exponential Dose Response Model." The basic exponential model has the mathematical form of:

$$P_I = 1 - e^{-d\,r}$$

which describes the probability of an exposed individual becoming infected (P_I) given an expected dose (d). The parameter r in this model, as discussed in more detail below, characterizes the likelihood of a host-organism interaction that will result in infection.

[1] A person is considered ill due to *Cryptosporidium* if they have symptoms of cryptosporidiosis. A person is considered infected if their stool contains oocysts.

The relatively simple mathematical form of the exponential dose response model can, to some extent, obscure the fact that it is the result of the combination of two other probability functions: (1) a Poisson distributed probability of ingesting one or more organisms capable of causing an infection given the number of infectious organisms present in the water that is consumed, and (2) a Binomially distributed probability of one or more of the ingested infectious organisms interacting with the host and causing an infection given the number of organisms ingested.

The mathematical derivation of the exponential model equation as shown above from the combination of the Poisson and binomial distributions is shown in detail in Haas et al. (1999).

At a somewhat simpler level, the $1 - e^{-d}$ part of the equation describes the probability that an individual will ingest at least one organism given an expected dose "d" of infectious organisms ingested, given the concentration in water and the expected amount of water consumption for an individual. In this context, d is effectively the product of the concentration of organisms in the water and the volume of water consumed. As such, it can take on a non-integer value even though an individual can in fact only ingest 0 or some integer number of organisms (not fractional numbers of organisms). Non-integer "expected" doses can be used, however, when applying the relationship to populations rather than to a single individual.

If the dose is 0, then $1 - e^{-d} = 0$, indicating that the probability of ingesting infectious organisms is 0 (and therefore P_I also becomes 0). If the dose is >0, $1 - e^{-d}$ is a value greater than 0 and approaches 1 as the dose becomes large, indicating a probability approaching certainty that one or more infectious organisms will be ingested when the expected dose is a high value.

This part of the equation reflects the underlying assumption that the organisms are Poisson distributed in the water that is ingested. In that regard, it implies that even when the "expected dose" is some non-zero value, the actual dose ingested by an individual can be some value other than the expected dose. This can be seen by considering a situation where the "known" concentration is 1 oocyst per liter, with an assumed ingestion of 1 liter of water. In this case, the "expected" ingestion for any individual is 1 organism. However, the value of $1 - e^{-1} = 0.632$, which is the cumulative Poisson probability that 1 or more organisms will be ingested 63.2% of the time if the "expected" number ingested is exactly 1. This also implies that the actual number ingested will be 0 approximately 36.8% of the time even when the expected number is exactly 1.

As noted above, the parameter "r" in the Exponential Dose Response equation provides information on the host-organism interactions that lead to infection. As discussed below, it is largely the treatment of the "r" parameter in the Exponential Dose Response model that differentiates the 6 models in Appendix N.

The "r" parameter in the Exponential Dose Response model can have values that lie only in the range of 0 to 1. This is because "r" is effectively a measure of the probability that any infectious organism that has been ingested will survive and cause an infection in the host, reflecting organism-host interactions that work in combination to result in that infection. Values of "r" closer to 0 reflect a low likelihood of infection occurring given ingestion of one or more infectious organism. Values of "r" closer to 1 reflect a high likelihood of an infection occurring given ingestion of one or more infectious organism. In the basic exponential model, the value of "r" is assumed to be the same for all host-organism interactions.

It is important to note that the basic exponential dose response model is a non-threshold, single-hit model. That is, this model allows for an individual to become infected by ingesting as few as one infectious oocyst that survives the host's defenses. The non-threshold assumption is supported both by what is known about Cryptosporidium's mechanism of infection and by some empirical data. The mechanism of infection by Cryptosporidium involves the oocyst that has been ingested releasing four sporozites which penetrate the cells lining the gastrointestinal tract where they reproduce. There is no evidence to suggest that cooperativity among more than one oocyst is required to initiate an infection. In addition, data show that mice have been infected following doses of 1 oocyst. Further, the basic exponential model does not account for immunity in the population that would preclude some individuals becoming infected regardless of the number of infectious organisms ingested.

The primary dose-response model and the six alternative dose response models included in Appendix N are modifications to this basic exponential model. In all cases, there are modifications to the model that address the assumption regarding “r” being the same for all host-organism interactions and the underlying data sets used to parameterize the models.

The primary model used for the baseline risk and benefits analysis comprises two different assumptions about the distribution of “r” values and two different sets of data for parameterizing those distributions (that is, a total of 4 models that are all included in the baseline risk simulation).

The six alternative models use data from six studies to parameterize the r distributions. In addition, two of the six alternative models considered also incorporate an additional adjustment to account for potential immunity (host susceptibility) to infection by these organisms. Exhibit 5.4 summarizes the characteristics of the primary dose-response model and the six alternative models.

Exhibit 5.4 Characteristics of the Primary Model and Six Alternative Models

Model	Data Sets	Functional form	Distribution of r	Assumptions	Mean risk[1]
Primary Model (random selection from 4 models)	Two models use 2 studies; two models us 3 studies	$P_I = 1 - e^{-d\,r}$	Two models use normal (logit); two models use t(3)-distribution	Assumes the 4 models are equally plausible; r distribution assumes organism variability	0.082
Alternative Model 1	6 studies	$P_I = 1 - e^{-d\,r}$	Normal (logit)	r distribution assumes organism variability	0.036
Alternative Model 2	6 studies	$P_I = 1 - e^{-d\,r}$	t(3)-distribution	r distribution assumes organism variability	0.046
Alternative Model 3	6 studies	$P_I = 1 - e^{-d\,r}$	Beta distribution	r distribution assumes organism variability	0.052
Alternative Model 4	6 studies	$P_I = \gamma \times (1 - e^{-d\,r})$	Beta distribution	r distribution assumes organism variability; additional parameter for information on host immunity	0.137
Alternative Model 5	6 studies	$P_I = 1 - e^{-d\,r}$	Beta distribution	r distribution assumes host variability	0.140
Alternative Model 6	6 studies	$P_I = \gamma \times (1 - e^{-d\,r})$	Beta distribution	r distribution assumes host variability; additional parameter for information on host immunity	0.105

[1] Mean risk calculated from the distribution of r and g values used as inputs for the dose-response model (primary model reflects combination of all four component models).

Primary Dose-Response Model and Alternative Models 1 - 3

The modifications made to the "r" value in the Primary dose-response model and in Alternative Models 1 - 3 are conceptually very similar to one another and so are described here together. In fact, Alternative Models 1 and 2 as described here are the two model forms that are used together in the primary dose-response model.

In these models, the value of "r" that is assumed in the basic exponential model to be the same for all host-organism interactions is replaced by a probability distribution of "r" values. These probability distributions capture both the variability and the uncertainty in the underlying human challenge data used to estimate the r parameter. Models 1 - 3 differ from one another only with respect to the assumed form of the probability distribution for r. Furthermore, Models 1 - 3 are fit to the human challenge data wherein it is assumed that the distribution in "r" is due to difference in the strains of Cryptosporidium used, and not to any variability in host sensitivity of the individuals in the challenge studies[2].

Model 1 uses a normal probability distribution and includes a logit transformation of the r values (that is, it is assumed to be the values of logit(r), rather than the values of r, that are normally distributed). The normal distribution is the basic bell-shaped curve probability distribution that is determined by two parameters: the mean and standard deviation. However, the normal distribution has a domain of -8 to +8, whereas the values for “r” as noted previously lie exclusively between 0 and 1. While it is possible to constrain values to fall within the 0 to 1 range in the normal distribution, such truncations can be computationally cumbersome and result in a distributional shape that is not truly a normal distribution. For this reason, the logit transformation is widely used in circumstances such as this where a distribution of a probability value is involved to convert the probability values that must fall in the range of 0 to 1 into values on the real number line from -8 to +8 so that they can be handled in the normal distribution. The logit transformation allows the modeler to both meet the requirement that the distribution of numbers being evaluated be bounded by 0 and 1, and employ the normal distribution (and others as noted below) which generally are not constrained to this range. Specifically, the logit transformation of “r” is logit(r) = x = log[r/(1-r)]. The human challenge data are used to estimate the parameters for the normal distribution of logit(r) values, which are then converted back to r values in the 0 to 1 range by the inverse of the logit transformation, which is r = ex / [(1 + ex)] where x = logit(r) as indicated.

Model 2 differs from Model 1 in that it uses a t-distribution rather than the normal distribution for the r values . It also includes the logit transformation of the r values for the same reasons as described for the normal distribution. The t-distribution, which is similar to the normal distribution, has one additional parameter besides the mean and the standard deviation - the degrees of freedom - that determines its shape. The specific model used assumes 3 degrees of freedom (df) and is therefore referred to more specifically as the t(3) distribution. The more degrees of freedom for a t-distribution, the closer it is to the standard normal distribution (essentially the same for df > ~30). The fewer the number of df, the more disperse the t-distribution is. Therefore, a t(3) distribution is more disperse than the normal distribution of a data set having the same mean and standard deviation, so it reflects more variability. The use of the t(3) distribution is based on a recommendation by the Science Advisory Board. The human challenge data are used to estimate the mean and standard deviation of the logit(r) values to use in the t(3) distribution of [logit(r)-mean / standard deviation]. As with Model 1, the logit(r) values obtained from this distribution are then converted back to r values in the 0 to 1 range from the inverse of the logit transformation noted above.

Again, Models 1 and 2 are used together as described in Appendix N as the primary dose-response model for the baseline risk and benefits analysis.

Model 3 differs from Model 1 and Model 2 in that it assumes the r values follow a Beta distribution. The Beta distribution is a standard, highly flexible distribution form that uses two parameters (alpha and beta) and has the advantage over the normal and t-distributions in that it describes a

[2]All fitting of these models (that is, estimating model parameters) to the empirical data was carried out using a Bayesian approach employing a Markov Chain Monte Carlo (MCMC) procedure. Bayesian approaches to estimating model parameters offer a number of advantages over classical statistical modeling methods. In particular, the outcome of Bayesian analysis is a distribution of plausible values of the parameters of interest rather than a single, most likely estimate typically provided by classical methods. MCMC procedures use "random walks" through the parameter space where each subsequent step is dependent upon the preceding step such that over time the entire space is considered. MCMC methods provide a means to solve complex multi-dimensional integrals that often arise in Bayesian analyses which can prove intractable to solution by numerical methods.

distribution of values in the domain of 0 to 1, and therefore does not require the logit transformation as used in Models 1 and 2.

In summary, Models 1 - 3 can be viewed as similar variations to the basic exponential dose response model in that they replace the assumed constant value for r with a probability distribution. The three models differ in that each uses a different underlying probability distribution assumption (normal, t(3), and beta). In all three cases, the parameters for these models are fit using a MCMC method wherein the distribution of r values is assumed to derive from differences in the infectivity of the various isolates used in the challenge studies, and not to any differences in the susceptibility of the hosts in those studies.

Alternative Model 4

Model 4 is a variation of Model 3 that includes an additional parameter referred to here as gamma (γ) outside of the basic dose-response model:

$$P_I = \gamma \times (1 - e^{-d\,r})$$

The values for r in this model are, just as in Model 3, assumed to be Beta distributed where the alpha and beta parameters of the Beta distribution are derived using the assumption that differences in r are due to the isolates not to the hosts. The additional parameter γ, is included to provide some information in the dose response model concerning the hosts. Specifically, it provides an estimate of the portion of the population that appears to have immunity to the organisms. The value of γ falls between 0 and 1 and is the probability that an exposed individual ingesting one or more infectious organisms is a non-immune person. Because γ represents the portion on the population that is not immune, the immune portion of the population is, therefore, equal to 1 - γ.

The value for the γ parameter is estimated from the human challenge data in the Bayesian / MCMC procedure in the same manner as the parameters for the distributions of r are estimated. That is, it is an additional parameter that, together with the other parameters for that model, provides the best fit to the observed data using the MCMC method.

Alternative Models 5 and 6

Model 5 and Model 6 are identical in form to Model 3 and Model 4, respectively. The difference between each of them is the assumption used in the MCMC procedure to estimate the parameters of the Beta distribution for the r values regarding the source of differences. As noted previously, Models 3 and 4 (and Models 1 and 2 as well) are parameterized from the human challenge data using a MCMC procedure that assumes any differences in r are due to differences in the isolates used, and not to any differences in the hosts in those studies. Models 5 and 6 are parameterized instead with the assumption that all of the differences in the r values are due to differences in the hosts, while none is due to differences in the isolates studied. Model 6 includes the additional host susceptibility factor of γ which implies that not only are there differences in the degree of susceptibility among hosts exposed to infectious organisms but that some fraction of hosts (1 - γ) are immune to infection.

It should be noted that the γ value in these models indicates the portion of the population that does not have complete immunity (again, 1 - γ is the fully immune portion). The variability in r reflected in the distributions derived in Models 5 and 6 describes differences in susceptibility among individuals to becoming infected to a given dose of Cryptosporidium, which in turn can be viewed to also reflect underlying differences in the resistance (partial immunity) to infection.

EPA has not attempted to estimate parameters for the distribution of r in the six model forms considered to simultaneously capture both differences in the isolates and differences in the exposed subjects. EPA considered efforts by Peter Teunis, who has attempted to do this, and determined that the underlying data are probably not adequate to estimate two separate sets of parameters simultaneously for hosts and isolates. In addition, the bulk of the total variability seen in the data appears to be explained by the wide variability resulting from the consideration of differences among hosts.

What are the merits and limitations of each model?

One of the primary merits of these dose-response models is the basic exponential model form of which they are all variations. A particular advantage of the exponential dose-response model form is that combined within its relatively simple equation are the two key elements that determine whether an individual consuming water containing infectious organisms will become infected.

The first of these elements is the probability that an individual who consumes contaminated water will ingest one or more of those organisms. This element is based on a Poisson distribution, which is the appropriate distributional form for describing this type of discrete "event" - namely, the presence of zero, one, or more organisms in a given volume of water consumed taken randomly from a larger volume containing a known concentration.

The second element addresses organism-host interactions in terms of the probability that the infectious organism(s) will survive once ingested to reach a site where it can cause an infection.

As discussed in the preceding section, the basic dose-response model form assumes a constant "r" value for all organism-host interactions. The use of a constant "r" value would imply that every individual ingesting the same number of organisms would be expected to respond the same, and that there would be no uncertainty around that response rate. Since this did not seem plausible or consistent with the available human challenge data, EPA did not pursue models with a constant "r" value. Rather, in the 6 variants of the exponential dose-response model considered in Appendix N, EPA described "r" as a distribution of values rather than a single value to capture the apparent variability and uncertainty in the host-organism interaction. Three different distributional forms are used for this purpose.

The two forms (normal and t(3) distributions) used in the primary model and Models 1 and 2, respectively, are standard distributions, and were recommended for use in these models by the SAB. Two limitations in both of these distributions are (1) the distributional shape of both is the typical bell-shaped (Gaussian) distribution and (2) these distributions are typically applied to data sets that can take on any values, whereas the distribution of r (being a probability) is limited to the range of 0 to 1. This latter limitation was overcome by using the logit transformation.

The limitation regarding the implied shape of the distribution of "r" values (more specifically, the logit(r) values) by assuming the normal and t(3) distributions was addressed in part by the use of the Beta distribution in Model 3. The Beta distribution has the advantage of not being constrained to a particular shape but is sufficiently flexible to take on a variety of shapes depending upon the estimated parameters alpha and beta. In addition, the Beta distribution considers values on the limited domain of 0 to 1 directly without the logit or other transformations being necessary.

EPA is not currently aware of any biological basis for preferring any one of these three distributional forms for "r" over the others.

Although the inclusion of "r" as a distribution of values in these models addresses variability and uncertainty in the organism-host interactions, the approach to estimating the parameters for the distributions of "r" values was limited to the assuming that the differences being due to either the organism (Models 1 - 4) or to the host (Models 5 and 6). The available human challenge study data are too limited to support developing models that would simultaneously account for the observed differences due to hosts and differences due to isolates (this would require that two parameters be estimated each for a distribution of "r" on isolate and a distribution of "r" on host). However, it appears that the models based on differences among hosts explain the bulk of the total variability seen in the data.

Models 4 and 6 include an additional γ parameter to account for the portion of the population that has complete immunity. In this respect, Model 4 does to some extent for both isolate and host differences, but the latter only in terms of complete immunity. Model 6 accounts for two aspects of host differences - both the complete immunity by virtue of the parameter as well as differences in susceptibility among hosts who are not completely immune.

Another area of potential limitation in these six models is that they all describe a non-threshold, single-hit mechanism. Alternative models could include consideration that more than one infectious organism would need to be ingested and survive to interact with the host to cause an infection. However, as noted in Haas et al. (1999) where various threshold models are discussed along with the exponential dose response model, there is strong evidence that the single-hit dose response models are consistent with observation and expected biological mechanisms leading to infection. It is well recognized that a single microorganism (including viruses, bacteria, and protozoa) can reproduce. Haas points out that in almost all cases considered, the use of the exponential model forms, which assume no threshold, results in a statistically significant improvement in fit over model forms that allow for a threshold.

How has each model been used in the literature for modeling the dose-response of Cryptosporidium or similar organisms?

The basic exponential model, which underlies the primary model and all six alternative dose-response models considered in Appendix N, has been discussed and applied extensively in the literature on microbial risk assessments. Variations of the exponential model that address "r" as a probability distribution, particularly the Beta distribution, rather than a fixed value have also been extensively discussed. Some key early papers describing these models and applications include Furomoto and Mickey (1967) and Regli et al. (1991), the latter of which considers these models specifically in the context of modeling microbial risk in drinking water.

An extensive presentation of the basic exponential dose-response model, including its derivation from the Poisson and Binomial distributions as discussed previously, is provided by Haas et al. (1999) in their book "Quantitative Microbial Risk Assessment" in the chapter on dose-response functions. That chapter of Haas et al. (1999) also provides a detailed discussion of the "Beta Poisson" model, which treats r in the exponential model as a Beta distribution similar to the approach used in Models 3 through 6. The Beta Poisson model is also discussed in detail by Teunis and Havelaar (2000).

The details of the Beta Poisson model discussed by Haas et al. (1999) and by Teunis and Havelaar (2000) with respect to how the Beta probability distribution of r is integrated with the Poisson component of the exponential function differs from that used in the Appendix N models. In these discussions, both an "exact" form and an approximate form of the Beta Poisson model are described. The exact form of the model involves an integration across all possible values of r (0 to 1) of the product of the basic exponential model function and the Beta probability distribution of r values. As discussed by both sets of authors, integrating these functions in the exact Beta Poisson does not have a closed form solution and must be solved numerically[3]. Both sets of authors also discuss a simplified approximation to the exact Beta Poisson that was first presented by Furomoto and Mickey (1967a, b) and which is also referred to as a "Pareto" function:

$$P_I = 1 - (1 + d/\beta)^{-\alpha}$$

Here, α and β are the equivalents of the alpha and beta parameters of the Beta distribution as described previously for Model 3. Both sets of authors, and particularly Teunis and Havelaar (2000), point out that this approximate form of the model gives results that agree closely with the exact form under many conditions, but it does not agree with it in all cases and can in some circumstances imply a risk of infection that exceeds the underlying risk of ingesting one or more infectious organisms.

The approach to incorporating the Beta probability distributions for r as used in Models 3 - 6 of Appendix N, where the r parameter is treated directly as a distribution in the exponential portion of the model where it appears, overcomes the complexity of the numerical integration of the exact Beta Poisson model, without the potential shortcomings of the Pareto approximation form of the Beta Poisson model.

The use of the logit normal and logit t(3) distributions in Models 1 and 2 as alternatives to using the Beta distribution for r was recommended to EPA by the SAB[4]. These model forms were not found discussed specifically elsewhere in the literature, but both Haas et al. (1999) and Teunis and Havelaar (2000) note the potential computational advantage of using probability distributions such as these for r rather than the Beta distribution which does not have a closed form and requires numerical integration. The latter authors specifically recognizing the potential need to include a logit transformation for certain types of alternative distributions.

With respect to the inclusion of the immunity factor γ in Models 4 and 6, Haas et al. (1999) discuss the effects of immunity in the population when performing microbial risk assessments, although they do not specifically include this factor in any of the dose-response models they present. However, this approach is presented specifically by Holcomb et al. (1999) as one of six dose response models they consider for use with food-borne pathogens. In their paper they refer to this as the “flexible exponential” model and it is the basic exponential model (constant r value) with the additional parameter added that sets a maximum probability of infection to a value less than 1. (The other models they include in their paper in addition to the simple exponential and this flexible exponential are a simple lognormal distributions model, the approximate form of the Beta Poisson as described above, a Weibull-Gamma model form that is similar to the approximate Beta Poisson, and a log-logistic model that is another variation of the basic exponential form.)

Some recent examples of risk assessments of waterborne Cryptosporidium that use the exponential dose-response model include Pouillot et al. (2004) and Makri et al. (2004), both of which

---

[3]The “exact” form of the Beta Poisson model is obtained from $1 - \int_0^1 e^{-d \times r} f(r) dr$ where *f(r)* is the Beta Distribution. With the Beta Distribution, this integral does not have a closed form solution and must be solve by numerical methods.

[4]Prior to SAB's review and recommendations, EPA used a different form of the exponential model ($1-e^{-d/k}$) The parameter k (note that k = 1/r), can be roughly interpreted as the number of organisms that must be ingested to ensure that at least 1 survives to initiate an infection. In this model form, k was treated as a lognormal distribution to capture uncertainty (constrained such that k > 1).

appeared in the February 2004 issue of Risk Analysis, which included a special issues section on microbial risk assessment.

What criteria should be used to select a model for theLT2 risk assessment?

Alternative dose response models for consideration in the LT2 risk assessment should conform to the basic requirements of biological plausibility as articulated by Haas et al. (1999). Those authors identify the two key requirements of plausibility for dose-response models for microbial pathogens as (1) the model should reflect that the population is exposed to a distribution of organisms, such that different individuals consuming water with the same concentration can ingest different numbers of organisms, and (2) the model should account for potential host-organism interactions whereby host barriers can mitigate the potential for infection even when one or more infectious organisms have been ingested. As discussed previously, the six dose-response models considered in the LT2 analysis are variants of the exponential doe response model which, in turn, is derived from consideration of a Poisson distribution for exposure and incorporates a specific parameter (r) for consideration of the host-organism interactions.

The selection of one or more specific models as the preferred alternative from among a set of models fit to the same data set should include appropriate tests that compare how the models conform to the underlying data used to estimate the model parameters. In the classical statistics (frequentist) context, such model fit testing methods include consideration of measures of deviance (- 2 log-likelihood ratio) to identify the models with the better fits (lower deviances) from among alternatives, as well as goodness-of-fit methods (e.g., using a χ^2 distribution) where the acceptance or rejection of a model as fitting the data is based on specified hypothesis tests.

The six models considered in Appendix N for the LT2 assessment were parameterized using a Bayesian approach employing MCMC procedures (see earlier footnote). The methods for comparing competing models in Bayesian analysis generally rest on estimates of the marginal likelihood. One approach based on marginal likelihood estimates that is used for model assessment in Bayesian analyses uses a measure referred to as the Deviance Information Criterion (DIC), also referred to as the Bayes Information Criterion (BIC). The DIC provides a measure of the likelihood of observing the data at hand given the estimated parameters for the models. In addition, the DIC includes a penalty for models that have more parameters even if they provide improved fit, and as such also serves as a means to assess model parsimony.

The DIC is generated as an output of the WinBUGS program used to estimate the parameters for the models considered in Appendix N, and was included in Exhibit N.20. Lower values of the DIC indicate better model fits. The DIC information for each of these models, as well as the estimated illnesses avoided estimated from the six models for each regulatory alternative (these are based on mean ICR occurrence data) are presented in Exhibit 5.5.

Overall, Models 4 - 6 appear to perform better by the DIC measure than Models 1 - 3. This suggests that the observed differences in infectivity reflected in the dose response models are likely driven more by the differences in susceptibility among hosts than differences in infectivity among isolates. Model 6, which had the lowest DIC value (DIC = 37.0) includes consideration of host differences both in terms of the portion of the population who are fully immune (the parameter) and the susceptibility among those who are not fully immune in the parameters of the r distribution. Model 5, which performs next best (DIC = 54.6) does not consider an immune subset of the population, but it does use differences in susceptibility among hosts to parameterize the distribution of r values as done in Model 6. Model 4 is the third best fit (DIC = 66.3), and although it assumes that differences in infectivity are due to isolates, it also includes a host component by virtue of the parameter to account for the portion of the population who are fully immune. Models 1 - 3 (DIC values of 122.6, 122.4, 111.3), which do not fit as well as Models 4 - 6, are all parameterized assuming that differences are due solely the isolates. While these results do not necessarily imply that there are no differences in infectivity among isolates, they do suggest that those differences are less influential to the overall observed differences than are the differences in host susceptibility.

Exhibit 5.5 Comparison of Annual Illnesses Avoided Predicted by the Dose Response Models Considered for Each Regulatory Alternative

Model	Baseline Illnesses	DIC[1]	A1	A2	A3	A4
Primary	3,603,515	NA	989,954	975,326	964,360	902,500
Model 1	1 381,593	122.6	369,328	363,178	358,732	332,908
Model 2	1,556,549	122.4	413,857	406,609	401,401	372,903
Model 3	2,454,679	111.3	689,748	680,404	673,445	633,853
Model 4	5,580,291	66.3	1,501,445	1,477,257	1,459,126	1,360,326
Model 5	5,418,751	54.6	1,495,997	1,473,280	1,456,257	1,360,725
Model 6	4,588,061	37.0	1,283,450	1,265,854	1,252,707	1,178,298

[1] The Deviance Information Criteria (DIC) provides a measure of the likelihood of observing the data given the estimated parameters for the model. See preceding text for more detail.

For comparison, the first row in Exhibit 5.5 shows the results using the model at proposal. The primary model used both Models 1 and 2, and separately applied them both to three (Iowa, TAMU, UCP) or only two (Iowa and TAMU) of the human challenge studies that were available at the time of proposal. (rather than to the six that are currently available and which were used to evaluate Alternative Models 1 - 6 as shown above). Each of these four combinations of models and studies generated a set of r values. In the primary analysis, the baseline risk and benefits were obtained using a Monte Carlo procedure to select r values randomly from these four sets of r to include in the dose-response calculations.

As can be seen in Exhibit 5.5 , the choice of model can significantly influence the estimate of illnesses avoided by the various rule alternatives. Because of the limitations of the human challenge studies (small numbers of subjects, high dosage relative to drinking water exposure) it is not possible to say with any confidence which, if any of these models, provides the "best" estimate of Cryptosporidium infectivity and thus the risk reduction that will result from the rule. To address this limitation, EPA has analyzed the human challenge data using a range of models, as recommended by the SAB and described in this chapter.

The full analysis in the remainder of the EA is conducted using the primary model, which is the same model used at proposal. This provides results that are roughly in the middle of the range of results from the other models, and facilitates comparison with the analyses conducted for the proposed rule. However, to more fully capture the range of possible results resulting from alternate model choices, EPA has also conducted the analyses using a "high" estimate of baseline risk (Model 4) and a "low" estimate of baseline risk (Model 1). These estimates should not be construed as upper and lower bounds on illnesses avoided and benefits. For each model, a distribution of effects is estimated, and the "high" and "low" estimates show only the means of these distributions for two different model choices. The detailed distribution of effects is presented for the proposal model. Further, the six models analyzed do not cover all the possible variations of models that might have been used to analyze the data, and it is possible that estimates with other models would fall outside the range presented. However, as discussed in this chapter, EPA believes that the models presented here provide a reasonable range of results based on important dimensions of model choice (e.g., whether “r” is modeled as varying by isolate or by host).

For purposes of the summary tables presented in the preamble to the rule, EPA determined that model choice was the most significant dimension of uncertainty affecting the analysis and is thus presenting the tables in a format that shows “high,” “medium” and “low” estimates of illnesses avoided and benefits. These represent the mean estimates using the high model (Model 4), the proposed model, and the low model (Model 1) respectively.

Morbidity Rate

The above elements of dose-response modeling relate to the prediction of an infection occurring given various exposure circumstances. As noted at the outset of this section, the hazard identification for *Cryptosporidium* includes not only the risk of infection, but also the risk of illness resulting from an infection. Not all infections will result in illness and observable symptoms. The probability of becoming ill given an infection is called the morbidity rate.

Some studies indicate that the morbidity rates increase at higher doses (DuPont et al. 1995). However, for this risk assessment, the morbidity rate is independent of dose. After examining the potential impact, EPA determined that a higher-morbidity-at-higher-dose effect was not significantly relevant to this analysis. The fundamental effect being quantified is the endemic rate of illness and death from persistent (and low) levels of *Cryptosporidium*, not the higher levels that might occur in an outbreak. The underlying dose data, both as measured and modeled, reflect at most a few oocysts per day for individuals. In the risk assessment model, the portion of the risk posed by the small portion of the population ingesting even an expected two oocysts/L is negligible; the portion of the risk posed by people ingesting three or more oocysts/L is virtually zero. Thus, the results of the analysis would not be affected by using increased morbidity rates with significantly higher doses. (Although not quantified, the risks of outbreaks are considered and are discussed in section 5.4.1.)

To develop an estimate of morbidity rate, EPA analyzed available literature and identified studies with applicable data. Some of the preliminary human ingestion trials were conducted on healthy individuals with no evidence of previous *C. parvum* infection (DuPont et al. 1995). Other studies challenged individuals with existing antibodies or re-challenged those who had participated in earlier studies. DuPont et al. (1995) found that 39 percent of those infected had clinical cryptosporidiosis. Haas et al. (1996) provided information based on the same data also suggesting a morbidity rate of 39 percent, but also computed 95 percent confidence limits of 19 and 62 percent. More recently, a study found that after repeated exposure to *C. parvum* (IOWA strain), the morbidity rate was the same as for the initial exposure in re-infected subjects (Okhuysen et al. 1998). Okhuysen et al. (1998) also found that 58 percent of their subjects who received doses of *Cryptosporidium* developed diarrhea, which is an underestimate of morbidity since symptoms other than diarrhea contribute to the morbidity rate. However, these subjects were given doses higher than those projected in water supplies. Chappell et al. (1997) observed that the rate of diarrheal illness was higher for the TAMU or UCP isolates of *C. parvum* than for the IOWA isolate first studied by DuPont et al. (1995) and Haas et al. (1996).

Given these results and the morbidity variability associated with *C. parvum* during reported outbreaks, the actual morbidity rate may vary with the type of strain to which a population is exposed, as well as with the immune status of the exposed population. However, the prevalence of strains and the immune status of the population are unknown and therefore not quantified for this risk assessment. The uncertainty around the value for morbidity, though, is considered in the risk assessment. The quality of available data does not support making more than a generalized estimate of the range and nature of uncertainty. The underlying data do support the use of a distribution with a central tendency and provide information to establish reasonable ranges. As a result, morbidity was modeled as an uncertain variable having a triangular distribution.

Analysis of the reviewed research resulted in a mode of 50 percent, lower bound of 30 percent, and upper bound of 70 percent for the triangular uncertainty distribution. The following limitations in the research were identified and considered in the derivation of the above values: the Okhuysen et al. (1998) results based on diarrheal rates are probably an underestimate; Chappell et al. (1997) found that diarrheal rates were higher for isolates other than IOWA; and the general population likely has a higher morbidity rate than the healthy individuals used in the study groups.

The central tendency (mode) for the distribution used in the risk assessment model is 50 percent. This is a bit below the Okhuysen et al. (1998) results (58 percent), but above the values estimated by Du Pont et al. (1995) and Haas et al. (1996) (39 percent). These studies used the IOWA isolate, and a simple average of them results in a value of 48.5 percent. The mode was rounded up to 50 percent to account for the apparent underestimation of these studies, as noted above.

The upper bound for the distribution used in the risk assessment model is 70 percent. The upper bound was set above the 95 percent confidence limit of 62 percent estimated by Haas et al. (1996). This reflects that the absolute limit of the triangular distribution would reasonably be above that 95 percent confidence limit and the apparent underestimation of these studies, as noted above. The difference in the upper bound (70 percent) and the Haas et al. 95 percent confidence limit (62 percent) represents only 3 percent of the triangular distribution, indicating that the upper tail of the triangular distribution is comparable to upper portion of Haas's distribution.

The lower bound for the distribution used in the risk assessment model is 30 percent. The lower bound was set higher than the 19 percent estimated by Haas et al. (1996). While this bound does not encompass the lower 95 percent confidence level in the distribution used in the risk assessment, it does account for the apparent underestimation in the studies.

Mortality Rate

The third dose-response relationship used in this analysis is the probability of fatality given that an illness has occurred. There are no general data on the rate of mortality from cryptosporidiosis. To derive mortality estimates, data from the Milwaukee outbreak are used and adjusted to reflect changes in rates of illnesses and advanced treatments that have lessened mortality among persons living with AIDS. Further adjustments are used to reflect the differences between the populations of those living in areas served by filtered and unfiltered systems. Since there is uncertainty around the mortality rate used in the dose-response model, EPA conducted a sensitivity analysis that varied the AIDS mortality rate by +/- 50 percent. This analysis and its results are described in Appendix R.

The starting point is the mortality rates associated with the Milwaukee *Cryptosporidium* outbreak. In that outbreak, 54 people died who had cryptosporidiosis listed on their death certificate. Of those, 46 also had AIDS listed as an underlying cause of death (Hoxie et al. 1997). The Milwaukee outbreak had an estimated 403,000 cases of illness (Kramer et al. 1996b). The unadjusted mortality rate for AIDS-related[5] deaths is thus 46 deaths/403,000 illnesses, or 11.41 deaths/100,000 illnesses. The rate for the

[5] The term "AIDS-related deaths" as used here and throughout this document refers only to deaths caused by cryptosporidiosis (as listed on death certificates), but for which AIDS was also listed as an underlying cause of death.

other, non-AIDS-related deaths is thus 8 deaths/403,000 illnesses, or 1.98 deaths/100,000 illnesses. (All calculations in this section are rounded for ease of presentation, but unrounded data are used in the analysis.)

There were no further adjustments made to the non-AIDS mortality rate. A review of available statistics showed that data to compare the incidence of the other underlying illnesses (coccidiosis (presumably cryptosporidiosis), viral hepatitis, brain tumor, heart failure, and alcoholic cirrhosis of the liver) between Milwaukee in 1993 and the nation in 1999 or 2000 were generally unavailable. Even comparison of proxy data (death rates rather than incidence) proved of little value. Data for Milwaukee were, in general, inconclusive; too few cases were reported to make statistics meaningful. Only in the case of alcoholic cirrhosis of the liver were data statistically significant, and in that case, the rate of deaths per 100,000 population was comparable between Milwaukee (3.36) and the nation as a whole (3.03) (CDC 2001a; Hoxie et al. 1997; CDC 1995). One factor that could affect the non-AIDS mortality rate is age. Hoxie et al. do not provide data on the age of those who died in the outbreak. Although Naumova et al. (2003) found that the rate of gastroenteritis during (and prior) to the outbreak increased with age, there is no information on whether the elderly have a higher mortality rate from cryptosporidiosis. It is conceivable that as the percentage of the population that is elderly increases in the coming decades, the percentage with underlying non-AIDS related disease could also increase, affecting the mortality rate indirectly. However, no data are yet available to support this hypothesis.

The Milwaukee AIDS-related mortality rate was adjusted to account for the decrease in the mortality rate among people with AIDS from the time of the Milwaukee incident to 2001 (the most recent year with comparable data), and the difference in the Milwaukee AIDS population in 1993 to the national AIDS population in 2001. These adjustments are described below; the adjusted calculation is:

> Deaths/100,000 illnesses in the Milwaukee outbreak (11.41) × factor to adjust for lessened mortality over time among persons with AIDS × factor to adjust for changes in the prevalence of AIDS in the general population = AIDS-related deaths per 100,000 cryptosporidiosis illnesses.

The mortality rate for AIDS has declined greatly since 1993 due to the use of combination retroviral therapies and other factors. Combination retroviral therapy raises the CD4+ cell count, enabling people with AIDS to better fight off infection. Correlations have been shown between cryptosporidiosis in AIDS patients and CD4+ counts (Inungu et al. 2000, Pozio et al. 1997). The AIDS mortality rate in 2001 was 4,845 deaths per 100,000 AIDS population (17,402 deaths in a population of 359,141) (CDC 2002). In 1993, this rate was 25,963 (45,271 deaths in a population of 173,772) (CDC 2001). The ratio of these rates is 18.4% percent, that is, the rate of deaths among AIDS patients for all reasons in 2001 was only 18.4 percent of what it was in 1993.

The second adjustment accounts for the difference in the percent of the national population that was living with AIDS in 2001 and the percent of the Milwaukee population that was living with AIDS in 1993. This adjustment is calculated separately for areas served by unfiltered systems and filtered systems. As an approximation of the value for populations served by unfiltered systems, the percentage of the population living with AIDS, which is 0.196 percent (62,349 in a population of 31,859,141), was used. As an approximation of the percentage in areas served by filtered systems, national estimates were used, less what had been accounted for by unfiltered systems. (See Appendix C for details on these data and calculations.) The rate for filtered systems is 0.118 percent (based on an AIDS population of 299,912 in a population base of 253,234,672) (CDC 2002; US Census 2001).

The percentages of people living with AIDS in 2001 served by filtered and unfiltered systems are used separately to adjust and update the 1993 incidence rate of AIDS in Wisconsin. The data on AIDS incidence and population should represent the same location; however, the areas for which data are available do not match the exact geography of the areas served.[6] The ratios that come from this approach are still useful as approximations, and their use is an improvement over not including adjustments for these factors at all. In Wisconsin in 1993, the percentage of the population that had AIDS was 0.017 (862 persons with AIDS in a population of 5,044,318). Extrapolating the Wisconsin data to all populations served by unfiltered and filtered systems, gives a factor of 11.45 for unfiltered systems (0.196 percent/0.017 percent) and a factor of 6.93 (0.118 percent/0.017 percent) for filtered systems. That is, the incidence of people living with AIDS in 2001 in areas served by unfiltered systems is 11.45 times the incidence in Wisconsin in 1993. Similarly, there are 6.93 times as many people living with AIDS in 2001 and served by filtered systems as there were in Wisconsin in 1993.

Using the Milwaukee AIDS-related mortality rate and the adjustment factors described above, the final mortality rate for unfiltered systems (expressed as deaths per 100,000 cryptosporidiosis illnesses) is 24.07 (11.41 × 18.4% × 11.45). Similarly, for filtered systems, the AIDS-related mortality rate is 14.56 deaths per 100,000 cryptosporidiosis illnesses.

The risk assessment model uses a combination of AIDS-related and non-AIDS-related mortality. Thus, adding together these rates yields an overall mortality rate for unfiltered systems of 26.05 deaths per 100,000 cryptosporidiosis illnesses (24.07 AIDS + 1.98 non-AIDS). For filtered systems, this figure is 16.53 deaths per 100,000 cryptosporidiosis illnesses (14.65 AIDS + 1.98 non-AIDS). These mortality factors are constants in the model (that is, no uncertainty is attributed to these parameters).

The mortality rate from the Milwaukee outbreak may not reflect the overall mortality rates from low-level endemic exposure. The estimated levels of *Cryptosporidium* in the finished water supplies during the Milwaukee outbreak were much higher than the levels expected in systems complying with the SWTR, IESWTR, and LT1ESWTR. Thus, the higher level of *Cryptosporidium* in the water supply could have resulted in a higher mortality rate than that expected from endemic exposure if responses increased more than proportionately at higher dose levels.

No data are yet available, however, to support this hypothesis; data are available to indicate only a higher probability of *infection* resulting from higher ingested doses. In an outbreak in Las Vegas, similar mortality rates were observed in AIDS patients (52.6 percent among AIDS patients in Las Vegas compared with 68 percent among AIDS patients in Milwaukee). These similar rates were observed despite the hypothesis that the drinking water had been contaminated over an extended period of time with intermittent low levels of oocysts, unlike Milwaukee's massive contamination (Rose 1997). A recent study by Hunter et al. (2001) suggests that the level of endemic diarrhea from all sources was underestimated in the Milwaukee incident, leading to an overestimation of the number of diarrheal illnesses due to cryptosporidiosis. A lower estimate of illness would consequently raise the mortality rate per case of illness by holding deaths constant as illnesses decreased. However, there is currently no consensus on whether to accept the Hunter et al. conclusions, and responses to their analysis are being prepared by other investigators of the Milwaukee outbreak. The model, therefore, uses the Hoxie et al. 1997 illness estimates (cited previously) for the Milwaukee outbreak.

---

[6] Data on the AIDS population and on the population served by the water system for the area directly affected by the Milwaukee *Cryptosporidium* outbreak are inconsistent in the sources used and the area covered, and individual estimates varied. Data for the entire State of Wisconsin are used as the best consistent source of AIDS data and population data. The State-level data are from U.S. Census and CDC sources. These data are comparable to other data used in this analysis. See Appendix C for more details.

5.2.4 Exposure Assessment

This section discusses the three elements needed for characterizing human exposure to infectious *Cryptosporidium* oocysts in drinking water.

- The distribution of total and infectious *Cryptosporidium* in finished water, reflecting source water levels and treatment effectiveness (section 5.2.4.1)

- The distribution of individual daily drinking water consumption and number of days of exposure (section 5.2.4.2)

- The estimated population served by systems potentially affected by the LT2ESWTR (section 5.2.4.3)

5.2.4.1 Distribution of Infectious *Cryptosporidium* in Finished Water

The distribution of infectious *Cryptosporidium* in finished water to which the affected population is exposed reflects three factors:

- The distribution of total *Cryptosporidium* concentrations in source water

- The fraction of those oocysts that are considered to be infectious

- The removal and inactivation rates of the infectious *Cryptosporidium* predicted for Pre-LT2ESWTR and predicted Post-LT2ESWTR treatment conditions

The National Distribution of Cryptosporidium Concentrations in Source Water

Simulated source water *Cryptosporidium* concentrations are drawn from the occurrence distributions described in Chapter 4. Section 4.2.2 gives a general overview of the occurrence modeling approach, and sections 4.4.3 and 4.5.3 provide more detail on the unfiltered and filtered occurrence models, respectively.

At the broadest level, there are four basic occurrence models that provide input to this EA: three based on filtered-system data from the ICR, ICRSSL and ICRSSM, and one based on unfiltered-system data from the ICR. The separate unfiltered system model is motivated by fundamental differences between the quality of source water in filtered and unfiltered systems. Differences among the three filtered systems data sets arise from different survey sampling plans, lab methods, and sampling periods (see section 4.2.1 for a detailed description of these survey differences).

National benefit estimates are derived from each of the three filtered-system data sets and compared with one another, but they are not combined or weighted in any way. Each of the data sets has strengths, but none was judged as superior in estimating national levels of filtered systems occurrence. The fact that there are three different data sets for filtered systems, leading to three distinct occurrence distributions, reflects significant uncertainty about the true national *Cryptosporidium* distribution and its stability over time. Using all three models serves two purposes: it captures this uncertainty and portrays it clearly, while at the same time providing three distinct, independently drawn, plausible representations of the true national distribution.

As discussed in section 4.2.2, rather than fitting a single log-normal occurrence distribution to each of the four data sets described above, the *Cryptosporidium* modeling approach generates a collection of log-normal distributions from each data set. So, for example, 1,000 mean and standard deviation pairs are drawn from the ICR filtered-systems model to serve as input to the risk assessment model. Each pair defines a single log-normal distribution that could have plausibly generated the ICR survey results for filtered systems. The other three models, corresponding to the other three data sets, are sampled in the same way. The result is the four collections of log-normal distributions that are summarized in Exhibits 4.6, and 4.11 through 4.13.

These collections of occurrence distributions serve as inputs to the Monte Carlo risk simulation (part of the risk assessment model) described in section 5.2.5. In this risk simulation, an outer loop captures uncertainty about risk parameters, and an inner loop models variability in risk from water system to water system. For each of these uncertainty loops, a single occurrence distribution is drawn from a given collection of 1,000 distributions. Then, within the variability loop, the selected log-normal distribution is used to simulate variability in occurrence—both system-to-system differences in average *Cryptosporidium* concentration and sample-to-sample differences over time. This process is repeated until 250 uncertainty loops have been completed, yielding 250 national risk curves.

Again, the overall risk model is described in more detail in section 5.2.5. The key point here is that the occurrence inputs to this risk model are carefully structured to separate uncertainty about the true national distribution, on the one hand, from the estimated system-to-system variability in *Cryptosporidium* concentration on the other. This approach provides a good match between the occurrence inputs and the general structure of the broader risk model.

Infectious Oocyst Fraction

An important parameter when assessing the risk associated with a given concentration of *Cryptosporidium* in a drinking water source is the percentage of oocysts that are infectious. The methods used to analyze *Cryptosporidium* in the ICR and ICRSSs measured total oocyst counts without regard to how many were actually infectious. Because oocysts degrade in the environment, it is expected that only a fraction of the oocysts counted in these surveys would be capable of causing infection in a susceptible host. Consequently, the distributions of *total Cryptosporidium* occurrence based on these surveys are believed to overestimate the concentration of infectious oocysts.

Further, the parameter actually of concern is the ratio of the infectious oocyst fraction in the environment to the same fraction in dose-response studies. Even in the best controlled laboratory studies, the fraction of infectious oocysts is less than 100 percent (but was above 80 percent in the studies considered here).

There is no direct way to assess the infectivity of oocysts counted with the ICR Method in the ICR or with Methods 1622/23 in the ICRSSs. Rather, related information is gleaned from two sources: the physical structure of observed oocysts and a comparison study where samples were analyzed with both Method 1623 and a cell culture test for oocyst infectivity. From these two sources, an estimate was made of the most likely proportion of counted oocysts (in the environment) that were infectious (at least in a laboratory setting).

As discussed in section 4.5.3, *Cryptosporidium* oocysts counted with the ICR Method or Methods 1622/23 are characterized in one of three ways: (1) those with internal structures, i.e., those having recognizable structure consistent with *Cryptosporidium*; (2) oocysts with amorphous structures, which indicates that material is present in the oocyst, but it cannot be confirmed as *Cryptosporidium*; or (3) empty oocysts. Assignment of these labels is dependent upon analyst judgment and none is a certain indicator of whether an oocyst is truly infectious. Oocysts with internal structures are generally considered to have the highest likelihood of being infectious, though laboratory studies have shown oocysts can lose infectivity without loss of internal structures. Oocysts with amorphous structures may be still infectious or, alternatively, may be some other microorganism that mimics the structure and properties of *Cryptosporidium*. Oocysts that are empty of internal structures are assumed to be non-infectious (LeChevallier et al. 1997a).

In the ICR data set, laboratories characterized 23 percent of the oocysts counted as having internal structures, 39 percent having amorphous structures, and 38 percent as being empty. With the ICRSSs, 37 percent of the oocysts had internal structures, 47 percent had amorphous structures, and 16 percent were empty. If it were assumed that the empty oocysts could not be infectious, then these data suggest that the percentage of counted oocysts that were infectious were at most 62 percent in the ICR and 84 percent in the ICRSS.

The lower percentage of empty oocysts in the ICRSS, versus the ICR, may be attributable to the improved sample purification technique in Methods 1622/23. This technique, immunomagnetic separation, prevents many non-*Cryptosporidium* particles from being transferred to the slide for examination; some of these non-*Cryptosporidium* particles may have been incorrectly counted as empty oocysts in the ICR (Connell et al. 2000). Moreover, the LT2ESWTR would require use of Methods 1622/23 for assigning systems to bins, so the ICRSS data may be more reflective of data that would be generated under this rule.

A study by LeChevallier et al. (2003) provides another indication of the percentage of oocysts counted by Method 1623 that are infectious. This study involved intensive sampling of six source waters for *Cryptosporidium* and other microbiological and water quality parameters. Each *Cryptosporidium* sample was analyzed by both Method 1623 and a method that used cell culture and polymerase chain reaction (CC-PCR) to measure viability and infectivity. *Cryptosporidium* oocysts were detected in 60 of 593 samples (10.1 percent) by Method 1623 and infectious oocysts were detected in 22 of 560 samples (3.9 percent) by the CC-PCR procedure. Recovery efficiencies for the two methods were similar. According to the authors, these results suggest that approximately 37 percent of the *Cryptosporidium* oocysts detected by Method 1623 were viable and infectious. Only one sample was positive by both Method 1623 and CC-PCR, though this result is consistent statistically with the low oocyst concentration.

When using the data sets derived from the ICRSS, EPA characterized the percent of oocysts that are infectious as an uncertain variable with a triangular distribution having a lower bound of 30 percent, a mode of 40 percent, and an upper bound of 50 percent. The mode is consistent with results from the LeChevallier et al. study (2003) where the number of samples with infectious oocysts was 37 percent of the number with oocysts counted using EPA Method 1623. It is also consistent with the 37 percent of oocysts counted during the ICRSS that had internal structures, which are considered the most likely to be infectious. The bounds were set at +/- 25 percent of the mode, balancing the good quality of the LeChevallier et al. (2003) data with the uncertainty in applying this result on a national basis. This distribution also recognizes that an unknown fraction of the 47 percent of oocysts counted in the ICRSS with amorphous structures were infectious, which could lead to a total fraction of infectious oocysts greater than 40 percent; alternatively, a fraction of the oocysts with internal structures were likely not infectious, which could lead to a total fraction of infectious oocysts less than 40 percent.

When using the data sets derived from the ICR, EPA characterized the percent of oocysts that are infectious as an uncertain variable with a triangular distribution having a lower bound of 15 percent, a mode of 20 percent, and an upper bound of 25 percent. The lower range for the ICR distribution reflects the higher rate of empty oocysts, which are considered to be non-infectious, detected by the ICR Method (38 percent in the ICR vs. 16 percent in the ICRSS), and the lower rate of oocysts with internal structures (17 percent in the ICR vs. 39 percent in the ICRSS).

Pre-LT2ESWTR Removal/Inactivation of Cryptosporidium

Filtration is currently the primary treatment mechanism used in PWSs to remove *Cryptosporidium*. Finished water *Cryptosporidium* concentrations developed for this risk characterization reflect predicted filtration improvements to meet IESWTR and LT1ESWTR requirements. Chapter 4, section 4.5.4 presents the methodology used to estimate Pre-LT2ESWTR (Post-IESWTR and Post-LT1ESWTR) removal levels. To summarize, Pre-LT2ESWTR removal is modeled as triangular distributions as follows:

- For small systems (serving fewer than 10,000 people): 2 to 4 log range of *Cryptosporidium* removal to capture system-to-system variability; possible modes of the triangular distributions between 2.25 and 3.25 to capture uncertainty in the "true" distribution of removal.

- For large systems (those serving at least 10,000 people): 2 to 5 log range of removal to capture system-to-system variability; possible modes of the triangular distributions between 2.5 and 3.5 to capture uncertainty in defining the "true" distribution of removal.

These distributions are intended to bound the uncertainty in the most likely removal values, as defined by the variable modes of the triangular distributions. Uncertainty and variability in removal are modeled independently of source water *Cryptosporidium* concentration. Also, removal is modeled independently of filtration type (e.g., conventional or direct). This is primarily because the analysis assumes that few systems designed their plants to account for *Cryptosporidium* concentrations. In addition, reviews of the ICR data do not reveal treatment designs to be correlated to *Cryptosporidium* levels. Further, few medium and small systems have collected data that they could have used for this purpose.

As noted in Chapter 4, a small fraction of filtered plants[7] are predicted to have added advanced technologies that provide 5.5 logs of removal or inactivation of *Cryptosporidium* before the implementation of LT2ESWTR. Although several technologies are capable of this level of performance, the model only specifically takes account of those using microfiltration/ultrafiltration (MF/UF). Those plants that had MF/UF in place are removed from the baseline for filtered plants because they are exempt from additional monitoring and treatment requirements under the LT2ESWTR. Therefore, no adjustments are made in the risk model to account for these plants. A small number of plants[8] are predicted to install these technologies to comply with the Stage 1 or Stage 2 Disinfection Byproduct Rule (Stage 1 DBPR or Stage 2 DBPR). These plants are also excluded from the model for estimating risks, although first-round monitoring costs are included. Benefits related to *Cryptosporidium* reduction for these plants are attributed to the other rules and thus not captured in this EA.

Pre-LT2ESWTR finished water *Cryptosporidium* concentrations (mean and median values) are summarized in Chapter 4, Exhibits 4.19a and b. Values are slightly lower for medium and large systems because they are predicted to have better removal performance following the implementation of the IESWTR and LT1ESWTR.

---

[7] Percent of plants shown in Exhibit 4.11, column C.

[8] Percent of plants shown in Exhibit 4.11, column F.

Post-LT2ESWTR Removal/Inactivation of Cryptosporidium

The additional *Cryptosporidium* reduction gained through the addition of advanced technologies for the LT2ESWTR is estimated through a four-step process:

STEP 1—Predict source water occurrence for each plant

At the beginning of each uncertainty loop, the model defines an occurrence distribution by randomly selecting a log-normal mean and standard deviation. At each iteration (at the variability level), the model then randomly draws annual plant means from the distribution defined in the associated uncertainty step, to simulate plant-to-plant variability in occurrence.

STEP 2—Predict bin classification for each plant

Section 4.5.6 and Appendix B summarize the predicted bin classification for the LT2ESWTR Preferred Regulatory Alternative, as well as the two alternative bin classifications considered in this EA (regulatory alternatives A2 and A4). In general, the risk model uses a probability function that takes a "true" source water concentration and adjusts for test method recovery to classify a plant into a treatment bin. Predicted binning has substantial impacts on estimated costs and benefits of the LT2ESWTR; therefore, a sensitivity analysis was performed to evaluate effects of predicted bin assignment based on alternative source water occurrence distributions (see Appendix B).

STEP 3—Adjust bin classification for plants with treatment credits prior to the LT2ESWTR

Some plants may have advanced treatment in place following the IESWTR and LT1ESWTR. Because these plants installed this treatment prior to the LT2ESWTR, benefits and costs associated with the associated toolbox options are not attributable to this rule. The risk model takes into account the higher level of treatment achieved by these systems for both pre-LT2ESWTR finished water occurrence and determining the required log credit. EPA estimated the percentage of plants that will achieve the treatment requirements for combined filter performance, presedimentation basin, and secondary filtration toolbox options, as described in Appendix A. Each of these toolbox options provides 0.5 log treatment credit. Additionally, a few of these plants may have more than one of these options in place and thus receive 1.0 log credit. Exhibit 5.6 shows the percent of plants estimated to receive 0.5 or 1.0 log credit.

Exhibit 5.6: Percent of Plants With Pre-LT2ESWTR Treatment Credit

System Size (population served)	Percent of Plants Achieving
Very Small and Small (10,000 and fewer)	37%
Medium (10,001-100,000)	55%
Large (more than 100,000)	58%

Source: Appendix A, Exhibit A.7.

STEP 4—Determine actual log reduction achieved

Systems have various treatment options available to meet *Cryptosporidium* reduction requirements for a given bin. Some technologies (such as bag and cartridge filters) are projected to be used only by small systems, and some technologies can only be used by larger systems. For example, chlorine dioxide, ozone, and secondary filters are judged to be impractical for systems serving fewer than 500 people (Exhibit 6.9). Once those constraints are accounted for, the selection of technologies (detailed in Chapter 6 and Appendix F) is performed using a "least-cost" approach, whereby EPA estimates (for the purpose of estimating the national costs attributable to this rule) that systems will, for the most part, select the least costly technology available to meet treatment requirements for that bin. In many cases, the least costly technology results in higher levels of *Cryptosporidium* inactivation or removal than required for that bin (this is always the case when UV is selected). Therefore, this risk analysis incorporates estimates of "actual" reduction achieved beyond bin requirements.

Exhibit 5.7a and 5.7b present the predicted *Cryptosporidium* reduction achieved for systems in five action levels for systems without and with Pre-LT2ESWTR credit, respectively. Different reduction estimates are shown for very small, small, medium, and large systems because the least-cost decision tree changes as system size changes, primarily because of different economies of scale among treatment technologies (that is, as system size increases, some technologies will become less costly per unit of water treated than others). Also, different technologies are available for different sizes of systems, usually because of practical limitations such as very small systems not having 24-hour per day staffing. The technology selections for each bin are developed independent of regulatory alternative and source water occurrence distribution. For example, for any regulatory alternative that requires 2.0 log reduction, it is estimated that large systems will actually select technologies that achieve a 3.0 log reduction 90 percent of the time (the remaining 10 percent achieve 2.0 and 2.5 log reduction), regardless of source water occurrence distribution.

Exhibit 5.7a: Predicted Log Removal Achieved for Systems without Credits[1]

	Actual Log Reduction Achieved	Targeted Log Reduction[2]				
		0.5 Log	**1 Log**	**1.5 Log**	**2 Log**	**2.5 Log**
Very Small Systems (Serving < 500)	**0.5**	0.00%	0.00%	0.00%	0.00%	0.00%
	1	90.00%	90.00%	0.00%	0.00%	0.00%
	1.5	0.00%	0.00%	0.00%	0.00%	0.00%
	2	0.00%	0.00%	90.00%	90.00%	0.00%
	2.5	1.00%	1.00%	1.00%	1.00%	10.00%
	3	9.00%	9.00%	9.00%	9.00%	90.00%
	Total	100%	100%	100%	100%	100%
Small Systems (Serving 500 to 9,999 people)	**0.5**	1%	0%	0%	0%	0%
	1	90%	90%	0%	0%	0%
	1.5	0%	0%	0%	0%	0%
	2	0%	0%	26%	26%	0%
	2.5	0%	1%	1%	1%	10%
	3	9%	9%	73%	73%	90%
	Total	100%	100%	100%	100%	100%
Medium Systems (Serving 10,000 to 99,999 people)	**0.5**	27%	0%	0%	0%	0%
	1	2%	8%	0%	0%	0%
	1.5	0%	1%	2%	0%	0%
	2	0%	1%	4%	5%	0%
	2.5	0%	1%	3%	5%	10%
	3	71%	90%	90%	90%	90%
	Total	100%	100%	100%	100%	100%
Large Systems (Serving at least 100,000 people)	**0.5**	27%	0%	0%	0%	0%
	1	1%	8%	0%	0%	0%
	1.5	0%	1%	3%	0%	0%
	2	0%	1%	4%	5%	0%
	2.5	0%	0%	3%	5%	10%
	3	71%	90%	90%	90%	90%
	Total	100%	100%	100%	100%	100%

Notes:
[1]Cells show percent of total number of systems assumed to achieve actual log reduction levels to meet specific treatment bin requirements.
[2]Log reduction requirements associated with treatment bins for all regulatory alternatives.
Source: Appendix F, Exhibits F.3 through F.18, "Actual Log Credit" and "Percent of Plants Selecting Technology by Bin" columns.

Exhibit 5.7b: Predicted Log Removal Achieved for Systems with Credits[1]

	Actual Log Reduction Achieved	Targeted Log Reduction[2]				
		0.5 Log	1.0 Log	1.5 Log	2.0 Log	2.5 Log
Very Small Systems (Serving < 500)	0.5	0.00%	0.00%	0.00%	0.00%	0.00%
	1.0	90.00%	90.00%	0.00%	0.00%	0.00%
	1.5	0.00%	0.00%	0.00%	0.00%	0.00%
	2.0	0.00%	0.00%	90.00%	90.00%	0.00%
	2.5	1.00%	1.00%	1.00%	1.00%	10.00%
	3.0	9.00%	9.00%	9.00%	9.00%	90.00%
	Total	100%	100%	100%	100%	100%
Small Systems (Serving 500 to 9,999 people)	0.5	1%	0%	0%	0%	0%
	1.0	90%	90%	0%	0%	0%
	1.5	0%	0%	0%	0%	0%
	2.0	0%	0%	26%	26%	0%
	2.5	0%	1%	1%	1%	10%
	3.0	9%	9%	73%	73%	90%
	Total	100%	100%	100%	100%	100%
Medium Systems (Serving 10,000 to 99,999 people)	0.5	11%	0%	0%	0%	0%
	1.0	2%	8%	0%	0%	0%
	1.5	0%	0%	1%	0%	0%
	2.0	0%	1%	5%	5%	0%
	2.5	0%	1%	4%	5%	10%
	3.0	87%	90%	90%	90%	90%
	Total	100%	100%	100%	100%	100%
Large Systems (Serving at least 100,000 people)	0.5	12%	0%	0%	0%	0%
	1.0	2%	8%	0%	0%	0%
	1.5	0%	0%	2%	0%	0%
	2.0	0%	1%	5%	5%	0%
	2.5	0%	1%	4%	5%	10%
	3.0	86%	90%	90%	90%	90%
	Total	100%	100%	100%	100%	100%

Notes:
[1]Cells show percent of total number of systems assumed to achieve actual log reduction levels to meet specific treatment bin requirements.
[2]Log reduction requirements associated with treatment bins for all regulatory alternatives.
Source: Appendix F, Exhibits F.3 through F.18, "Actual Log Credit" and "Percent of Plants Selecting Technology by Bin" columns.

5.2.4.2 Distribution of Individual Daily Drinking Water Consumption

The second element of the exposure assessment is the characterization of drinking water consumption in the exposed population. EPA bases its estimates of per-capita water ingestion on data collected by the U.S. Department of Agriculture's (USDA) 1994-96 Continuing Survey of Food Intakes by Individuals (CSFII). Data derived from this survey are presented in the report, "Estimated Per Capita Water Ingestion in the United States" (USEPA 2000k).

The EPA water ingestion study reports water consumption data for two different aggregations of the population: all respondents (which is used in this exposure assessment) and only those respondents who report consuming water directly ("consumers"). The category of all respondents is more appropriate to this exposure assessment because EPA assumes that all people consume or are exposed to tap water, even if they reported no tap water consumption in the CSFII. That is, even people who report no consumption of public water ingest water indirectly (for example, through washing vegetables and other foods, and consuming foods prepared in restaurants) or are potentially exposed pathogens in tap water (during showers and brushing teeth, for example). The survey also reports information by type of source water (community water, bottled water, other sources, and non-reported source). The survey questions categorized respondents based on their reported "main"source of direct water and indirect water. Thus, many respondents who reported that their main source of drinking water was bottled water or another source may still consume water from community sources at least some of the time. Likewise, respondents who categorize their drinking water as being mainly from a community source may also consume bottled water and water from other sources. More important, those who are not now served by community water systems would report "other sources" or bottled water as their main source of water.

For estimating the impacts of the LT2ESWTR, EPA is most interested in the consumption of water by those served by public water systems. The EPA study reports consumption data for source water types and as national averages, where one group cannot be subtracted from the total without affecting the value of the national average. Thus, the consumption of those who reported no source or "other sources" as their main source of drinking water is included in the national average, because subtracting these categories would lead to an underestimate of average consumption levels. Lacking the available data, it is reasonable to assume their consumption patterns are similar to those served only by "community" systems (analogous to public systems under SDWA). Therefore, no adjustments to average consumption were made for those who reported no source or other sources as their main source of water.

Bottled water, however, is thought to replace of tap water, and thus an adjustment to average consumption is more appropriate. In the CSFII study, 13 percent of all water was consumed by those who categorized bottled water as their "main" source of water for direct or indirect ingestion. To reflect this pattern in the exposure assessment, EPA uses the mean of water consumption from all sources, less the mean of water consumed by those who identify bottled water as their main source of water for either direct or indirect ingestion. Because the survey did not attempt to determine for each individual the proportion of water from each source, the approach used in the exposure assessment may understate or overstate actual consumption from public water systems, depending on the extent and direction of overlap in drinking water sources. EPA believes, however, that making this adjustment produces an estimate of drinking water consumption closer to actual practices.

The exposure assessment uses a mean national consumption of 1.071 liters per person per day. This value is the mean consumption from all water sources (1.232 liters per person per day) less the mean consumption of those who reported bottled water as their main source of drinking water (0.161 liters per person per day).

The exposure assessment does not include variability in the mean (1.071 liters per person per day). In the CSFII report, there is information about the 90 percent confidence interval of the mean for both the total (All Sources) and for those relying mainly on bottled water. The 90 percent confidence range for All Sources is 1.199 to 1.265 liters per person per day with a mean of 1.232, or less than +/-3 percent. The 90 percent confidence range for consumption by those relying mainly on bottled water is 0.147 to 0.176 liters per person per day with a mean of 0.161, or under +/-10 percent[9]. The statistics for these ranges alone cannot be used to derive a confidence range for the mean estimate used in the exposure assessment. Given the narrow boundaries in the confidence intervals, EPA judged it more important to adjust the average consumption to reflect the use of bottled water (a 13 percent reduction) than to use the data for All Sources only, which would allow for the use of confidence bounds. Variability in individuals' consumption was reflected in calculating the individual risk reductions estimates (Exhibits

[9] The difference in the variance of these two means might challenge the appropriateness of subtracting their means; however, EPA has judged that the value of obtaining a more accurate estimate of tap water consumption is more relevant to understanding the impacts of the rule alternatives than is additional information about the variability.

5.14 and 5.15), but that variability is not reflected in the overall estimates of variability in illnesses, which are based solely on the mean. Exhibit 5.8 shows the percentile values for individual consumption from all sources and from all sources less bottled water.

Exhibit 5.8 Distribution of Individual Daily Drinking Water Consumption (L/person/day)

Percentile	All Sources	All Sources Less Bottled Water (13 percent)
1	0.01	0.01
5	0.16	0.14
10	0.28	0.25
25	0.57	0.50
50	1.04	0.90
75	1.63	1.42
90	2.34	2.04
95	2.91	2.53
99	4.81	4.18

Source: All Sources from USEPA 2000k.

5.2.4.3 Population Affected by the LT2ESWTR and Exposure

The number of systems and the total population affected by the LT2ESWTR are discussed in Chapter 4 for both unfiltered (section 4.4.2) and filtered (section 4.5.2) plants. Exhibit 5.9 summarizes these numbers. Note that unfiltered plants are all within CWSs. Note also that more than 85 percent of the population affected by the LT2ESWTR are served by medium and large CWSs.

Exhibit 5.9: Number of Systems, Population Served, and Annual National Exposure by System Type

System Size (Population Served)	Number of Systems	Total Population Served	Annual National Exposure in Person-Days
	A	B	C
Unfiltered CWSs			
< 500	5	1,270	444,500
500 - <10,000	32	137,470	48,114,500
10,000 - <100,000	17	135,003	47,251,050
≥ 100,000	6	554,838	194,193,300
Totals	**60**	**828,581**	**290,003,350**
Percent of All PWSs	**0.8%**	**0.5%**	**0.5%**
Filtered CWSs			
< 500	993	195,338	68,368,326
500 - <10,000	2,438	8,510,213	2,978,574,402
10,000 - <100,000	1,327	42,799,971	14,979,989,877
≥ 100,000	283	116,452,533	40,758,386,590
Totals	**5,041**	**167,958,055**	**58,785,319,195**
Percent of All PWSs	**64.1%**	**92.1%**	**95.5%**
Filtered NTNCWSs			
< 500	465	73,997	18,499,141
500 - <10,000	205	324,040	81,010,011
10,000 - <100,000	5	125,710	31,427,418
≥ 100,000	1	166,735	41,683,817
Totals	**676**	**690,482**	**172,620,386**
Percent of All PWSs	**8.6%**	**0.4%**	**0.3%**
Filtered TNCWSs			
< 500	1,883	167,600	30,168,000
500 - <10,000	193	275,237	49,542,660
10,000 - <100,000	12	221,299	39,833,820
≥ 100,000	3	12,144,000	2,185,920,000
Totals	**2,091**	**12,808,136**	**2,305,464,480**
Percent of All PWSs	**26.6%**	**7.0%**	**3.7%**

Sources:
[A] Unfiltered CWSs: Exhibit 4.5, Column A; Filtered PWSs: Exhibit 4.12, Column C.
[B] Unfiltered CWSs: Exhibit 4.5, Column D; Filtered PWSs: Exhibit 4.12, Column E.
[C] Column B x Exposure Days Per Year from Exhibit 5.10.

The risk assessment model also accounts for the number of days per year that individuals in the affected population consume water from the different types of systems. This is needed to calculate the annual risk of infection and illness, as described above. The model assigns different exposure durations to people served by community water systems (CWSs), nontransient noncommunity water systems (NTNCWSs), and transient NCWSs (TNCWSs). Exhibit 5.10 shows EPA's estimates of the number of days per year tap water is consumed by users of different types of water systems.

Exhibit 5.10: EPA Estimates for Exposure Days[1]

Type of System	Exposure Days Per Year
CWS	350
NTNCWS	250
TNCWS	180 [2]

[1] Number of days in which tap water is consumed.
[2] A triangular distribution 90-270 (mode 180) is used to represent "person days" reflecting a large number of individuals, with fewer days exposure per individual to more appropriately characterize consumption and risk among these transient populations.

National exposure (days per year) is calculated as a function of exposure days and population served. These components are addressed in two separate parts of the risk model. The first part of the model incorporates average days of exposure, allowing individual annual risk to be estimated with precision for each type of PWS. The second part of the model incorporates population served, multiplying it by individual annual risk for each system type to obtain national risk.

Overall exposure is not directly proportional to population served due to the differences in average days exposed for the three system types. For example, 100 people served by a CWS will have a greater aggregate exposure than 100 people served by a TNCWS due to the greater number of days exposed for CWS.

To account for the transient nature of the population served by TNCWSs, population is multiplied by a factor between 90 and 270 (drawn from the triangular uncertainty distribution described in Exhibit 5.10). Without this adjustment, the reported TNCWS population would underestimate the true population exposed, since each TNCWS system reports only a peak-season population and each individual exposure is assumed to be just 10 days. The lower end of the triangular distribution represents a 3 month peak season (9 x 10 days = 90 days) and the upper end a 9 month peak season (27 x 10 = 270 days). By making this adjustment to the aggregate TNCWS population, rather than to the average number of TNCWS days exposed, the analysis of individual risk remains distinct from the analysis of aggregate national impact.

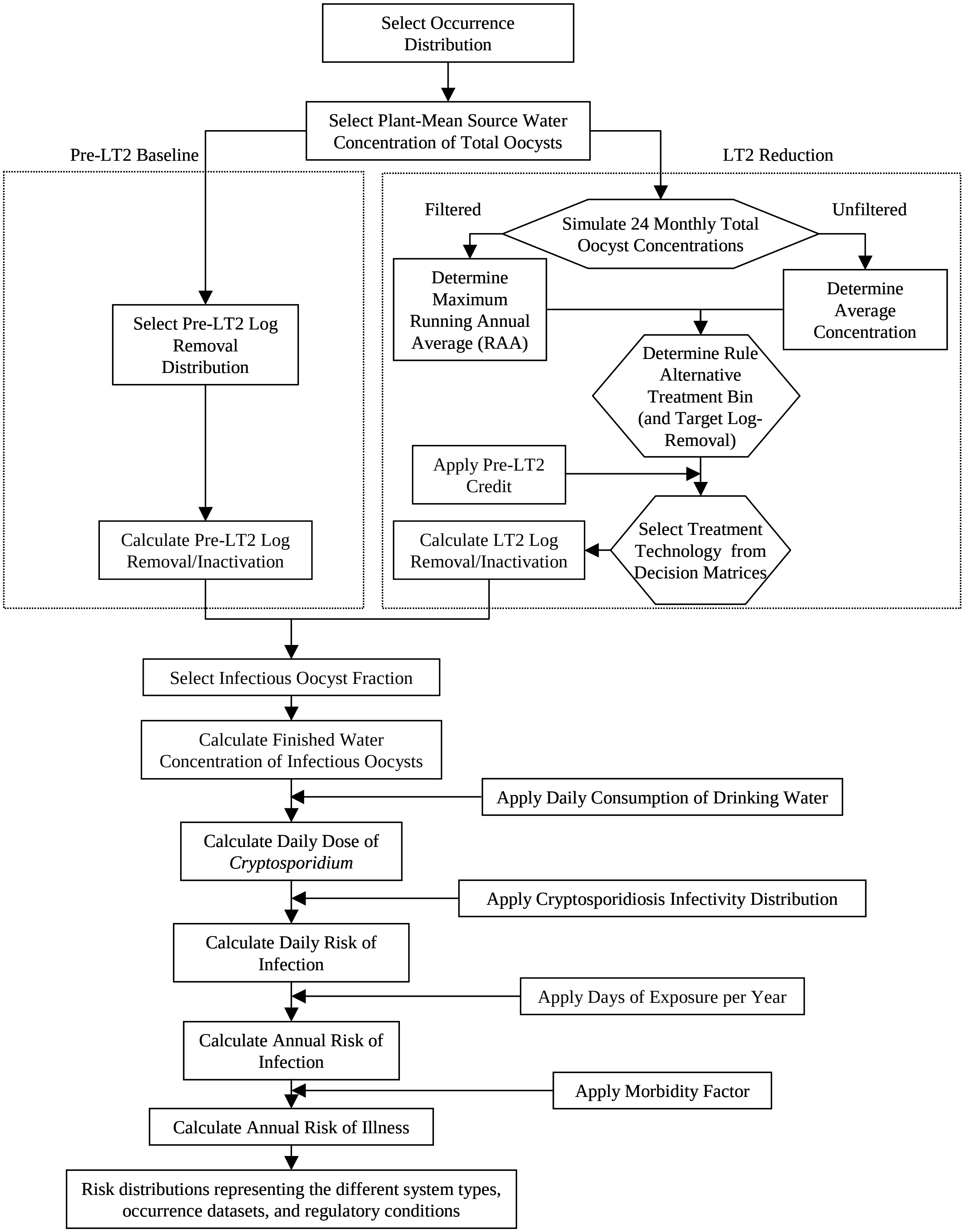
5.2.5 Risk Model Structure

The risk assessment model integrates the dose-response and exposure assessment components discussed above into a Monte Carlo simulation structured to characterize (1) the distribution of individual risk of illness and mortality and (2) the total number of national illnesses and deaths annually due to *Cryptosporidium* in finished drinking water. Modeling is conducted for two treatment conditions: Pre-LT2ESWTR and Post-LT2ESWTR, the former representing baseline (no action) conditions and the latter incorporating assumptions of treatment improvements due to the LT2ESTWR. The difference between the results obtained for the improved conditions and for Pre-LT2ESWTR conditions (in terms of cases of illness and deaths avoided) constitute the quantified benefits of the rule.

The risk assessment modeling is carried out in two steps. The first step focuses on calculating the annual risk of illness. The endpoints of this step are (1) the distribution of annual risks of illness experienced by different individuals in the population, reflecting variability in exposure and infectivity conditions, and (2) the estimated average annual risk for the population as a whole, with confidence intervals on that estimate to reflect uncertainty. The flowchart in Exhibit 5.11 summarizes this first step of risk modeling.

The second step applies the estimated average annual risk of illness, including secondary spread, to the overall population to estimate the annual cases of illness, the annual number of deaths, and the regulatory benefits in terms of illnesses and deaths avoided due to each proposed rule. Discussed further in section 5.3, the second step also integrates information about the monetized values of illnesses and deaths avoided to provide a dollar value for the overall benefits of the rule.

Exhibit 5.11: Flowchart of Risk Model–Step 1: Computing Annual Individual Risk of Illness



Step 1 of the Risk Characterization

Step 1 is structured as a two-dimensional Monte Carlo simulation to appropriately address variability and uncertainty in model inputs. The basic algorithm for Step 1 of the modeling is:

$$P_M = M*(1 - [\exp((-C*v*I)*r)]^n)$$

or more simply,

$$= M*(1-\exp(-C*v*I*r*n))$$

Where:

P_M is the individual annual risk of illness
M is the morbidity factor, or the probability of illness given an infection
C is the *Cryptosporidium* concentration in finished water (oocysts/Liter)
v is the ratio of the percentage of infectious oocysts in the environment to the percentage of infectious oocysts in doses tested in clinical studies
I is mean individual daily drinking water consumption (Liters)
r is the infectivity dose-response parameter (the expected probability of a single ingested oocyst, surviving long enough to reach an infection site in the body)
n is the average annual days per year of exposure

This formula is equivalent to that presented earlier in section 5.2.3 describing the dose-response function for calculating the risk of illness. The difference is that the *d* variable (dose in infectious oocysts/day) has been expanded to show its components, namely *Cryptosporidium* occurrence in finished water (measured oocysts/liter), infectious *Cryptosporidium* rate (infectious oocysts/measured oocyst), and drinking water consumption (liters/day).

As noted above, the first step of the risk assessment model was structured as a two-dimensional Monte Carlo simulation. A two-dimensional simulation is used when the model includes both uncertainty and variability components in the inputs, and where it is necessary to clearly distinguish the influences of these elements on the model output. SAS v8.2 software was used to carry out the analysis (see Appendix T for programming details).

In the risk formula shown above, the uncertainty and variability components are:

Uncertainty:	Data set representing source water concentration (ICR, ICRSSL, ICRSSM)
	True distribution of source water oocyst concentration
	True distribution of Pre-LT2ESWTR removal
	Morbidity factor (the probability of illness given an infection) (M)
	Infectious oocyst fraction (per total oocyst's detected) (v)
	True mean dose-response infectivity parameter (r)
Variability:	Source water concentration (from a selected distribution)
	Pre-LT2ESWTR *Cryptosporidium* removal (from a selected distribution)
	Predicted binning
	Earned log credit for enhanced filtration (0 or 0.5 log)
	Actual log reduction achieved due to LT2ESWTR treatment
	Variable daily ingestion (applied to step 1 results) (I)

The form and values for these variability and uncertainty distributions were discussed in the preceding sections on hazard identification (section 5.2.2) and exposure assessment (section 5.2.4). Exhibit 5.12 summarizes the model parameters.

In the two-dimensional simulation structure, a set value or a distribution of values is randomly selected for each of the uncertainty parameters identified above. These uncertainty parameters are then "frozen," and a specified number of iterations are performed, generating randomly selected values for the variability parameters (referred to as "inner loops"). These results are stored, and a second set of uncertainty parameters is chosen, for which the specified number of iterations are again run for the variability factors. This process is repeated for some specified number of sets of uncertainty parameters (referred to as "outer loops").

In the risk model used here, 250 sets of uncertainty parameters, or outer loops, were generated, each with 1,000 variability iterations, or inner loops. For the model end-point of this step of the analysis "P_M, the annual individual risk of illness," the following key results were computed for each of the 250 uncertainty iterations based on the results of the 1,000 variability iterations performed within each of those uncertainty loops:

- Mean
- Standard Deviation
- Minimum
- Maximum
- Percentiles (every 5th percentile between the 5th and 95th)
- Percentage of population having individual risk levels exceeding 10^{-2}, 10^{-3}, 10^{-4}, 10^{-5}, 10^{-6}, and 10^{-8}

There were 250 sets of these estimates for individual annual risk of illness produced, each reflecting a different possible combination of the uncertainty factors. These 250 estimates of each of the above statistics were then used to compute an overall mean value for each simulation group and confidence bounds on those mean values.

By structuring the first step of the risk analysis in this way, it was possible to characterize both the distribution of individual annual risk of illness in the affected population (reflecting variability in *Cryptosporidium* occurrence levels and daily water consumption), and the overall population average annual risk of illness. This latter value, and the associated uncertainty in it reflected by the 250 alternative values obtained, was then used in the second step of the modeling to compute the number of cases of illness and death by applying these population average risks to the population exposed.

Exhibit 5.12: Overview of Risk Assessment Model Parameters

Variable	Units	Values/Range	Variability or Uncertainty	Depends upon
Top Level Factors				
Proposed regulatory alternative		A1, A2, A3, A4		
PWS size		Nine size categories	Variability	
PWS type		CWS, NTNCWS, TNCWS	Variability	
PWS filtration status		Filtered, Unfiltered	Variability	
Cryptosporidium occurrence dataset		ICR, SSL, SSM	Uncertainty	
***Cryptosporidium* Exposure**				
Source water C*ryptosporidium* concentration (C)	plant mean oocysts/liter	Est [5th, 95th] %tiles [0.0011, 2.7657] ICR [0.0033, 0.6765] SSM [0.0059, 0.3460] SSL [0.0004, 0.1177] Unfiltered	Both (V and U)	Occurrence dataset Filtration
Infectious oocysts per oocyst detected (v)	rate/probability	[15%, 25%] ICR [30%, 50%] SSM, SSL	Uncertainty	Dataset
Drinking water consumption (I)	L/person/day	Mean = 1.07	Variability	
Average annual daily exposures (n)	per individual	10 (TNCWS) 250 (NTNCWS) 350 (CWS)	Constant Constant Constant	
Population at risk (pop)	per PWS size and type	see Exhibit 5.8	Constants	PWS type and size
TNCWS peak population multiplier	multiplication factor	[9, 27]	Variability	PWS type (TNCWS only)
Dose-Response Model				
Dose-response mean infectivity (r)	rate/probability	[0,1] See Appendix N	Uncertainty	
Morbidity rate (prob of illness given infection) (M)	rate/probability	[30%, 70%]	Uncertainty	
Secondary illness factor	rate/probability	[10%, 40%]	Uncertainty	
Mortality rate (prob of death given illness) (F)	rate/probability	1.06E-04 (Filtered) 1.66E-04 (Unfiltered)	Constants	Filtration (Population characterisitics)
***Cryptosporidium* Treatment Reductions**				
Pre-LT2ESWTR C*ryptosporidium* reduction	log(oocysts/liter)	2.0 to 4.5 log	Both (V and U)	PWS size
Pre-LT2ESWTR enhanced filtration credit	log(oocysts/liter)	0 to 0.5 log	Variability	PWS size
LT2 treatment bin removal requirement	log(oocysts/liter)	0 to 2.5 log	Variability	Regulatory alternative Occurrence dataset Infectious oocyst rate PWS size PWS type (including Filtration)
Predicted LT2 technology selection		LT2 toolbox options	Variability	Predicted treatment bin
Actual C*ryptosporidium* reduction due to LT2 treatment	log(oocysts/liter)	0 to 3 log	Variability	Predicted treatment bin Predicted LT2 technology selection

Step 2 of the Risk Characterization

In Step 2 of the risk analysis, the key algorithms used were:

$C_M = P_M \text{ x Pop}$

$C_F = C_M \text{ x } F$

Where:

C_M is the cases of illness in the affected population
P_M is the distribution of individual annual probability of illness
Pop is the number of individuals in the affected population (a probability distribution for TNCWS)
C_F is the count of fatalities in the affected population
F is the probability of fatality given an illness (two values, see section 5.2.3)

Step 2 was conducted with a Monte Carlo simulation (separate from the simulation in Step 1) in which the variable $P_{M(Avg)}$ is treated as an uncertainty variable, values for which were derived from a custom distribution based on the 250 estimates of the mean individual annual risk obtained in Step 1 of the analysis. From this process, estimates of the cases of illness and mortality were computed, as well as the confidence bounds on those estimates, for the various baseline and Post-LT2ESWTR assumptions regarding *Cryptosporidium* removal from source water.

Secondary Spread

The last step of Step 2 is to adjust the number of illness cases to account for secondary spread (mortality is calculated from illness and this is also affected by secondary spread). Secondary spread in this case is infection passed through contact with an individual initially infected by ingestion of contaminated water. Secondary spread is quantified by the ratio of secondary cases to primary cases. The ratio varies depending on a number of factors, such as whether infected persons are symptomatic (or asymptomatic “carriers”), the age, health and immune status of the exposed, and sanitary conditions within the household, office, or day care centers.

The secondary spread rate associated with endemic waterborne cryptosporidiosis is estimated using data on secondary spread and household secondary attack rate compiled from past cryptosporidiosis outbreaks (Exhibit 5.13). The outbreak data reported in the exhibit have secondary spread or household secondary attack rates ranging from 4 percent to 46 percent. Most (8 of 11) values are in the range between 15 percent and 37 percent.

In analyzing the available outbreak data, it is necessary to be aware of at least three potential effects. First, infection by *Cryptosporidium* appears to confer limited immunity, so the secondary spread rate may be affected by the immune status (previous infection history) of the potential secondarily exposed population. Second, the number of secondary cases during a common source outbreak may be limited because the outbreak is so large that most people are affected by the common source, so many fewer people are available to be exposed through secondary spread. Third, secondary spread rates associated with children (who often acquire infection in day-care centers) are high from the frequent handling of soiled diapers and training pants and poor toddler hygiene habits.

The outbreak data in Exhibit 5.13 suggest a triangular distribution for the range of possible secondary spread rates associated with endemic exposure. A preponderance of the rates are in the middle of the distribution rather than at the margins, yet the unusual scenarios discussed above (and others) will occasionally lead to extremes on both the high and low side of the typical range.

To capture uncertainty, a triangular distribution was used with a low at 10 percent, a high at 40 percent and a most likely value of 25 percent. The peak at 25 percent reflects the average value of secondary spread and attack rates shown in Exhibit 5.13 The high value of 40 percent in the distribution is below the highest reported rate in Exhibit 5.13, and the low value of 10 percent is above the lowest reported rate. EPA chose to eliminate extreme values to minimize the impact of any hidden bias in available data.

With the basic risk model described, we move on to a discussion of how the model is used to estimate LT2ESWTR benefits. In short, the model is used to estimate baseline conditions (Pre-LT2) and then expected conditions arising under each of the proposed rules. The differences–baseline to rule–are the basis for obtaining the “cases avoided” (and confidence bounds on those estimates of cases avoided). As further discussed in section 5.3, estimates of “cases avoided” generated in Step 2 of the risk modeling are integrated with estimated costs of illness and mortality to produce the monetized benefit estimates for the LT2ESWTR. The following subsections present these results.

5.2.6 Individual Annual Risk Distributions

The benefits of the LT2ESWTR regulatory alternatives have been explicitly estimated for two health end-points: avoided illnesses and avoided deaths due to endemic cases of cryptosporidiosis. These benefits are measured both in terms of the number of cases of illness and death avoided, and in terms of the monetized value of those avoided cases. This section focuses on the reduction in risk as measured by anticipated changes in the distribution of individual risks in the exposed population (Step 1 of the risk characterization). Section 5.2.7 shows how those changes in the distribution of individual risks aggregated across the exposed population translates into the reduction in cases of illness and death from *Cryptosporidium* on a national level (Step 2). Results for the small population of unfiltered systems are presented first, followed by filtered systems. Section 5.3 extends the benefits analysis to address the monetization of those avoided cases.

The reader is reminded that this section and the next are narrowly focused on risks and benefits related to endemic cases of cryptosporidiosis. Other recognized benefits from the LT2ESWTR that are not explicitly captured in the analysis presented here are those associated with avoided *Cryptosporidium* outbreaks, as well as benefits of avoided endemic and outbreak illnesses and deaths from waterborne pathogens other than *Cryptosporidium* that might also be prevented or controlled by these regulations.

As summarized in the previous section, a key output of the risk model is the estimated *distribution* of annual individual risks of endemic cryptosporidiosis. The variability in individual risks in the exposed population reflects the differences in *Cryptosporidium* concentration from one location to the next, treatment effectiveness, and individual average daily water consumption. As a result, the endemic risk of cryptosporidiosis varies substantially across individuals in the population. Characterizing how individual risks are distributed prior to the LT2ESWTR and how that distribution of risks is expected to change after the regulation is an important component of the overall benefits analysis.

Exhibit 5.13: Secondary Spread and Secondary Attack Rates Associated with Cryptosporidiosis Outbreaks

	Tangerman et al. 1991	Millard et al. 1994	Heijbel et al. 1987	Willocks et al. 1998	MacKenzie et al. 1995a	Brown et al. 1989	Bridgman et al. 1995	Morgan et al. 1995	MacKenzie et al. 1995b
Secondary Spread [1]		17/50 34%	6/26 23%	17% -24%			21%	37%	
Household Secondary Attack Rate [2]	31/101 31%	53/353 15%	77/204 38%		6/118[3] 5%	32/69 46%	-	-	3/69 4%
Number of Confirmed Cases (Adults and Children)	39	50	35	345	339	39	47	64	22
Outbreak Type	Day-care	Food	Day-care	Ground Water	Surface Water	Unknown	Ground Water	Ground Water	Recreational Water
Location and Year	Atlanta, 1989	Maine, 1993	Tulsa, 1984	London, UK, 1997	Milwaukee, 1993	Great Yarmouth, UK, 1986	Warrington, UK, 1992	UK, 1993	Oshkosh, 1993

Notes:
[1]Ratio of secondary cases to primary cases for those with laboratory-confirmed cryptosporidiosis.
[2]Ratio of the number of illness cases (not laboratory confirmed) to the total number of people potentially exposed in the household of laboratory-confirmed cryptosporidiosis cases.
[3]Ratio of the number of illness cases (not laboratory confirmed) to the total number of people potentially exposed in the household of an ill visitor to Milwaukee during the outbreak (two visitors had laboratory confirmed cryptosporidiosis and were associated with 44 household members).

Exhibits 5.14 and 5.15 present the distribution of individual annual endemic illness risk for populations in CWSs that filter their water, and for populations in CWSs that do not filter their water, using the ICR occurrence data set. These exhibits show the portion of the population that has individual risk levels at or above specified values. This provides a means of focusing on the portion of population having the highest individual risks, how large that portion of the population is, and how the upper tails of the risk distribution change as a result of the regulatory alternatives. Appendix C presents similar exhibits for the ICRSSM and ICRSSL data sets. Appendix S further analyzes the filtered risk distributions according to bin requirements.

The filtered CWS individual risk distributions vary as a result of the regulatory alternatives considered for this EA. Exhibit 5.14 shows the risk decreases from regulatory alternative A4 to A1.

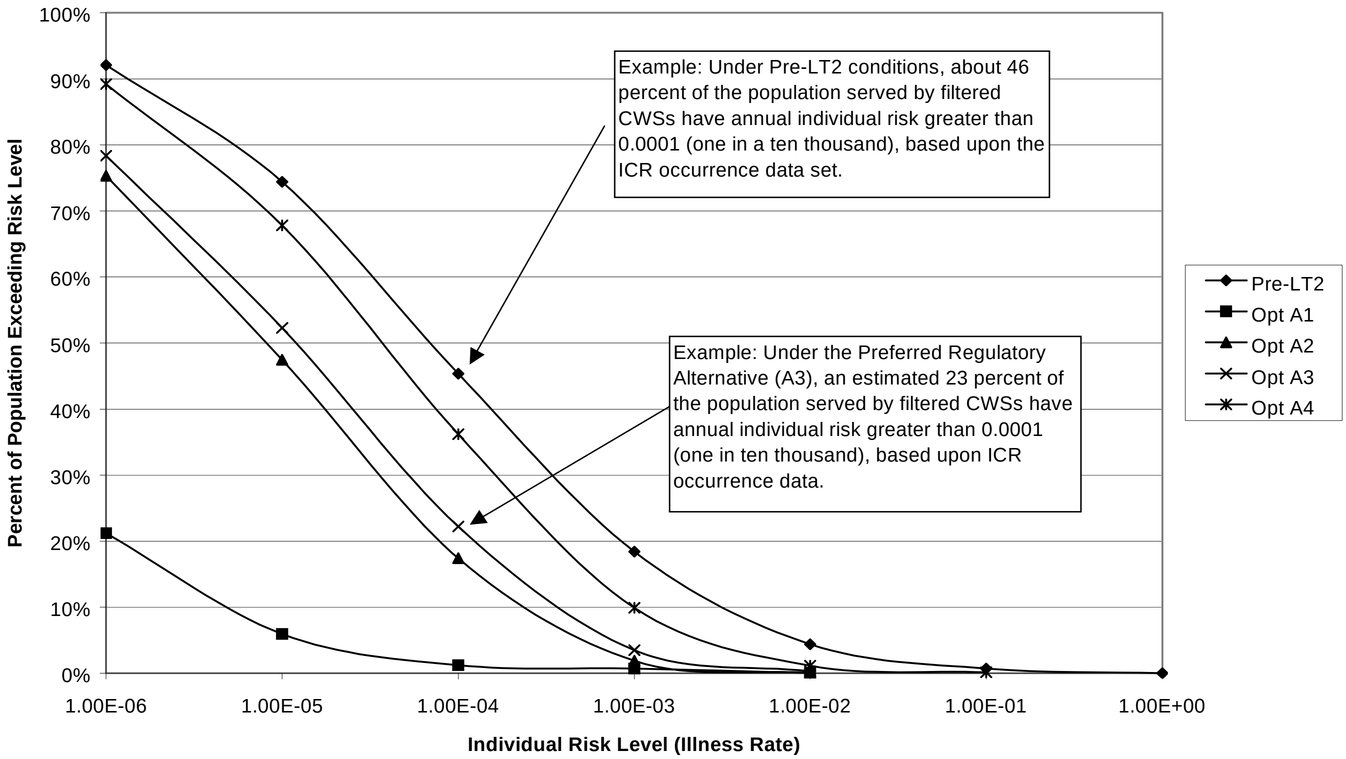
In Appendix C, the filtered risk distributions are displayed again based on the ICRSS data sets. Using different occurrence data sets produces different estimates of cases avoided and cases remaining. The cases avoided using the ICR data set appear greater compared to using the ICRSS data sets (i.e., the distance between the Pre-LT2ESWTR and regulatory alternatives' distributions is greater for the ICR data set). This is because the ICR data predict higher concentrations of *Cryptosporidium* in source water, which leads to more systems requiring treatment. Because many of the treatment options achieve more treatment than is actually needed (see Exhibit 5.7), there is a greater reduction in exposure than if lower levels of *Cryptosporidium* are assumed. Thus, analyses using higher predicted *Cryptosporidium* levels will show that proportionally more cases are avoided (because of especially efficient technologies).

5.2.7 General Population Risk–Number of Cases Avoided

This analysis uses a two-dimensional Monte Carlo simulation to develop estimates of the range of individual risks of infection and illness experienced in the general population, and of the number of annual infections and illnesses resulting from those risks. The algorithms used for calculating individual risk and the resulting number of infections and illnesses in the overall population at risk, as well as the details on the forms of the distributions used in the Monte Carlo simulation employing those algorithms, have been described previously in this chapter.

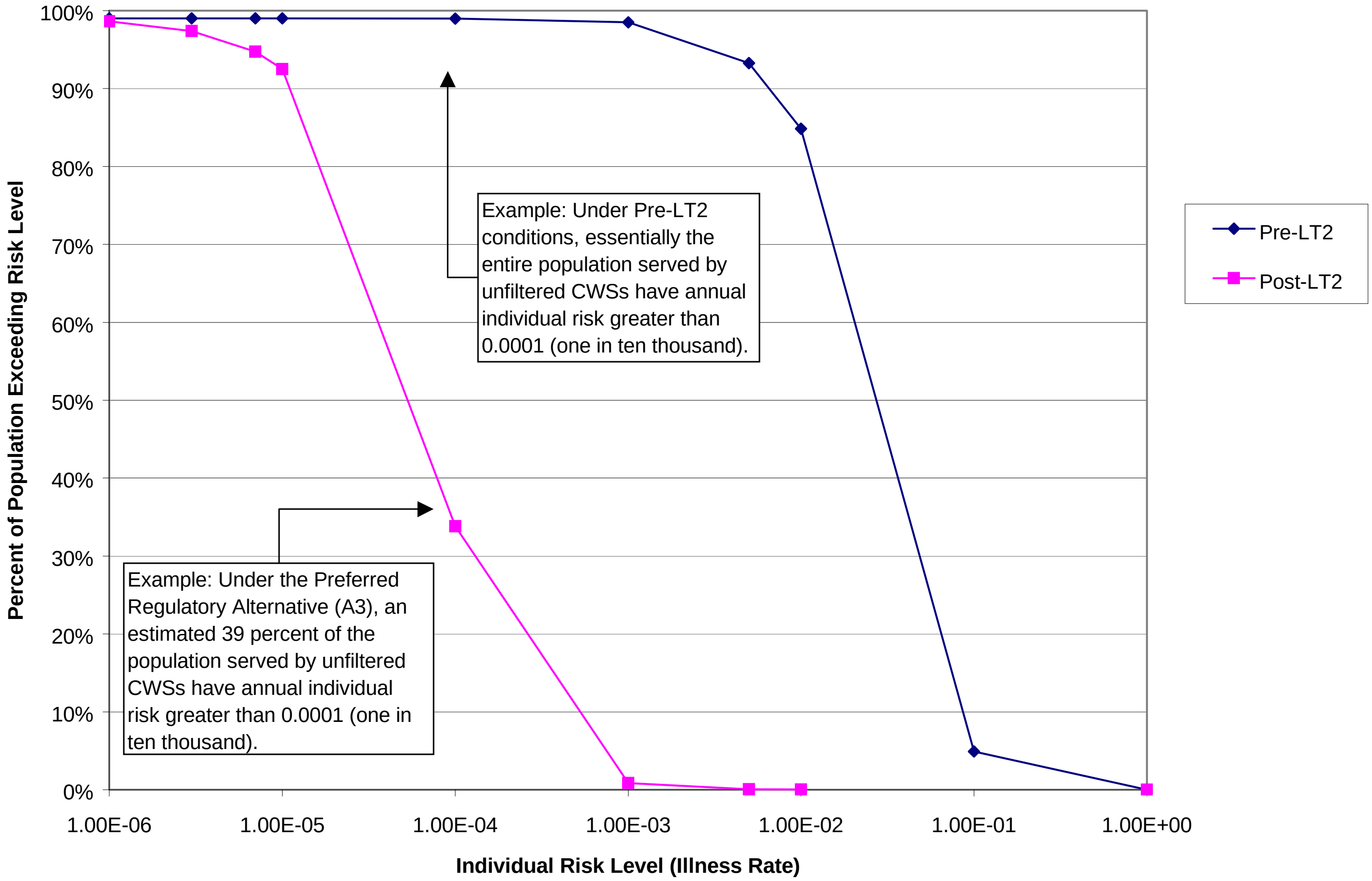
This section summarizes the reduction in general population risk for unfiltered systems followed by filtered systems. Summary results presented in this chapter include all system categories. More results are presented in Appendix C.

Exhibit 5.14: Annual Individual Risk Distributions Based Upon ICR Occurrence Data Set, Filtered CWSs



Source: Risk Assessment Model.

Exhibit 5.15: Annual Individual Risk Distributions Based Upon ICR Occurrence Data Set, Unfiltered CWSs



Source: Risk Assessment Model.

5.2.7.1 Unfiltered Systems

Exhibit 5.16 summarizes modeled results for unfiltered systems. It gives both the baseline estimate of illnesses and deaths, prior to the LT2ESWTR, and the estimated number of illnesses and deaths avoided as a result of implementing the LT2ESWTR. The results represent the total cases avoided at full implementation, and are presented for small and large (those serving 10,000 people or more) systems separately. Population figures are provided for reference.

The ICRSSM and ICRSSL data sets did not have adequate unfiltered data to generate modeled source water occurrence. Therefore, the unfiltered benefits are estimated indirectly, using the ICR benefit estimates. Because of the differences in occurrence data sets, the unfiltered ICR cases of illness and death could not be directly added to the filtered ICRSSM and ICRSSL data sets. Instead, ICR unfiltered cases were adjusted by the ratio of *filtered* cases, ICRSS to ICR. This ratio was calculated for each size category and rule alternative.

Exhibit 5.16: Annual Cases of Illness and Deaths Avoided for the LT2ESWTR, Preferred Alternative, Unfiltered Systems, by Data Set

	Mean			90% Confidence Bound for All Systems	
	Serving <10,000	Serving ≥ 10,000	All Systems	Lower (5th %tile)	Upper (95th %tile)
Population at Risk	*138,740*	*10,245,405*	*10,384,145*		
	A	B	C	D	E
Illnesses					
ICR Data					
Pre-LT2ESWTR	5,492	496,214	501,706	101,303	986,331
Post-LT2ESWTR	28	1,386	1,414	154	4,215
Illnesses Avoided	5,464	494,828	500,291	101,149	982,116
ICRSSL Data					
Pre-LT2ESWTR	1,766	144,683	146,449	29,583	287,769
Post-LT2ESWTR	6	322	328	27	984
Illnesses Avoided	1,760	144,361	146,121	29,556	286,785
ICRSSM Data					
Pre-LT2ESWTR	3,059	254,284	257,342	51,984	505,670
Post-LT2ESWTR	11	587	598	52	1,755
Illnesses Avoided	3,048	253,696	256,744	51,932	503,915
Deaths					
ICR Data					
Pre-LT2ESWTR	1	129	131	26	257
Post-LT2ESWTR	0	0	0	0	1
Deaths Avoided	1	129	130	26	256
ICRSSL Data					
Pre-LT2ESWTR	0	38	38	8	75
Post-LT2ESWTR	0	0	0	0	0
Deaths Avoided	0	38	38	8	75
ICRSSM Data					
Pre-LT2ESWTR	1	66	67	14	132
Post-LT2ESWTR	0	0	0	0	0
Deaths Avoided	1	66	67	14	131

Note: Detail may not add due to independent rounding.
Sources: Population at risk from the risk assessment model.
[A] Pre-LT2ESWTR data from Appendix C, Exhibit C.3, Columns B and E, Row - Small Systems, ICR, ICRSSL, and ICRSSM Unfiltered. Illnesses Avoided data from Appendix C, Exhibit C.7, Columns A and D, Row - Small Systems, ICR, ICRSSL, and ICRSSM
[B] Pre-LT2ESWTR data from Appendix C, Exhibit C.3, Columns B and E, Row - Large Systems, ICR, ICRSSL, and ICRSSM Unfiltered. Illnesses Avoided data from Appendix C, Exhibit C.7, Columns A and D, Row - Large Systems, ICR, ICRSSL, and ICRSSM
[C] Pre-LT2ESWTR data from Appendix C, Exhibit C.3, Columns B and E, Row - All Systems, ICR, ICRSSL, and ICRSSM Unfiltered. Illnesses Avoided data from Appendix C, Exhibit C.7, Columns A and D, Row - All Systems, ICR, ICRSSL, and ICRSSM
[D] Pre-LT2ESWTR data from Appendix C, Exhibit C.3, Columns C and F, Row - All Systems, ICR, ICRSSL, and ICRSSM Unfiltered. Illnesses Avoided data from Appendix C, Exhibit C.7, Columns B and E, Row - All Systems, ICR, ICRSSL, and ICRSSM
[E] Pre-LT2ESWTR data from Appendix C, Exhibit C.3, Columns D and G, Row - All Systems, ICR, ICRSSL, and ICRSSM Unfiltered. Illnesses Avoided data from Appendix C, Exhibit C.7, Columns C and F, Row - All Systems, ICR, ICRSSL, and ICRSSM

Exhibit 5.17: Annual Cases of Illness and Deaths Avoided Due to the LT2ESWTR, Preferred Alternative, All Filtered Systems, by Data Set

	Mean			90% Confidence Bound for All Systems	
	Serving <10,000	**Serving ≥ 10,000**	**All Systems**	**Lower (5th %tile)**	**Upper (95th %tile)**
Population at Risk	*9,546,424*	*171,910,248*	*181,456,672*		
	A	B	C	D	E
Illnesses					
ICR Data					
Pre-LT2ESWTR	51,350	439,740	491,091	46,523	1,404,589
Post-LT2ESWTR	3,651	23,371	27,022	2,782	79,692
Illnesses Avoided	47,700	416,369	464,069	43,741	1,324,897
ICRSSL Data					
Pre-LT2ESWTR	16,432	130,753	147,185	15,445	426,739
Post-LT2ESWTR	7,416	55,159	62,575	7,668	172,224
Illnesses Avoided	9,016	75,594	84,609	7,778	254,515
ICRSSM Data					
Pre-LT2ESWTR	28,481	229,504	257,985	24,193	802,927
Post-LT2ESWTR	7,383	52,176	59,559	6,370	171,165
Illnesses Avoided	21,098	177,328	198,426	17,823	631,762
Deaths					
ICR Data					
Pre-LT2ESWTR	8	73	81	8	232
Post-LT2ESWTR	1	4	4	0	13
Deaths Avoided	8	69	77	7	219
ICRSSL Data					
Pre-LT2ESWTR	3	22	24	3	71
Post-LT2ESWTR	1	9	10	1	29
Deaths Avoided	1	13	14	1	42
ICRSSM Data					
Pre-LT2ESWTR	5	38	43	4	133
Post-LT2ESWTR	1	9	10	1	28
Deaths Avoided	3	29	33	3	105

Note: Detail may not add due to independent rounding.
Sources: Population at risk from the risk assessment model.
[A] Pre-LT2ESWTR data from Appendix C, Exhibit C.3, Columns B and E, Row - Small Systems, ICR, ICRSSL, and ICRSSM Filtered. Illnesses Avoided data from Appendix C, Exhibit C.6, Columns A and D, Row - Small Systems, ICR, ICRSSL, and ICRSSM
[B] Pre-LT2ESWTR data from Appendix C, Exhibit C.3, Columns B and E, Row - Large Systems, ICR, ICRSSL, and ICRSSM Filtered. Illnesses Avoided data from Appendix C, Exhibit C.6, Columns A and D, Row - Large Systems, ICR, ICRSSL, and ICRSSM
[C] Pre-LT2ESWTR data from Appendix C, Exhibit C.3, Columns B and E, Row - All Systems, ICR, ICRSSL, and ICRSSM Filtered. Illnesses Avoided data from Appendix C, Exhibit C.6, Columns A and D, Row - All Systems, ICR, ICRSSL, and ICRSSM
[D] Pre-LT2ESWTR data from Appendix C, Exhibit C.3, Columns C and F, Row - All Systems, ICR, ICRSSL, and ICRSSM Filtered. Illnesses Avoided data from Appendix C, Exhibit C.6, Columns B and E, Row - All Systems, ICR, ICRSSL, and ICRSSM
[E] Pre-LT2ESWTR data from Appendix C, Exhibit C.3, Columns D and G, Row - All Systems, ICR, ICRSSL, and ICRSSM Filtered. Illnesses Avoided data from Appendix C, Exhibit C.6, Columns C and F, Row - All Systems, ICR, ICRSSL, and ICRSSM

This method is applicable to the Pre-LT2ESWTR estimates of cases avoided. However, when estimating the number of illnesses avoided due to the LT2ESWTR, estimates are dependent on the regulatory alternative. In order to carry out the calculation above, an ICRSSL/ICR illnesses-avoided ratio for filtered systems is required, but which ratio is best? There are four regulatory alternatives for filtered systems, and four corresponding ICRSSL/ICR ratios. (This question does not arise for unfiltered systems because there is only one regulatory alternative.)

To address this issue, EPA evaluated all regulatory alternatives to identify the one with filtered treatment requirements most similar to the unfiltered requirements. EPA concluded that alternative A1 was most similar, in terms of expected reductions in *Cryptosporidium*. Alternative A1 is an across-the-board 2 log reduction that impacts all filtered systems regardless of initial monitoring results, as opposed to alternatives A2 through A4 that are expected to impact fewer than half of filtered systems (see Appendix B).

Therefore, in the equation above, the alternative A1 ratio, ICRSSL to ICR, was used to compute the expected number of illnesses avoided for unfiltered systems based on the ICRSSL data set. This single estimate of ICRSSL unfiltered illnesses avoided then, was added to the each of four ICRSSL estimates for filtered system illnesses avoided to obtain a national estimate for each regulatory alternative.

5.2.7.2 Filtered Systems

Exhibit 5.17 summarizes the estimated Pre-LT2ESWTR cases of illness and deaths associated with endemic *Cryptosporidium* occurrence, and estimated cases of illness and deaths avoided for populations served by filtered water systems as a result of the LT2ESWTR. Results are presented for small and large systems (those serving at least 10,000 people) separately and for the three occurrence distribution data sets. Population figures are provided for reference.

5.2.8 Reduction in Sensitive Subpopulation Risk

Morbidity risk in this analysis is based on studies of infectivity and morbidity done on healthy volunteers. No data currently exist that would give a differential infectivity or morbidity for the immunocompromised and other sensitive subpopulations. Therefore, this analysis has not accounted for possible elevated infectivity and morbidity in these populations. The mortality risk from *Cryptosporidium* in this analysis is expressed as the probability of death given an illness, derived from the study of the 1993 Milwaukee outbreak. The majority of the fatalities due to cryptosporidiosis in that outbreak were AIDS patients, and the remainder were elderly. Since all observed mortality has been in sensitive subpopulations, all of the quantified deaths avoided due to the LT2EWSTR are presumed to be lives saved in sensitive populations.

5.3 Monetized Benefits from Reduction in Exposure to *Cryptosporidium* Resulting from the LT2ESWTR

Once the annual endemic illnesses and deaths avoided as a result of the LT2ESWTR are estimated using the risk model described in the previous sections, monetary unit values can be applied to these estimates to establish the monetary benefits attributable to the rule. Because the quantified projection of illnesses avoided is underestimated (risks from outbreaks and risks from other pathogens are not quantified), the projection of monetized benefits is similarly underestimated. Monetary benefits are estimated using different methodologies for illnesses and deaths avoided. In addition, two alternative values are used for estimates of the cost of illness (COI) avoided–the Enhanced COI and Traditional

COI. The methodologies and the resulting monetary benefits estimates are presented in the subsections that follow.

5.3.1 Value of Reduction in Cryptosporidiosis Cases

5.3.1.1 Value of Illnesses Avoided

The goal of this analysis is to provide as complete an accounting as possible of the social welfare impacts of the regulatory options under consideration. In this context, based on the principles of welfare economics, the preferred approach for valuing reductions in the risk of cryptosporidiosis-related morbidity is to rely on estimates of willingness to pay for these risk reductions. However, a review of the literature indicates that the available studies address illnesses having significantly different effects from those associated with cryptosporidiosis; hence, estimates from this literature are inappropriate here. This analysis instead estimates the value of averted morbidity risks based on (1) the avoided medical costs and (2) the value of averted time losses. The rationale for, and limitations of, this approach are introduced below and discussed in greater detail in Appendix K. Appendix L describes the calculations used in the appendix. Appendix P contains a sensitivity analysis using alternative values for two key inputs to the Enhanced COI.

The calculation of medical costs includes the costs of medical services and medications received by ill individuals. The assumption behind using these costs as a benefit measure is that reduced incidence of illness will yield benefits that are at a minimum equal to the costs saved. However, COI estimates may significantly underestimate individual willingness to pay, for a variety of reasons. In particular, these estimates: (1) may not fully address the value of avoiding pain and suffering; (2) do not include costs that individuals incur to avoid the illness (i.e., defensive or averting expenditures);[10] (3) do not reflect aversion to risk (the fear of becoming ill); (4) do not consider *ex ante* values (they are based on *ex post* costs, or costs determined after the fact); and (5) do not consider whether treatment returns individuals to the original state of health (i.e., is equivalent to avoiding the illness entirely).

A number of researchers have explored the relationship between the COI and individual willingness to pay to reduce risk from illnesses other than cryptosporidiosis. That research suggests that the ratio of these two quantities varies greatly depending on the nature of the health effect, the characteristics of the individuals studied, and the factors included in the construction of each estimate. Comparison studies result in ratios of willingness to pay to cost of illness that range from about a factor of 2 to as much as a factor of 79 (in one case); many of the ratios are between 3 and 6.[11] In other words, the cost of illness estimates were typically one-third to one-sixth of the willingness to pay estimates, but the ratio varied greatly.

In some cases, COI studies include indirect, as well as direct costs. These indirect costs usually include lost earnings due to missed market work time (i.e., work time for which payment is received), and may also include costs associated with reduced productivity while at work and/or lost nonmarket work time (e.g., child care or housekeeping). Typically, these costs are estimated using the human

---

[10] Although estimates of averting expenditures incurred during *Cryptosporidium* outbreaks are available, the value of avoiding these expenditures is not quantified in this analysis. The risk assessment focuses on endemic risk rather than risk from outbreaks, and risk-averting behaviors would be less likely to occur in the absence of a publicized outbreak.

[11] See Appendix B of EPA's *Handbook for Non-Cancer Health Effects Valuation* (USEPA 2000f) for a review of these studies.

capital approach, which focuses on the value of goods and services that are bought and sold in the marketplace and ignores other aspects of time use that affect individual well-being.

The analysis of cryptosporidiosis-related morbidity uses two measures of the COI–Traditional and Enhanced. Both approaches include direct medical costs and the value of lost work time, but differ in the assessment of the value of lost work time. Both consider the impact of time lost on foregone market production, which affects the individual worker (e.g., in terms of lost income) as well as other members of society (who benefit from the availability of the goods or services produced and the taxes paid); and foregone nonmarket (household and volunteer) production, which affects the individual and other household members and often has impacts outside the home. The Traditional COI values nonmarket (unpaid) work time at its replacement cost. The other approach, the Enhanced COI, values nonmarket work time based on opportunity costs. Both approaches include values for the nonmarket time lost by friends or family members caring for those who are sick,[12] but they use different values for this lost time.

The Enhanced COI also includes the value of lost leisure time and lost productivity—the reduced utility (or sense of well-being) associated with decreased enjoyment of time spent in both market and nonmarket activities. The Enhanced COI is an attempt to more completely measure the loss of welfare from an illness.

Regarding how best to value lost work time, a review of the literature suggests that researchers have not attempted to directly estimate (e.g., through surveys) the difference between the value of time in a well state compared to an ill state. Hence, this analysis relies on wage and compensation data to estimate the opportunity costs of time usage. This approach recognizes that, because resources are limited, any decision to use resources for one purpose means that they cannot be used for other purposes. Therefore, the value of the unpriced resource can be determined based on the value of its next best use.

The application of the opportunity cost approach to market work time is relatively clear, since compensation can be used to estimate these costs. More precisely, lost market work is valued at the median gross (pre-tax) wage rate plus benefits, also referred to as total compensation or employer's costs. This approach most accurately represents the full social impact of lost work time because it incorporates both the income loss to the individual and the loss to society in terms of reduced tax revenue and decreased production of goods and services.

For unpaid time spent in nonmarket work and for leisure time, wage data are also used. The Enhanced COI assumes that (at the margin) the wage represents the opportunity cost of engaging in such activities. Lost nonmarket work and leisure time are valued at the median net (post-tax) wage rate. This approach reflects the assumption that, at the margin, an individual will choose to engage in nonmarket work or leisure activities only if the value of these activities exceeds the post-tax wage rate that the individual would otherwise earn.[13] These values are applied both to complete losses of time (time spent in illness-related activities rather than normal activities) and to partial losses (time spent in normal activities that are less productive or pleasurable than in the absence of illness). In the latter case, however, the dollar value of the loss is prorated to reflect the fact that the individual does not completely lose the productivity or utility associated with the activity. These values are applied to

[12] Paid care is included in the medical cost component of the analysis and hence is not discussed in the discussion of time losses.

[13] A sensitivity analysis that uses alternative values for nonmarket work and leisure time in the calculation of the Enhanced COI is included in Appendix P.

nonmarket caretakers whose normal activities are affected by illness as well as to time losses accruing to the ill individual.[14]

For unpaid time spent in nonmarket work, the Traditional COI also uses wage data. The value used is half of the after-tax wage. The use of 50 percent of the wage rate is consistent with the common practice in the human capital literature of valuing nonmarket work time at the market rate for domestic workers.[15] This literature uses replacement cost as a measure of the productivity of nonmarket work, rather than focusing on the opportunity cost (or utility loss) for the individual who chooses to engage in nonmarket work. In support of the use of 50 percent of the after-tax wage rate, the median weekly earnings of private household workers in the service industry were $276 per week in 2002, about 45 percent of the median weekly earnings of $609 for all workers (U.S. Census Bureau Table 641, 2003). Private household workers include childcare workers, cleaners, and servants. The Traditional COI does not include values for lost leisure time or lost productivity.

Sleep time presents special problems in this analysis, in part because data on the effect of cryptosporidiosis-related morbidity on the amount or quality of sleep time is not available. Thus, this analysis conservatively assumes that lost sleep time has zero value.

The use of medical costs and the opportunity cost of time to value cryptosporidiosis-related morbidity may understate the value of these risk reductions for a variety of reasons.[16] As noted earlier, COI estimates generally understate willingness to pay for a variety of reasons, e.g., because they may not fully consider the value of avoided pain and suffering or of risk aversion. In addition, the use of wage and compensation data to value lost time may understate the utility of time spent in its preferred use. The use of wage rates may understate the total utility associated with an activity even in the case of market work, because individuals may derive intrinsic pleasure from the activity above and beyond the income they receive. For nonmarket work and leisure, the value of the activity to the individual may exceed the opportunity cost for similar reasons. In addition, nonmarket work and other activities can provide benefits to other members of society that are not reflected in the individual wage rate. Finally, neither the Tradtional or Enhanced COI approach includes the value of lost sleep time.

In addition, relying on wage data for valuing lost time presents difficulties in the case of individuals for whom these data do not exist, such as children, the unemployed who are seeking employment, and those out of the labor market. The approach taken in this analysis is to value all time losses at the rates applicable to adult wage earners. It is unclear whether this approach under- or overstates the value of times losses for the individuals in these other categories, given the lack of information on these values.

[14] A sensitivity analysis that uses alternative values for lost productivity in the calculation of the Enhanced COI is included in Appendix P.

[15] A pioneering example of this approach is Rice 1966; a more recent example is Thamer et al. 1998.

[16] A number of other simplifying assumptions inherent in this approach may lead it to under- or overstate the value of time losses. These relate to factors such as the functioning of the labor market, the treatment of individuals who are not labor force participants, the use of average or median (rather than marginal) earnings data, and the possibility that substitute activities (e.g., watching TV instead of normal activities) have some positive value if not offset by the utility losses from the discomfort and stress of being sick. It is unclear whether, in total, these practical limitations serve to increase or decrease the bias that results from the sources discussed in this paragraph.

COI Calculations

The primary risk of illness that LT2ESWTR addresses is from endemic exposure to *Cryptosporidium* and the resulting cases of cryptosporidiosis. Direct measurements of many elements of the COI were made as part of an investigation of the 1993 Milwaukee *Cryptosporidium* outbreak. Some of the data collected during that outbreak have been reported in Corso et al. (2003), whose data sources include the original epidemiological investigation by CDC and State personnel, including telephone surveys and a review of hospital records. The epidemiological investigation collected information on the duration of illness, types of medication taken, medical care sought, if any, and the costs associated with these services. The data from that report and other sources of information used in the analysis that follows are shown in Appendix L.

The computation of COI involves two broad categories—direct medical costs and the value of lost time (Exhibit 5.18). The components are updated to a common month and year (December 2003), which is used as the starting point for projecting benefits into future time periods. For each of these components, separate estimates are made based on the severity of the illness. Illnesses are sorted into three severity categories as follows:

- Mild: the person did not seek professional medical care for the illness.

- Moderate: the person had one or more outpatient visits to a physician or emergency room, but the person was ultimately not hospitalized.

- Severe: the person was hospitalized one or more times.

The percentage of people in each of the severity classifications is used to derive an average weighted cost per patient. The average loss per case of cryptosporidiosis incorporating all categories is approximately $844 for the Enhanced COI and $274 for the Traditional COI. Of those totals, approximately $107 is for direct medical costs (Exhibit 5.18). The details of the computations are discussed in the next three subsections.

Direct Medical Costs

As Exhibit 5.18 shows, the weighted average of direct medical costs per case of illness is $106.91. Costs for doctor visits, emergency room (ER) visits, hospital stays, ambulance costs, and costs of medication comprise the direct medical costs. (As mentioned earlier, medications can relieve some symptoms, but do not cure infection). All direct medical costs are obtained in December 1993 dollars and updated by a 1.47 cost per illness (CPI-U) update factor to December 2003 dollars.[17] The Corso et al. (2003) report states that those with mild cases did not visit a doctor (a non-ER physician) but 95 percent of those with moderate cases and 29 percent of those with severe cases did. Conversely, 5 percent of moderate cases and 71 percent of severe cases went to the ER. Multiplying through by the respective costs of doctor visits ($66.15) and ER visits ($329.28) yields average costs of $62.84 per moderate case and $19.18 per severe case for doctor visits, and an average of $16.46 per moderate case and $233.79 per severe case per ER visit.

[17] Bureau of Labor Statistics, 302.1 (Dec2003$)/205.2 (Dec1993$) = 1.47 CPI-U medical cost update factor.

Exhibit 5.18: Direct Medical Costs of a Case of Cryptosporidiosis

Medical Cost	Average Cost[1]						Average Cost Per Patient		
	1993$			December 2003$			December 2003$		
	Mild	Moderate	Severe	Mild	Moderate	Severe	Mild (88%)	Moderate (11%)	Severe (1%)
Doctor Visits	NA	$45.00	$45.00	NA	$66.15	$66.15	NA	95%*$66.15 =$62.84	29%*$66.15 =$19.18
Emergency Room Visits	NA	$224.00	$224.00	NA	$329.28	$329.28	NA	5%*$329.28 =$16.46	71%*$329.28 =$233.79
Hospital Stays	NA	NA	$6,152.96	NA	NA	$9,044.85	NA	NA	100%*$9,044.85 =$9,044.85
Ambulance	NA	$228.00	$228.00	NA	$335.16	$335.16	NA	4.9%*5%* $335.16 =$0.82	16.3%*$335.16 =$54.63
Medication	$5.73	$5.92	$6.74	$8.42	$8.70	$9.91	30%*$8.42 =$2.53	30%*$8.70 =$2.61	29%*$9.91 =$2.87
Medication after Health Care	NA	$8.91	$70.52	NA	$13.10	$103.66	NA	54%*$13.10 =$7.07	48%*$103.66 =$49.76
Medication Taken upon Recurrence	$2.44	$2.44	$2.44	$3.59	$3.59	$3.59	21%*$3.59 =$0.75	21%*$3.59 =$0.75	21%*$3.59 =$0.75
Totals							$3.28	$90.56	$9,405.84
								Weighted Total	$106.91

Notes: Detail may not add to totals due to independent rounding.
[1]All direct medical costs are obtained in December 1993$ and updated by a 1.47 CPI-U update factor to December 2003$. CPI-U update factor = 302.1 (Dec2003$)/205.2 (Dec1993$) = (rounded to) 1.47.
Sources: Appendix L, 1993$ average cost data from Corso et al. (2003).
CPI-U data - Bureau of Labor Statistics.

The average cost of a hospital stay was $9,044.85. This figure is applied only to severe cases. Hospital costs include all costs of hospitalization except those for consultations by specialists; insufficient data were available on the latter costs.

Medication costs were the same for all levels of severity for medication taken upon recurrence of cryptosporidiosis. The average cost of medication for recurrence was $3.59 per person. Of the people infected with cryptosporidiosis, 21 percent had at least one recurrence. Otherwise, medication costs varied depending on severity of illness. For medication used before receiving medical attention, costs are similar across severity groups; $8.42 for mild, $8.70 for moderate and $9.91 for severe cases of cryptosporidiosis. Medication costs after health care varied. In addition, these costs only applied to non-mild cases; costs amounted to $13.10 for moderate cases and $103.66 for severe cases, but are weighted based on the percentage of people taking medication. Summing all of the above costs and obtaining a weighted average by severity level yields an overall weighted average of $106.91 for direct medical costs per illness.

Value of Lost Time Per Day

The value of lost time is derived through several steps shown in summary below and discussed in detail in Appendix L. First, the number of days lost and days with lessened productivity (for the Enhanced COI) must be calculated. Exhibit 5.19 shows days lost by severity of illness, and Exhibit 5.20 calculates average days lost weighted by percent of cases with each severity of illness. For the 21 percent of cases with a 2-day recurrence of the illness (Corso et al., 2003), the analysis assumes that these have at least 2 days' reduced productivity (Appendix L).

Exhibit 5.19: Days Lost and Days with Lost Productivity, by Severity of Illness

	Time Category		
	Mean Duration of Illness (Days)	Days Lost to Illness	Lost Productivity Days
Illness Severity	A	B	C=A-B
Mild	4.7	1.3	3.4
Moderate	9.4	3.8	5.6
Severe	34.0	5.6	20.5

Source: Exhibit L.5.

Exhibit 5.20: Weighted Average Days Lost for Particular Illness

	Severity	Days Lost	Weight	Weighted Average Days
Work Losses (Patients)	Mild	1.3	88%	1.144
	Moderate	3.8	11%	0.418
	Severe	13.5	1%	0.135
			Total	**1.697**
Caregivers Losses	Mild	0.1	88%	0.088
	Moderate	1.3	11%	0.143
	Severe	3.9	1%	0.039
			Total	**0.270**
Productivity Losses (Patients)	Mild	3.4	88%	2.992
	Moderate	5.6	11%	06.616
	Severe	20.5	1%	0.205
	Recurrence	2.0	21%	0.420
			Total	**4.233**

Source: Exhibit L.6

Second, the value of time must be estimated. Exhibit 5.21 presents the hours lost per day of illness. These values are based on estimates of the number of hours worked, adjusted by the percent of the population engaged in market and nonmarket work, and assumes 8 hours of sleep per day per person. Details of the sources, calculations, and assumptions to derive these values are provided in Appendix L.5.

Exhibit 5.21 also presents the per-hour value of lost time. These values derive from reported usual weekly earnings of $609 (U.S. Census Bureau Table 641, 2003). To value lost work time, this figure is increased to reflect employers' costs (adding in benefits paid). Because employers are willing to pay for workers' time at this level, it is the best measure of the value of that lost time ($20.82 per hour). For the Enhanced COI, the value of lost nonmarket work time is the median after tax wage. To derive this figure, the weekly earnings estimate of $609 was adjusted downward to reflect after tax wages (to $12.46). For the Traditional COI, half of this figure is used (or $6.23), as discussed above, and in detail in Appendices K and L. Details of the sources, calculations, and assumptions to derive these values are provided in Appendix K and Appendix L.6.

The two right-hand columns of Exhibit 5.21 multiply these dollar-per-hour values by the time allocations to determine the weighted average value of time per hour and per day.

Exhibit 5.21: Value of Time, 2003

	Time Loss Category	Hours Per-Day of Illness	Per-Hour Value	Per-Day Value
Enhanced COI	Market Work Time	3.4	$20.82	$70.79
	Nonmarket Work Time	2.3	$12.46	$28.66
	Nonmarket Leisure Time	10.3	$12.46	$128.34
	Caregiver Day	Sum of per-day value of lost market work, nonmarket work, and leisure days		$227.79
Traditional COI	Market Work Time	3.4	$20.82	$70.79
	Nonmarket Work Time	2.3	$6.23	$14.33
	Caregiver Day	Sum of per-day value of lost market and nonmarket work days		$85.12

Note: Detail may not add due to independent rounding.
Source: Exhibit L.9.

Total Morbidity Cost of Illness

There are two major components of the total value of the morbidity cost of avoiding a case of cryptosporidiosis–direct medical costs and lost time. As discussed above, the total direct medical costs are $106.91 per illness. Lost time estimates are derived from the estimate of the average days lost and the value of each day lost. For the Enhanced COI, productivity losses are included. Because patients are only fractionally as productive at work as well people, the loss associated with the less productive days is a portion of the value of a full lost day, specifically 30 percent (rounded from Harrington 1991). For example, this may be the result of frequent trips to the bathroom, reduced concentration on tasks, or preparation of special meals. Summing the subcategories of total value of lost time yields a weighted cost of $737.33 (Enhanced COI) and $167.43 (Traditional COI) per case of cryptosporidiosis in 2003.

Exhibit 5.22 shows these calculations. The total loss per case in 2003$ is $844.24 for the Enhanced COI and about a third of that, or $274.34, for the Traditional COI.

Exhibit 5.22: Total Loss Per Case, Enhanced and Traditional COI, 2003$

Loss Category	Average Days Lost Per Illness	Value Per Day		Total Loss Per Case	
		Enhanced COI	Traditional COI	Enhanced COI	Traditional COI
	A	B	C	D=A*B	E=A*C
Direct Medical Costs				**$106.91**	**$106.91**
Lost Market Work Days	1.697	$70.79	$70.79	$120.13	$120.13
Lost Nonmarket Work Days		$28.66	$14.33	$48.64	$24.32
Lost Leisure Time		$128.34	-	$217.79	-
Lost Caregiver Days	0.270	$227.79	$85.12	$61.50	$22.98
Lost Leisure Productivity	4.233	$128.34 x 30%	-	$162.98	-
Lost Productivity at Work		($70.79 + $28.66) x 30%	-	$126.29	-
Lost Time Subtotal				**$737.33**	**$167.43**
Total				**$844.24**	**$274.34**

Notes: Detail may not calculate to totals due to independent rounding.
The Traditional COI only includes valuation for medical costs and lost work time (including some portion of unpaid household production). The Enhanced COI also factors in valuations for lost personal time (non-work time) such as child care and homemaking (to the extent not covered by the traditional COI), time with family, and recreation, and lost productivity at work on days when workers are ill but go to work anyway.
Source: Exhibit L.10.

The value of lost time can increase or decrease over time, depending on the change in real income. Real income (after inflation) is projected to increase based on forecasts in growth in the gross domestic product (GPD) and population. Real per capita income growth reflects the overall increase in society's productivity. These changes in income growth and, therefore, the value of time, are shown in Exhibit 5.23 and are derived in Appendix C. These changes in income growth mean that the loss due to an illness would increase over time because lost time is recovered by wage rates or their equivalent. In the benefits model, the cases avoided in each year are valued as shown in Exhibit 5.23 (the model uses unrounded data). Benefits derived from medical costs are not adjusted for changes in income over time, because medical costs do not necessarily have a direct or indirect link with income.

Exhibit 5.23: Yearly Total Loss Per Case, Enhanced and Traditional COI

Year	%Change in Income (Real GDP per Capita)	Lost Time		Direct Medical Costs	Total Loses Per Case	
		Enhanced COI	Traditional COI		Enhanced COI	Traditional COI
	A	B=(1+A) x previous year	C=(1+A) x previous year	D	E = B+D	F= C+D
2003	Base Year	$737.33	$167.43	$106.91	$844.24	$274.34
2004	2.3%	$754.34	$171.29	$106.91	$861.25	$278.20
2005	3.9%	$783.82	$177.99	$106.91	$890.73	$284.90
2006	3.3%	$809.88	$183.90	$106.91	$916.79	$290.81
2007	2.3%	$828.85	$188.21	$106.91	$935.76	$295.12
2008	1.9%	$844.23	$191.70	$106.91	$951.14	$298.61
2009	2.0%	$860.79	$195.46	$106.91	$967.70	$302.37
2010	2.0%	$877.73	$199.31	$106.91	$984.64	$306.22
2011	1.8%	$893.29	$202.84	$106.91	$1,000.20	$309.75
2012	1.7%	$908.22	$206.23	$106.91	$1,015.13	$313.14
2013	1.7%	$923.39	$209.68	$106.91	$1,030.30	$316.59
2014	1.7%	$938.83	$213.19	$106.91	$1,045.74	$320.10
2015	1.7%	$954.55	$216.76	$106.91	$1,061.46	$323.67
2016	1.7%	$970.57	$220.39	$106.91	$1,077.48	$327.30
2017	1.7%	$986.89	$224.10	$106.91	$1,093.80	$331.01
2018	1.7%	$1,003.55	$227.88	$106.91	$1,110.46	$334.79
2019	1.7%	$1,020.55	$231.74	$106.91	$1,127.46	$338.65
2020	1.7%	$1,037.91	$235.68	$106.91	$1,144.82	$342.59
2021	1.7%	$1,055.60	$239.70	$106.91	$1,162.51	$346.61
2022	1.7%	$1,073.60	$243.79	$106.91	$1,180.51	$350.70
2023	1.7%	$1,091.91	$247.95	$106.91	$1,198.82	$354.86
2024	1.7%	$1,110.54	$252.18	$106.91	$1,217.45	$359.09
2025	1.7%	$1,129.50	$256.48	$106.91	$1,236.41	$363.39
2026	1.7%	$1,148.81	$260.87	$106.91	$1,255.72	$367.78
2027	1.7%	$1,168.48	$265.33	$106.91	$1,275.39	$372.24
2028	1.7%	$1,188.48	$269.88	$106.91	$1,295.39	$376.79
2029	1.7%	$1,208.91	$274.51	$106.91	$1,315.82	$381.42

Note: Full precision is used in model calculations. Rounded data are shown here.
The Traditional COI only includes valuation for medical costs and lost work time (including some portion of unpaid household production). The Enhanced COI also factors in valuations for lost personal time (non-work time) such as child care and homemaking (to the extent not covered by the traditional COI), time with family, and recreation, and lost productivity at work on days when workers are ill but go to work anyway.
Source: Exhibit L.11.

The sensitivity of different assumptions on the Enhanced COI was tested and is described in Appendix P. Alternative values for several underlying variables were considered, but only the following two were judged important to test in a sensitivity analysis:

- The hourly value of nonmarket work and leisure time. The Enhanced COI uses a value of $12.46 per hour (in 2003), but an alternative value of $6.23 per hour was used in the “low estimate” sensitivity analysis, and a value of $18.69 was used in the “high estimate” sensitivity analysis. These bounds represent the effect of (1) assuming that all nonmarket work and leisure time is valued at a rate higher than the best estimate and (2) assuming that some of the nonmarket work and leisure time lost is an incomplete loss of utility. The basis for using these bounds at 50 percent and 150 percent of the best estimate is discussed in detail in Appendix P.

- The percent decrease in productivity for days in which work could be performed, but effects of the illness prevented full productivity. The Enhanced COI uses 30 percent, and the bounds for the sensitivity analysis are 20 percent and 40 percent. Related studies and the basis for selecting these levels for a sensitivity analysis is discussed in Appendix P.

The total value of lost time using the Enhanced COI is $737.33 (in 2003$), and using these alternative values in the derivation of that estimate would lower that value to $420.04 (57 percent of the Enhanced COI) and raise that value to $1,121.08 (152 percent of the Enhanced COI). The overall effect on total benefits is less pronounced because of the value of fatalities, and fixed direct medical costs. Appendix P calculates the effect of using these alternatives on the total COI and total benefits.

5.3.1.2 Value of Avoiding Fatal Cases of Cryptosporidiosis

Benefits of the LT2ESWTR also derive from avoiding fatal cases of cryptosporidiosis. The Value of a Statistical Life (VSL) is used to measure the value of these benefits. The VSL represents an estimate of the monetary value of reducing risks of premature death. The VSL, therefore, is not an estimate of the value of saving a particular individual's life. The value of a "statistical" life represents the sum of the values placed on small individual risk reductions across an exposed population. For example, if a regulation were to reduce the risk of premature death from cryptosporidiosis by 1/1,000,000 for 1 million exposed individuals, the regulation would "save" one statistical life (1,000,000 x 1/1,000,000). If each of the 1,000,000 people were willing to pay $5 to achieve the individual risk reduction anticipated from the regulation, the VSL would be $5 million ($5 x 1,000,000).

An EPA study characterized the range of possible VSL values as a Weibull distribution with a mean of $4.8 million (1990 price level), based on 26 individual study estimates (USEPA 1997b). This represents the value recommended for use in benefits analyses in EPA's *Guidelines for Preparing Economic Analyses* (USEPA 2000d) and endorsed by the Science Advisory Board (SAB) Arsenic review panel (USEPA 2001d). For purposes of the LT2ESWTR benefits analysis, the VSL Weibull distribution (with parameters of location = 0, scale = 5.32, shape = 1.51) was incorporated into the benefits model Monte Carlo simulation. This enables quantification of the uncertainty surrounding benefits estimates derived from the VSL. The VSL was also updated to a year 2003 price level using a CPI adjustment factor (see Appendix C) and the distribution in 2004 has a mean of $7.5 million, median of $6.5 million, a 5^{th} percentile value of $1.1 million and a 95^{th} percentile value of $17.2 million.

5.3.1.3 Measuring Benefits Over the LT2ESWTR Implementation Schedule

In order to extract benefits data from the model and present these benefits in comparable terms to a similarly calculated stream of costs, it is necessary to calculate the present value of all benefits over the lifetime of the implementation schedule. LT2ESWTR implementation occurs over several years as States and PWSs learn the requirements, inform their staffs, and perform monitoring. A 25-year horizon was chosen for this analysis because systems have several years to begin treatment associated with LT2ESWTR, and many technologies in this analysis have a 20-year life-cycle. Calculations using this time frame allows the analysis to capture all of the period when technologies would be installed and avoids the complications that would be necessary to estimate rehabilitation or replacement costs for installed equipment. This time frame also matches that used in other recent analyses such as the one for the Stage 2 DBPR. A complete schedule of when costs are expected to be incurred and benefits obtained is presented in Appendix O.

5.3.1.4 Adjustment for Income Elasticity

Although the price level (year 2003) is held constant across all benefits projections, values in future years are adjusted to reflect changes in the valuation of avoiding health effects associated with changes in income over time. Estimates of how valuation varies with income growth (i.e, income elasticities) are available from the economic literature, and in those cases income elasticities are combined with estimates of income growth. Benefits based on potentially fatal health effects, which are based on willingness to pay estimates that vary with income, are adjusted using estimates of income elasticity and income growth. This section describes how this adjustment is carried out.

In the case of avoided-death benefits, income elasticity adjustments are applied to values in future years. In general, income elasticity represents changes in valuation in relation to changes in real income. For example, if, for every 1 percent increase in real income, a particular consumer's willingness to pay for a particular item increases by 1 percent, this would be represented by an income elasticity of 1. For most willingness to pay estimates, income elasticity values are less than 1, reflecting slower growth in willingness to pay than in income.

In order to apply the income elasticity values in the benefits model, they must be combined with projections of real income growth over the time frame for analysis. To accomplish this, population and real gross domestic product (GDP) projections are combined to calculate per-capita real GDP values[18] (see Exhibit C.14). Percent changes in these values over time can then be combined with income elasticity figures to derive a single adjustment factor.[19] Given any two points in time, this factor is calculated as follows:

$$\text{Income elasticity adjustment factor} = (eI_1 - eI_2 - I_2 - I_1) / (eI_2 - eI_1 - I_2 - I_1)$$

where: e = income elasticity
I_1 = real income (per-capita GDP) in the base year
I_2 = real income (per-capita GDP) in the year of analysis

When applying this formula, income elasticity adjustment factors are calculated from the same base year as the values subject to adjustment. In this case, income elasticity factors for fatal cryptosporidiosis cases are calculated from a 1990 base year (I_1 = 1990 in the above formula) because that is the base year used in the study from which VSL estimates are derived.[20]

Kleckner and Neumann (2000) identified published studies from which elasticity values could be derived for potentially fatal health effects. They suggest a triangular distribution with a mode of 0.40, and endpoints at 0.08 and 1.00. In the Monte Carlo simulation that assigns dollar values to benefits, income elasticity values (*e* in the above equation) are drawn from this probability distribution. Based on this formula and inputs, income elasticity factors are computed and applied to avoided-death benefits in future years. At the average income elasticity value (0.49), the income elasticity factors applied range from 1.224 (2009) to 1.445 (2029).

---

[18] Ideally, income elasticity and income growth measurements would be calculated using real per capita personal income growth. However, real per capita GDP is used as a proxy for real per capita personal income growth due to lack of appropriate data projections for real personal income growth. Historical data suggests that GDP and personal income grow at similar rates (i.e., Table B-31 of the 2002 Economic Report of the President shows that both real per capita GDP and real per capita disposable personal income grew at an average annual rate of 2.3 percent between 1959 and 2000).

[19] See Appendix A of Kleckner and Neumann (2000) for additional information on the derivation and application of income elasticity adjustments.

[20] The distribution of VSL values used in this EA is derived based on a meta-analysis of 26 different VSL studies, all representing different year price levels. These price levels were updated to a common 1990 price level as part of the analysis in "The Benefits and Costs of the Clean Air Act, 1970-1990" (USEPA 1997b), from which the distribution used in this EA is taken.

Exhibit 5.24: Mean of Yearly Values for a Statistical Life ($Million)

Year	Mean of 10,000 Values
2009	7.72
2010	7.80
2011	7.87
2012	7.93
2013	8.00
2014	8.06
2015	8.13
2016	8.20
2017	8.27
2018	8.33
2019	8.40
2020	8.47
2021	8.54
2022	8.62
2023	8.69
2024	8.76
2025	8.83
2026	8.91
2027	8.98
2028	9.05
2029	9.13

Source: Derived from Exhibit C.16.

The estimates for the value of a statistical life derive from a distribution of the value of statistical life (discussed in section 5.3.1.2), and adjustments for income elasticity (discussed in this section). In the benefits model, each year from 2009 to 2029 has a vector of 10,000 values for a statistical life, and each value is used exactly once. The complete distributions (200,000 values) are documented in the model, but to illustrate how these distributions are affected by the income elasticity adjustments, the mean of each year's distribution of values is shown above in Exhibit 5.24. The values are shown starting in the year 2009 because that is the first year with benefits. Appendix C has additional discussion of the derivation of these data.

5.3.1.5 Present Value of Future Benefits

To allow comparison of future streams of costs and benefits, it is common practice to adjust both streams to a present value (PV) using a social discount rate. This process takes into account the time preference that society places on expenditures and benefits and allows comparison of cost and benefit streams that vary over a given time period.[21] A present value for any future period can be calculated using the following equation:

$$PV = V(t) / (1 + R)^t$$

Where: t = The number of years from the reference period (year 0 of the benefits stream)
R = Social discount rate
V(t) = The benefits occurring t years from the reference period

The present values presented in this EA are the sum of the PVs for each year.

[21] See EPA's *Guidelines for Preparing Economic Analyses* (USEPA 2000d) for a full discussion of the use of social discount rates in the evaluation of policy decisions.

There is much discussion among economists of the proper social discount rate to use for policy analysis. Therefore, for this EA, PV calculations are made using two social discount rates, 3 and 7 percent, which reflect OMB guidance to Federal agencies on the development of regulatory analyses (OMB, 2003). The 3 percent rate is an estimate of how society discounts future consumption flows to their present value, while the 7 percent rate is an estimate of the average before-tax rate of return to private capital (OMB, 2003)[22]. To present results on an annual basis, the total PV of benefits are annualized using the same social discount rates.

5.3.1.6 Summary of Quantified Benefits of LT2ESWTR

The risk assessment methodology described in this chapter estimates the quantified benefits of reducing endemic cryptosporidiosis as applied to each of the regulatory alternatives considered for LT2ESWTR. These alternatives—which are described in detail in Chapter 3—were evaluated to provide EPA with information on different approaches for implementation of these regulations. Exhibits 5.25 to 5.26 provide summaries of the cumulative monetary benefits estimated for the Preferred Alternative using three occurrence distribution data sets and two COI estimates. Exhibit 5.25 presents benefits categorized by system size, Exhibit 5.26 presents benefits categorized by filtered and unfiltered systems, and lastly, Exhibit 5.27 categorizes by illnesses and deaths avoided. All monetized benefits presented in this chapter represent the value at full implementation, averaged over the 25-year evaluation period in accordance with the schedule benefits are incurred.

[22]See OMB's Circular A-4 (OMB, 2003) for a discussion of the use of social discount rates in the evaluation of policy decisions.

Exhibit 5.25a: Annualized Benefits of Illnesses and Deaths Avoided, Preferred Alternative, Enhanced Cost of Illness[1]
($ Millions/Year, 2003$)

System Size (Population Served)	ICR			ICRSSL			ICRSSM		
	Mean	5th %ile	95th %ile	Mean	5th %ile	95th %ile	Mean	5th %ile	95th %ile
	A	B	C	D	E	F	G	H	I
3% Discount Rate									
Illnesses and Deaths Avoided									
<100	$ 0.42	$ 0.03	$ 1.36	$ 0.07	$ 0.00	$ 0.22	$ 0.16	$ 0.01	$ 0.53
100-499	$ 2.29	$ 0.19	$ 6.96	$ 0.41	$ 0.03	$ 1.34	$ 0.95	$ 0.07	$ 3.09
500-999	$ 2.84	$ 0.26	$ 8.52	$ 0.54	$ 0.04	$ 1.73	$ 1.24	$ 0.10	$ 3.96
1,000-3,299	$ 17.20	$ 1.67	$ 50.48	$ 3.46	$ 0.30	$ 10.94	$ 7.78	$ 0.67	$ 24.35
3,300-9,999	$ 51.59	$ 5.30	$ 149.09	$ 10.83	$ 1.04	$ 33.50	$ 23.84	$ 2.22	$ 73.25
10,000-49,999	$ 121.21	$ 12.72	$ 354.45	$ 25.03	$ 2.59	$ 76.39	$ 54.77	$ 5.36	$ 167.86
50,000-99,999	$ 95.90	$ 10.57	$ 275.92	$ 20.40	$ 2.22	$ 60.83	$ 43.86	$ 4.54	$ 131.99
100,000-999,999	$ 461.94	$ 48.69	$ 1,314.28	$ 103.09	$ 10.78	$ 298.86	$ 213.39	$ 21.43	$ 621.30
≥ 1 Million	$ 1,100.12	$ 140.49	$ 2,856.23	$ 294.17	$ 37.69	$ 761.40	$ 539.90	$ 68.07	$ 1,409.10
Total	$ 1,853.49	$ 223.83	$ 4,940.84	$ 457.99	$ 54.94	$ 1,242.24	$ 885.89	$ 103.31	$ 2,419.77
7% Discount Rate									
Illnesses and Deaths Avoided									
<100	$ 0.32	$ 0.02	$ 1.03	$ 0.05	$ 0.00	$ 0.17	$ 0.12	$ 0.01	$ 0.40
100-499	$ 1.73	$ 0.15	$ 5.27	$ 0.31	$ 0.02	$ 1.02	$ 0.72	$ 0.05	$ 2.34
500-999	$ 2.15	$ 0.19	$ 6.44	$ 0.41	$ 0.03	$ 1.31	$ 0.94	$ 0.07	$ 3.00
1,000-3,299	$ 13.02	$ 1.26	$ 38.25	$ 2.62	$ 0.23	$ 8.28	$ 5.89	$ 0.51	$ 18.44
3,300-9,999	$ 39.05	$ 4.01	$ 112.78	$ 8.20	$ 0.78	$ 25.37	$ 18.05	$ 1.68	$ 55.50
10,000-49,999	$ 95.35	$ 10.01	$ 278.75	$ 19.69	$ 2.03	$ 60.13	$ 43.09	$ 4.22	$ 132.04
50,000-99,999	$ 77.20	$ 8.48	$ 222.32	$ 16.42	$ 1.79	$ 49.09	$ 35.31	$ 3.65	$ 106.41
100,000-999,999	$ 376.11	$ 39.61	$ 1,069.81	$ 83.94	$ 8.76	$ 243.19	$ 173.75	$ 17.44	$ 506.40
≥ 1 Million	$ 896.07	$ 114.51	$ 2,328.34	$ 239.62	$ 30.65	$ 619.74	$ 439.77	$ 55.36	$ 1,149.33
Total	$ 1,501.01	$ 181.38	$ 3,997.81	$ 371.26	$ 44.56	$ 1,005.17	$ 717.64	$ 83.58	$ 1,961.08

Notes:
[1]The traditional COI only includes valuation for medical costs and lost work time (including some portion of unpaid household production). The enhanced COI also factors in valuations for lost personal time (non-work time) such as child care and homemaking (to the extent not covered by the traditional COI), time with family, and recreation, and lost productivity at work on days when workers are ill but go to work anyway.
Sources:
[A] Appendix C, Exhibits C.4a and C.5a, Column M, Row - A3
[B] Appendix C, Exhibits C.4a and C.5a, Column N, Row - A3
[C] Appendix C, Exhibits C.4a and C.5a, Column O, Row - A3
[D] Appendix C, Exhibits C.4c and C.5c, Column M, Row - A3
[E] Appendix C, Exhibits C.4c and C.5c, Column N, Row - A3
[F] Appendix C, Exhibits C.4c and C.5c, Column O, Row - A3
[G] Appendix C, Exhibits C.4b and C.5b, Column M, Row - A3
[H] Appendix C, Exhibits C.4b and C.5b, Column N, Row - A3
[I] Appendix C, Exhibits C.4b and C.5b, Column O, Row - A3

Exhibit 5.25b: Annualized Benefits of Illnesses and Deaths Avoided, Preferred Alternative, Traditional Cost of Illness[1]
($ Millions/Year, 2003$)

System Size (Population Served)	ICR			ICRSSL			ICRSSM		
	Mean	5th %ile	95th %ile	Mean	5th %ile	95th %ile	Mean	5th %ile	95th %ile
	A	B	C	D	E	F	G	H	I
3% Discount Rate									
Illnesses and Deaths Avoided									
<100	$ 0.28	$ 0.02	$ 0.97	$ 0.04	$ 0.00	$ 0.16	$ 0.11	$ 0.01	$ 0.38
100-499	$ 1.55	$ 0.11	$ 5.06	$ 0.28	$ 0.02	$ 0.96	$ 0.65	$ 0.04	$ 2.24
500-999	$ 1.93	$ 0.14	$ 6.16	$ 0.37	$ 0.02	$ 1.26	$ 0.84	$ 0.05	$ 2.87
1,000-3,299	$ 11.75	$ 0.93	$ 36.76	$ 2.38	$ 0.17	$ 8.04	$ 5.33	$ 0.36	$ 17.90
3,300-9,999	$ 35.42	$ 2.93	$ 108.83	$ 7.50	$ 0.58	$ 24.70	$ 16.42	$ 1.22	$ 54.15
10,000-49,999	$ 83.77	$ 7.02	$ 263.43	$ 17.44	$ 1.44	$ 56.46	$ 37.98	$ 2.95	$ 124.22
50,000-99,999	$ 66.74	$ 5.86	$ 205.51	$ 14.34	$ 1.25	$ 45.68	$ 30.65	$ 2.54	$ 98.64
100,000-999,999	$ 325.54	$ 27.71	$ 991.93	$ 73.53	$ 5.99	$ 229.04	$ 151.11	$ 11.90	$ 476.01
≥ 1 Million	$ 814.26	$ 80.48	$ 2,324.94	$ 219.20	$ 21.35	$ 622.33	$ 400.83	$ 37.94	$ 1,150.53
Total	$ 1,341.24	$ 127.85	$ 3,929.17	$ 335.07	$ 31.03	$ 989.12	$ 643.92	$ 57.80	$ 1,919.36
7% Discount Rate									
Illnesses and Deaths Avoided									
<100	$ 0.22	$ 0.01	$ 0.73	$ 0.03	$ 0.00	$ 0.12	$ 0.08	$ 0.00	$ 0.29
100-499	$ 1.17	$ 0.08	$ 3.84	$ 0.21	$ 0.01	$ 0.73	$ 0.49	$ 0.03	$ 1.70
500-999	$ 1.46	$ 0.11	$ 4.68	$ 0.28	$ 0.02	$ 0.96	$ 0.64	$ 0.04	$ 2.18
1,000-3,299	$ 8.91	$ 0.70	$ 27.86	$ 1.80	$ 0.13	$ 6.09	$ 4.04	$ 0.27	$ 13.58
3,300-9,999	$ 26.87	$ 2.22	$ 82.55	$ 5.69	$ 0.44	$ 18.74	$ 12.46	$ 0.92	$ 41.06
10,000-49,999	$ 66.05	$ 5.53	$ 207.48	$ 13.75	$ 1.13	$ 44.43	$ 29.95	$ 2.33	$ 98.09
50,000-99,999	$ 53.87	$ 4.74	$ 166.08	$ 11.57	$ 1.01	$ 36.90	$ 24.74	$ 2.05	$ 79.50
100,000-999,999	$ 265.76	$ 22.59	$ 809.67	$ 60.03	$ 4.89	$ 186.41	$ 123.37	$ 9.71	$ 387.92
≥ 1 Million	$ 664.80	$ 65.75	$ 1,897.94	$ 178.97	$ 17.39	$ 508.00	$ 327.26	$ 30.98	$ 941.56
Total	$ 1,089.13	$ 103.74	$ 3,194.64	$ 272.33	$ 25.28	$ 802.43	$ 523.02	$ 46.98	$ 1,559.02

Notes:
[1]The traditional COI only includes valuation for medical costs and lost work time (including some portion of unpaid household production). The enhanced COI also factors in valuations for lost personal time (non-work time) such as child care and homemaking (to the extent not covered by the traditional COI), time with family, and recreation, and lost productivity at work on days when workers are ill but go to work anyway.
Sources:
[A] Appendix C, Exhibits C.4d and C.5d, Column M, Row - A3
[B] Appendix C, Exhibits C.4d and C.5d, Column N, Row - A3
[C] Appendix C, Exhibits C.4d and C.5d, Column O, Row - A3
[D] Appendix C, Exhibits C.4f and C.5f, Column M, Row - A3
[E] Appendix C, Exhibits C.4f and C.5f, Column N, Row - A3
[F] Appendix C, Exhibits C.4f and C.5f, Column O, Row - A3
[G] Appendix C, Exhibits C.4e and C.5e, Column M, Row - A3
[H] Appendix C, Exhibits C.4e and C.5e, Column N, Row - A3
[I] Appendix C, Exhibits C.4e and C.5e, Column O, Row - A3

Exhibit 5.26a: Annualized Benefits by Filtered and Unfiltered Systems, Preferred Alternative, Enhanced Cost of Illness[1] ($ Millions/Year, 2003$)

System Type (Population Served)	ICR			ICRSSL			ICRSSM		
	Mean	5th %ile	95th %ile	Mean	5th %ile	95th %ile	Mean	5th %ile	95th %ile
	A	B	C	D	E	F	G	H	I
3% Discount Rate									
Illnesses and Deaths Avoided									
Filtered									
<10,000	$ 64.61	$ 5.54	$ 193.67	$ 12.17	$ 0.82	$ 40.78	$ 28.55	$ 1.98	$ 93.39
≥10,000	$ 688.49	$ 58.81	$2,125.35	$ 124.52	$ 9.11	$ 419.07	$ 292.78	$ 21.88	$ 958.66
Total	$ 753.10	$ 64.63	$2,311.72	$ 136.69	$ 9.94	$ 459.51	$ 321.34	$ 23.91	$1,058.10
Unfiltered									
<10,000	$ 9.71	$ 1.62	$ 24.14	$ 3.13	$ 0.52	$ 7.78	$ 5.42	$ 0.90	$ 13.47
≥10,000	$1,090.68	$ 148.85	$2,740.57	$ 318.17	$ 43.43	$ 799.39	$ 559.14	$ 76.33	$1,404.81
Total	$1,100.40	$ 150.53	$2,762.39	$ 321.30	$ 44.01	$ 806.31	$ 564.56	$ 77.32	$1,416.80
7% Discount Rate									
Illnesses and Deaths Avoided									
Filtered									
<10,000	$ 48.91	$ 4.19	$ 146.56	$ 9.21	$ 0.62	$ 30.87	$ 21.62	$ 1.49	$ 70.79
≥10,000	$ 557.03	$ 47.49	$1,719.31	$ 100.73	$ 7.35	$ 339.27	$ 236.85	$ 17.68	$ 776.48
Total	$ 605.94	$ 51.90	$1,861.67	$ 109.94	$ 7.98	$ 370.12	$ 258.47	$ 19.20	$ 850.65
Unfiltered									
<10,000	$ 7.36	$ 1.22	$ 18.29	$ 2.37	$ 0.39	$ 5.89	$ 4.10	$ 0.68	$ 10.20
≥10,000	$ 887.71	$ 120.81	$2,233.24	$ 258.95	$ 35.25	$ 651.57	$ 455.07	$ 61.95	$1,145.05
Total	$ 895.06	$ 122.04	$2,252.00	$ 261.32	$ 35.66	$ 657.52	$ 459.17	$ 62.66	$1,155.35

Notes:
[1]The traditional COI only includes valuation for medical costs and lost work time (including some portion of unpaid household production). The enhanced COI also factors in valuations for lost personal time (non-work time) such as child care and homemaking (to the extent not covered by the traditional COI), time with family, and recreation, and lost productivity at work on days when workers are ill but go to work anyway.
Sources:
[A] Appendix C, Exhibits C.6a, C.7a, C.8a, and C.9a, Column M, Row - A3, ICR.
[B] Appendix C, Exhibits C.6a, C.7a, C.8a and C.9a, Column N, Row - A3, ICR.
[C] Appendix C, Exhibits C.6a, C.7a, C.8a and C.9a, Column O, Row - A3, ICR.
[D] Appendix C, Exhibits C.6a, C.7a, C.8a and C.9a, Column M, Row - A3, ICRSSL.
[E] Appendix C, Exhibits C.6a, C.7a, C.8a and C.9a, Column N, Row - A3, ICRSSL.
[F] Appendix C, Exhibits C.6a, C.7a, C.8a and C.9a, Column O, Row - A3, ICRSSL.
[G] Appendix C, Exhibits C.6a, C.7a, C.8a and C.9a, Column M, Row - A3, ICRSSM.
[H] Appendix C, Exhibits C.6a, C.7a, C.8a and C.9a, Column N, Row - A3, ICRSSM
[I] Appendix C, Exhibits C.6a, C.7a, C.8a and C.9a, Column O, Row - A3, ICRSSL..

Exhibit 5.26b: Annualized Benefits by Filtered and Unfiltered Systems, Preferred Alternative, Traditional Cost of Illness[1] ($ Millions/Year, 2003$)

System Type (Population Served)	ICR			ICRSSL			ICRSSM		
	Mean	5th %ile	95th %ile	Mean	5th %ile	95th %ile	Mean	5th %ile	95th %ile
	A	B	C	D	E	F	G	H	I
3% Discount Rate									
Illnesses and Deaths Avoided									
Filtered									
<10,000	$ 43.62	$ 3.06	$ 140.20	$ 8.20	$ 0.44	$ 29.34	$ 19.27	$ 1.06	$ 67.41
≥10,000	$ 466.86	$ 32.01	$1,543.95	$ 84.30	$ 4.86	$ 297.62	$ 198.43	$ 11.45	$ 691.84
Total	$ 510.48	$ 35.28	$1,682.87	$ 92.50	$ 5.35	$ 328.11	$ 217.70	$ 12.56	$ 758.56
Unfiltered									
<10,000	$ 7.31	$ 0.93	$ 20.11	$ 2.35	$ 0.30	$ 6.48	$ 4.08	$ 0.52	$ 11.22
≥10,000	$ 823.45	$ 85.97	$2,297.23	$ 240.21	$ 25.08	$ 670.14	$ 422.14	$ 44.08	$1,177.69
Total	$ 830.76	$ 86.81	$2,319.33	$ 242.57	$ 25.35	$ 677.24	$ 426.22	$ 44.53	$1,190.00
7% Discount Rate									
Illnesses and Deaths Avoided									
Filtered									
<10,000	$ 33.09	$ 2.33	$ 106.30	$ 6.22	$ 0.33	$ 22.23	$ 14.62	$ 0.80	$ 51.18
≥10,000	$ 378.78	$ 25.89	$1,251.74	$ 68.38	$ 3.95	$ 241.48	$ 160.97	$ 9.29	$ 561.54
Total	$ 411.87	$ 28.45	$1,359.24	$ 74.61	$ 4.31	$ 264.21	$ 175.59	$ 10.14	$ 611.53
Unfiltered									
<10,000	$ 5.55	$ 0.70	$ 15.24	$ 1.79	$ 0.23	$ 4.91	$ 3.09	$ 0.39	$ 8.50
≥10,000	$ 671.71	$ 70.03	$1,872.71	$ 195.94	$ 20.43	$ 546.34	$ 344.34	$ 35.90	$ 960.13
Total	$ 677.25	$ 70.63	$1,889.78	$ 197.73	$ 20.62	$ 551.92	$ 347.43	$ 36.24	$ 969.79

Notes:
[1]The traditional COI only includes valuation for medical costs and lost work time (including some portion of unpaid household production). The enhanced COI also factors in valuations for lost personal time (non-work time) such as child care and homemaking (to the extent not covered by the traditional COI), time with family, and recreation, and lost productivity at work on days when workers are ill but go to work anyway.
[A] Appendix C, Exhibits C.6b C.7b C.8b and C.9b Column M, Row - A3, ICR.
[B] Appendix C, Exhibits C.6b C.7b C.8a and C.9b Column N, Row - A3, ICR.
[C] Appendix C, Exhibits C.6b C.7b C.8a and C.9b Column O, Row - A3, ICR.
[D] Appendix C, Exhibits C.6b C.7b C.8a and C.9b Column M, Row - A3, ICRSSL.
[E] Appendix C, Exhibits C.6b C.7b C.8a and C.9b Column N, Row - A3, ICRSSL.
[F] Appendix C, Exhibits C.6b C.7b C.8a and C.9b Column O, Row - A3, ICRSSL.
[G] Appendix C, Exhibits C.6b C.7b C.8a and C.9b Column M, Row - A3, ICRSSM.
[H] Appendix C, Exhibits C.6b C.7b C.8a and C.9b Column N, Row - A3, ICRSSM
[I] Appendix C, Exhibits C.6b C.7b C.8a and C.9b Column O, Row - A3, ICRSSL..

Exhibit 5.27a: Annualized Benefits by Illnesses and Deaths Avoided, Preferred Alternative, Enhanced Cost of Illness[1] ($ Millions/Year, 2003$)

Benefit Type	ICR			ICRSSL			ICRSSM		
	Mean	5th %ile	95th %ile	Mean	5th %ile	95th %ile	Mean	5th %ile	95th %ile
	A	B	C	D	E	F	G	H	I
3% Discount Rate									
Illnesses Avoided	$ 729	$ 113	$ 1,718	$ 175	$ 29	$ 395	$ 345	$ 55	$ 838
Deaths Avoided	$ 1,124	$ 71	$ 3,511	$ 283	$ 18	$ 881	$ 541	$ 33	$ 1,716
7% Discount Rate									
Illnesses Avoided	$ 587	$ 91	$ 1,382	$ 141	$ 24	$ 318	$ 278	$ 44	$ 675
Deaths Avoided	$ 914	$ 57	$ 2,856	$ 230	$ 15	$ 716	$ 440	$ 27	$ 1,391

Exhibit 5.27b: Annualized Benefits by Illnesses and Deaths Avoided, Preferred Alternative, Traditional Cost of Illness[1] ($ Millions/Year, 2003$)

Benefit Type	ICR			ICRSSL			ICRSSM		
	Mean	5th %ile	95th %ile	Mean	5th %ile	95th %ile	Mean	5th %ile	95th %ile
	A	B	C	D	E	F	G	H	I
3% Discount Rate									
Illnesses Avoided	$ 217	$ 34	$ 511	$ 52	$ 9	$ 117	$ 103	$ 16	$ 250
Deaths Avoided	$ 1,124	$ 71	$ 3,511	$ 283	$ 18	$ 881	$ 541	$ 33	$ 1,716
7% Discount Rate									
Illnesses Avoided	$ 176	$ 27	$ 413	$ 42	$ 7	$ 95	$ 83	$ 13	$ 202
Deaths Avoided	$ 914	$ 57	$ 2,856	$ 230	$ 15	$ 716	$ 440	$ 27	$ 1,391

Notes:
[1]The traditional COI only includes valuation for medical costs and lost work time (including some portion of unpaid household production). The enhanced COI also factors in valuations for lost personal time (non-work time) such as child care and homemaking (to the extent not covered by the traditional COI), time with family, and recreation, and lost productivity at work on days when workers are ill but go to work anyway.

5.3.2 Monetization of Benefits to Sensitive Subpopulations

The infectivity estimates used in this analysis are derived from clinical studies performed on healthy adults and are applied to all populations. No separate monetization of benefits for sensitive subpopulations was therefore performed. The morbidity estimates are based on a large population—those affected by the Milwaukee outbreak—that included a mix of the general population and sensitive subpopulations. By using morbidity factors from that outbreak, the monetization of benefits to sensitive subpopulations is included, but could not be separately itemized. The mortality rates used in this study are derived from data from the Milwaukee outbreak, where 46 of the 54 deaths were persons with AIDS; the other fatalities were elderly and some had other illnesses. For normally healthy adults, cryptosporidiosis is not considered a fatal disease. Therefore, all the mortality benefits estimated for this rule are deaths avoided within sensitive subpopulations. Avoided illnesses and deaths were not separately quantified for children, so monetization of these benefits is not shown separately. Further discussion of the impact of the rule on sensitive populations is in Chapter 7, section 7.9.

5.4 Summary of Uncertainties

Throughout the section 5.2, the uncertainties and variability associated with each parameter of the risk assessment model have been described. Exhibit 5.28 combines these discussions with a flow chart illustrating each parameter and how the estimates are incorporated in the model. In the benefits model, applying a distribution for one variable to a distribution of a second variable widens the range of estimates, but has minimal effect on mean estimates. In the cases where the distributions are not skewed (as is for most of the benefits variables) the mean estimate resulting from the two distributions is similar to the result of calculating using two point estimates. Therefore, to demonstrate a range of possible true values, all results presented in this chapter and other summary chapters show confidence bounds along with the mean estimate.

While the assessment leading to the number of illnesses and deaths avoided incorporates uncertainty and variability at numerous points, the monetization of these benefits also incorporates uncertainty and variability. EPA uses two estimates for the cost of illness (enhanced and traditional) and a distribution for values of a statistical life. EPA also conducted sensitivity analyses of the AIDS mortality rate (see Appendix R). Exhibit 5.29 further assesses the uncertainties by indicating whether uncertainties from either the risk assessment or monetization of benefits likely causes an under or over estimation of benefits. In most cases, the direction of uncertainty is not known.

Exhibit 5.28: Uncertainty and Variability in the Number of Illnesses Avoided

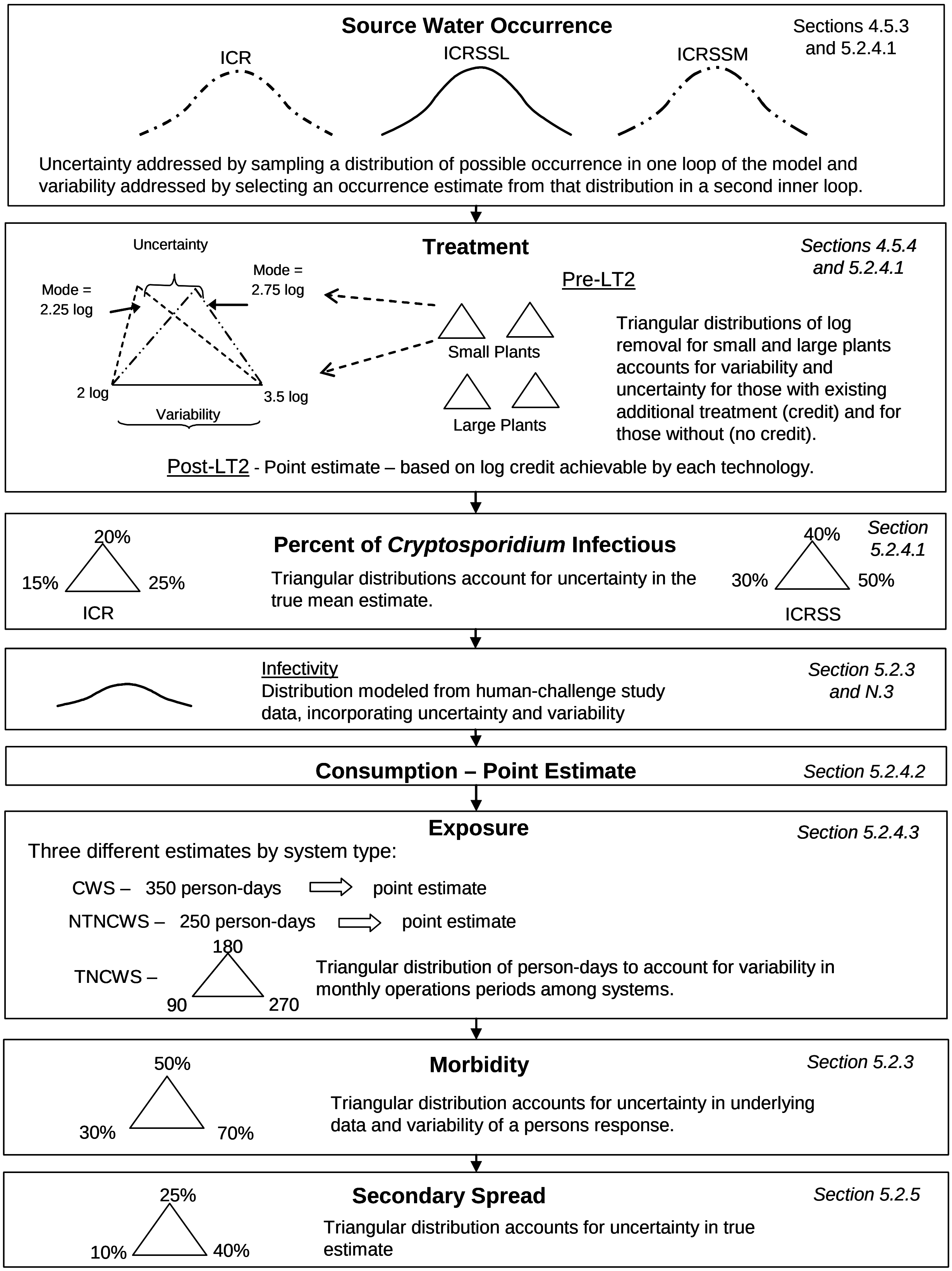


Exhibit 5.29: Summary of Uncertainties Affecting LT2ESWTR Benefits Estimates

Uncertainty	Section with Discussion of Uncertainty	Effect on Benefits Estimates		
		Underestimate	Overestimate	Under or Over Estimate
Quantifying only cases of endemic illness of cryptosporidiosis	5.2.3	X		
Infectivity for *C. parvum* estimated from only three isolates at higher dose levels	5.2.3, Appendix N			X
Morbidity based on triangular distribution	5.2.3			X
Mortality based primarily on deaths of patients with AIDS	5.2.3, Appendix R			X
Source water concentrations estimated using three data sets, calculation of central tendencies and bounds	5.2.4.1			X
Proportion of measured oocysts that were infectious, represented by triangular distribution	5.2.4.1			X
Binning assignments	4.5.6, Appendix B			X
Estimate of plant implementation of enhanced filtration	5.2.4.1			X
Pre-LT2 removal/Inactivation using triangular distributions (with uncertain modes)	5.2.4.1			X
LT2 treatment log reduction achieved	5.2.4.1			X
Morbidity benefits based on COI data	5.3.1, Appendix	X		
Benefits from other rule provisions EPA was not able to quantify	5.6.5	X		

5.5 Comparison of Regulatory Alternatives

Although the models were run separately for combinations of PWS type and size and different *Cryptosporidium* occurrence data sets, all four regulatory alternatives (and the baseline) were always computed within a given model run. This method effectively "blocked" the variability and uncertainty from other sources so that direct, more precise comparisons could be made among all the regulatory alternatives in a given simulation.

The five modeled regulatory conditions are (see Chapter 3 for descriptions of these):

- Pre-LT2 Baseline (Regulatory Alternative A0)
- Regulatory Alternative A1
- Regulatory Alternative A2
- Regulatory Alternative A3 (the Preferred Regulatory Alternative)
- Regulatory Alternative A4

Exhibit 5.30 summarizes the quantified benefits for each regulatory alternative. Quantified benefits do not vary substantially among alternatives for two reasons. First, roughly half of the benefits are attributed to the unfiltered systems and the requirements for those systems are the same for each alternative. Second, UV is the least expensive technology for most systems (thus the most selected technology) and provides 3 log treatment regardless of the treatment requirements.

Exhibit 5.30a: Summary of Benefits of Annual Illnesses and Deaths Avoided from LT2ESWTR for Regulatory Alternatives, Enhanced Cost of Illness[1] ($Millions, 2003$)

Data Set	Rule Alternative	Estimated Value of Cases of Illnesses Avoided ($ Millions)			Estimated Value of Deaths Avoided ($ Millions)			Total Value, All Systems
		Serving < 10,000	Serving ≥ 10,000	All Systems	Serving < 10,000	Serving ≥ 10,000	All Systems	
		A	B	C	D	E	F	G
3% Discount Rate								
ICR	A1	$ 35	$ 713	$ 748	$ 4.1	$ 110	$ 1,146	$ 1,895
	A2	$ 34	$ 703	$ 737	$ 4.0	$ 109	$ 1,134	$ 1,871
	A3 - Preferred Alt.	$ 33	$ 696	$ 729	$ 3.9	$ 108	$ 1,124	$ 1,853
	A4	$ 29	$ 655	$ 683	$ 3.5	$ 104	$ 1,070	$ 1,753
ICRSSL	A1	$ 11	$ 210	$ 221	$ 1.3	$ 33	$ 337	$ 558
	A2	$ 9	$ 181	$ 189	$ 1.0	$ 30	$ 300	$ 489
	A3 - Preferred Alt.	$ 7	$ 168	$ 175	$ 0.8	$ 28	$ 283	$ 458
	A4	$ 5	$ 145	$ 150	$ 0.6	$ 26	$ 254	$ 405
ICRSSM	A1	$ 20	$ 369	$ 388	$ 2.0	$ 57	$ 593	$ 981
	A2	$ 17	$ 343	$ 360	$ 1.8	$ 54	$ 559	$ 919
	A3 - Preferred Alt.	$ 15	$ 329	$ 345	$ 1.6	$ 52	$ 541	$ 886
	A4	$ 12	$ 291	$ 303	$ 1.4	$ 48	$ 493	$ 796
7% Discount Rate								
ICR	A1	$ 27	$ 576	$ 603	$ 3.1	$ 89	$ 931	$ 1,534
	A2	$ 26	$ 568	$ 594	$ 3.0	$ 88	$ 921	$ 1,515
	A3 - Preferred Alt.	$ 25	$ 562	$ 587	$ 3.0	$ 87	$ 914	$ 1,501
	A4	$ 22	$ 529	$ 551	$ 2.7	$ 84	$ 870	$ 1,421
ICRSSL	A1	$ 9	$ 170	$ 178	$ 1.0	$ 27	$ 274	$ 452
	A2	$ 7	$ 146	$ 153	$ 0.8	$ 24	$ 244	$ 396
	A3 - Preferred Alt.	$ 5	$ 136	$ 141	$ 0.6	$ 23	$ 230	$ 371
	A4	$ 4	$ 118	$ 121	$ 0.5	$ 21	$ 207	$ 328
ICRSSM	A1	$ 15	$ 298	$ 313	$ 1.5	$ 46	$ 481	$ 794
	A2	$ 13	$ 277	$ 290	$ 1.3	$ 44	$ 455	$ 744
	A3 - Preferred Alt.	$ 11	$ 266	$ 278	$ 1.2	$ 42	$ 440	$ 718
	A4	$ 9	$ 235	$ 244	$ 1.0	$ 39	$ 401	$ 645

Notes:
[1]The traditional COI only includes valuation for medical costs and lost work time (including some portion of unpaid household production). The enhanced COI also factors in valuations for lost personal time (non-work time) such as child care and homemaking (to the extent not covered by the traditional COI), time with family, and recreation, and lost productivity at work on days when workers are ill but go to work anyway.
Sources:
[A] Appendix C, Exhibits C.4a-c and C.5a-c, Column G, Row - Small Systems, A1-A4, ICR, ICRSSL, and ICRSSM.
[B] Appendix C, Exhibits C.4a-c and C.5a-c, Column G, Row - Large Systems, A1-A4, ICR, ICRSSL, and ICRSSM.
[C] Appendix C, Exhibits C.4a-c and C.5a-c, Column G, Row - All Systems, A1-A4, ICR, ICRSSL, and ICRSSM.
[D] Appendix C, Exhibits C.4a-c and C.5a-c, Column J, Row - Small Systems, A1-A4, ICR, ICRSSL, and ICRSSM.
[E] Appendix C, Exhibits C.4a-c and C.5a-c, Column J, Row - Large Systems, A1-A4, ICR, ICRSSL, and ICRSSM.
[F] Appendix C, Exhibits C.4a-c and C.5a-c, Column J, Row - All Systems, A1-A4, ICR, ICRSSL, and ICRSSM.
[G] Appendix C, Exhibits C.4a-c and C.5a-c, Column M, Row - All Systems, A1-A4, ICR, ICRSSL, and ICRSSM.

Exhibit 5.30b: Summary of Benefits of Annual Illnesses and Deaths Avoided from LT2ESWTR for Regulatory Alternatives, Traditional Cost of Illness[1] ($Millions, 2003$)

Data Set	Rule Alternative	Estimated Value of Cases of Illnesses Avoided ($ Millions)			Estimated Value of Deaths Avoided ($ Millions)			Total Value, All Systems
		Serving < 10,000	Serving ≥ 10,000	All Systems	Serving < 10,000	Serving ≥ 10,000	All Systems	
		A	B	C	D	E	F	G
3% Discount Rate								
ICR	A1	$ 10	$ 212	$ 223	$ 1.2	$ 33	$ 1,146	$ 1,369
	A2	$ 10	$ 209	$ 220	$ 1.2	$ 32	$ 1,134	$ 1,353
	A3 - Preferred Alt.	$ 10	$ 207	$ 217	$ 1.2	$ 32	$ 1,124	$ 1,341
	A4	$ 8	$ 195	$ 203	$ 1.0	$ 31	$ 1,070	$ 1,273
ICRSSL	A1	$ 3	$ 63	$ 66	$ 0.4	$ 10	$ 337	$ 403
	A2	$ 3	$ 54	$ 56	$ 0.3	$ 9	$ 300	$ 356
	A3 - Preferred Alt.	$ 2	$ 50	$ 52	$ 0.2	$ 8	$ 283	$ 335
	A4	$ 2	$ 43	$ 45	$ 0.2	$ 8	$ 254	$ 299
ICRSSM	A1	$ 6	$ 110	$ 116	$ 0.6	$ 17	$ 593	$ 708
	A2	$ 5	$ 102	$ 107	$ 0.5	$ 16	$ 559	$ 666
	A3 - Preferred Alt.	$ 4	$ 98	$ 103	$ 0.5	$ 16	$ 541	$ 644
	A4	$ 4	$ 87	$ 90	$ 0.4	$ 14	$ 493	$ 583
7% Discount Rate								
ICR	A1	$ 8	$ 172	$ 180	$ 0.9	$ 27	$ 931	$ 1,112
	A2	$ 8	$ 170	$ 178	$ 0.9	$ 26	$ 921	$ 1,099
	A3 - Preferred Alt.	$ 7	$ 168	$ 176	$ 0.9	$ 26	$ 914	$ 1,089
	A4	$ 6	$ 158	$ 165	$ 0.8	$ 25	$ 870	$ 1,034
ICRSSL	A1	$ 3	$ 51	$ 53	$ 0.3	$ 8	$ 274	$ 327
	A2	$ 2	$ 44	$ 46	$ 0.2	$ 7	$ 244	$ 289
	A3 - Preferred Alt.	$ 2	$ 41	$ 42	$ 0.2	$ 7	$ 230	$ 272
	A4	$ 1	$ 35	$ 36	$ 0.1	$ 6	$ 207	$ 243
ICRSSM	A1	$ 4	$ 89	$ 93	$ 0.4	$ 14	$ 481	$ 575
	A2	$ 4	$ 83	$ 87	$ 0.4	$ 13	$ 455	$ 541
	A3 - Preferred Alt.	$ 3	$ 80	$ 83	$ 0.4	$ 13	$ 440	$ 523
	A4	$ 3	$ 70	$ 73	$ 0.3	$ 12	$ 401	$ 474

Notes:
[1]The traditional COI only includes valuation for medical costs and lost work time (including some portion of unpaid household production). The enhanced COI also factors in valuations for lost personal time (non-work time) such as child care and homemaking (to the extent not covered by the traditional COI), time with family, and recreation, and lost productivity at work on days when workers are ill but go to work anyway.
Sources:
[A] Appendix C, Exhibits C.4d-f and C.5 d-f, Column G, Row - Small Systems, A1-A4, ICR, ICRSSL, and ICRSSM.
[B] Appendix C, Exhibits C.4d-f and C.5 d-f, Column G, Row - Large Systems, A1-A4, ICR, ICRSSL, and ICRSSM.
[C] Appendix C, Exhibits C.4d-f and C.5 d-f, Column G, Row - All Systems, A1-A4, ICR, ICRSSL, and ICRSSM.
[D] Appendix C, Exhibits C.4d-f and C.5 d-f, Column J, Row - Small Systems, A1-A4, ICR, ICRSSL, and ICRSSM.
[E] Appendix C, Exhibits C.4d-f and C.5 d-f, Column J, Row - Large Systems, A1-A4, ICR, ICRSSL, and ICRSSM.
[F] Appendix C, Exhibits C.4d-f and C.5 d-f, Column J, Row - All Systems, A1-A4, ICR, ICRSSL, and ICRSSM.
[G] Appendix C, Exhibits C.4d-f and C.5 d-f, Column M, Row - All Systems, A1-A4, ICR, ICRSSL, and ICRSSM.

5.6 Other Benefits of LT2ESWTR Provisions

Section 5.6 describes qualitative benefits of the LT2ESWTR provisions. Although sufficient information was not available to quantify these benefits of LT2ESWTR implementation, the benefits—in terms of both health and monetary value—are thought to be significant.

5.6.1 Reduction in Outbreak Risk

Besides reducing the endemic risk of cryptosporidiosis, the LT2ESWTR will reduce the likelihood of major outbreaks, such as occurred in Milwaukee. The economic value of reducing the risk of outbreaks could be quite high when the magnitude of potential costs is considered. For example, if the $745 COI per cryptosporidiosis infection estimate is applied to the estimated 2,000 cases attributed to a sewage-contaminated well in Braun Station, Texas (Craun et al. 1998), health damages could reach $1.5 million. Other costs associated with outbreaks include spending by Local, State, and national public health agencies; emergency corrective actions by utilities; and possible legal costs if liability is a factor. Affected water systems and local governments may incur costs through provision of alternative water supplies and issuing customer water use warnings and health alerts. Commercial establishments (e.g., restaurants) and their customers may incur costs due to interrupted and lost service. Local businesses, institutions, and households may incur costs associated with undertaking averting and defensive actions. To the extent that LT2ESWTR reduces the likelihood of waterborne disease outbreaks, avoided response costs are potentially numerous and significant.

During outbreaks, consumers and businesses may use alternative water sources or may adopt behaviors to reduce risk, such as boiling water. If the rule reduces the need for these risk-averting behaviors, an economic benefit will accrue. To give a source of the possible scale, during an outbreak of giardiasis, a disease with gastrointestinal symptoms similar to cryptosporidiosis, expenditures on risk-averting behaviors, such as hauling in safe water, boiling water, and purchasing bottled water, were estimated (in 2000$) between $1.74 to $5.53 per person per day during the Milwaukee outbreak (Harrington et al. 1991). If these figures are applied to a small drinking water system serving 10,000 customers, total expenditures on risk-averting behavior during a *Cryptosporidium* outbreak could range between $17,400 and $55,300 per day (2000$). Determining the reduction in outbreak risk and the resulting benefits from avoiding risk-averting behaviors is not possible given current information, but potential benefits are expected to be substantial.

Five studies were identified that used the averting cost approach to estimate household and other costs attributable to short-term contamination of drinking water supplies (Abdalla 1990; Abdalla et al. 1992; Harrington et al. 1991; Sun et al. 1992; Van Houtven et al. 1997). The most relevant of these for the LT2ESWTR analysis is a study by Harrington et al. (1991), that analyzes the costs associated with drinking water contamination by *Giardia* in Luzerne County, Pennsylvania. The December 1983 outbreak resulted in 366 confirmed giardiasis cases resulting from sewage leaking into the unfiltered source water. The total affected population was 75,000 individuals across Pittston Borough and 17 other municipalities. The Harrington study also developed a theoretical and empirical example of how outbreak costs are incurred, based on the Luzerne County example.

The four steps associated with a waterborne outbreak that may impose costs on society are discovery, survey and testing, reaction, and aftermath. (Harrington et al. 1991). These are described below:

- **Discovery.** Health care providers or State, Local, or hospital laboratory technicians send reports to State authorities notifying them of the need for further investigation when the rate of new cases suddenly increases above the normal rate.

- **Survey and testing.** Epidemiological surveys may be conducted, along with tests of the water supply, once a few cases are confirmed.

- **Reaction.** Local authorities and the water system may issue boil-water advisories or other warnings to reduce exposure once a link is made between the drinking water supply and the disease outbreak. Businesses, as well as households, may be affected by such action, requiring government agencies to begin surveillance and enforcement activities and, in some cases, provide alternative water sources.

- **Aftermath.** Long-term solutions to the problem are discussed, as well as how the costs of the outbreak and prevention of future ones may be shared. These discussions can only take place once the outbreak is contained by actions taken during the previous phase.

In the Luzerne County outbreak, individuals took actions to avoid exposure to the contaminated water and those actions resulted in estimated losses between $20.8 million and $61.8 million (2000$). The predominant cost was due to the need to boil water and the associated time lost. Losses due to averting actions for restaurants, bars, schools and other businesses during the outbreak exceeded $1.0 million. The burden for government agencies was $230,000 and the outbreak cost the water supply utility $1.8 million. These costs are in year 2000$ and do not include legal fees, adverse effects on businesses (which were not investigated), leisure activities, or net losses due to substituting more expensive beverages for tap water.

5.6.2 Costs to Households to Avert Infection

In addition to averting actions taken with regard to outbreaks, a reduction of everyday risk-averting behaviors can be achieved. Many households may undertake on a daily basis the same averting actions that they take during an outbreak (e.g., buying bottled water, boiling water, installing point-of-use (POU) filtration). To the extent that the LT2ESWTR can be expected to reduce a household's perceptions of the health risks associated with drinking water, regulatory action may reduce the frequency of such averting actions and their costs.

5.6.3 Enhanced Aesthetic Water Quality

Some treatment improvements resulting from the implementation of the rule are likely to improve the aesthetic quality of the drinking water. Consumers, presumably, would be willing to pay to protect the aesthetic quality of drinking water, and therefore, these benefits should result in an economic benefit. However, the benefits from such water quality improvements due to the rule are not quantified for this analysis.

5.6.4 Risk Reduction from Co-occurring and Emerging Pathogens

While the benefits analysis for the LT2ESWTR only includes reductions in illness and mortality attributable to *Cryptosporidium*, the rule is expected to reduce exposure to other pathogens (e.g., *Giardia* or other waterborne bacterial or viral pathogens such as *Cyclospora* and *Microsporidium*). For example, membrane processes that remove *Cryptosporidium* are also shown to achieve equivalent log removal of *Giardia* under worst-case and normal operating conditions, and nanofiltration also shows similar removal of *Giardia* as *Cryptosporidium* (USEPA 2003c). Goodrich and Lykins (1995) evaluated bag filters and concluded that any microbe or object greater than 4.5 microns in size would be subject to 0.5 to 2.0 log removal. Strengthened regulatory requirements will translate into increased removal of additional pathogens and a resulting reduction in risk. This may prove valuable in reducing overall risk because the impact of emerging pathogens, although not well established, could be significant.

5.6.5 Benefits from Reduction in Disinfection Byproducts

Treatment changes resulting from implementation of the rule may lead to decreased or increased disinfection byproducts (DBPs). Systems that install chemical disinfection technologies like ozone may increase certain DBPs but systems that install physical disinfection technologies like membranes or UV and reduce their chemical disinfectant may reduce certain DBPs. A reduction in DBPs could lead to reduction in DBP-related negative health effects.

5.6.6 Benefits from Other Rule Provisions

The benefit estimates discussed in this chapter result from increased treatment requirements that improve the consumers' water quality. However, other provisions of the LT2ESWTR not directly involving changes to treatment practices will also provide benefits to water consumers. Due to data constraints, EPA was not able to quantify these benefits. Instead, a qualitative discussion of these benefits is provided below.

Benefits of Source Water Monitoring

While source water monitoring does not provide any direct monetary benefits, the information gained from turbidity, *Cryptosporidium*, and *E. coli* testing may provide benefits to the water systems and ultimately to their customers. Although some large systems currently monitor their source water for these contaminants, many do not. Most small systems do not monitor source water. Monitoring allows systems to better understand variations in their source water and to adjust their operations accordingly. For example, if a system discovers that pathogen levels are elevated in the spring, they could plan to add more coagulant or bring another sedimentation basin online during that period. Systems that find little or no *Cryptosporidium* will be able to boost consumer confidence in their water, providing benefits through fewer home treatment devices and less time spent in dealing with customer complaints. Systems that detect *Cryptosporidium* can use that information for public education about source water protection and watershed management. These can help bring about changes in watershed protection that will ultimately result in better source water quality. Improved source water quality can produce cost savings for treatment.

Benefits of Covered Finished Water Reservoirs

The quality of water in uncovered finished water reservoirs is subject to similar environmental influences as surface water, including deposition of airborne chemicals, surface water runoff, animal carcasses, animal or bird droppings, and growth of algae and other aquatic organisms. In one study, gulls contaminated a 10 million gallon reservoir and increased bacteriological growth; in another, waterfowl were found to elevate coliform levels in small recreational lakes by 20 times their normal levels (Morra 1979). Algal growth increases the biomass in the reservoir, which reduces dissolved oxygen and thereby increases the release of iron, manganese, and nutrients from the sediments. This, in turn, supports more algal growth (Cooke and Carlson 1989). Algae can cause taste and odor problems. Further, uncovered finished water reservoirs may be subject to contamination by illegal swimming and dumping. Documented water quality problems in open finished water reservoirs include increased algal cells; heterotrophic plate count (HPC) bacteria; turbidity; color; particle counts; biomass; and decreased chlorine residuals (Pluntze 1974; AWWA 1983; Silverman et al. 1983; LeChevallier et al. 1997b).

Finished water is usually not treated or tested again prior to consumption, so any contamination in the uncovered reservoir may be passed directly to the customer. Therefore, requirements to cover all finished water reservoirs or to treat the effluent will reduce the risk of contamination and result in positive health benefits. Covering reservoirs or providing additional treatment of finished water will also provide some additional protection from possible acts of terrorism. Data are not available, however, to quantify the benefits associated with covering all finished water reservoirs.

5.6.7 Summary of Nonquantified Benefits

As explained above, several types of potential benefits were not included in the quantitative analysis. Exhibit 5.31 shows how the rule provisions that have not been quantified would be expected to affect the overall benefits derived from LT2ESWTR.

Exhibit 5.31: Summary of Nonquantified Benefits

Benefit Type	Potential Effect on Benefits	Comments
Reducing outbreak risks and response costs	Increase	Some outbreaks are caused by human or equipment failures that may occur even with the proposed new requirements; however, by adding barriers of protection for some systems, the rule will reduce the possibility of such failures leading to outbreaks.
Reducing averting behavior (e.g., boiling tap water or purchasing bottled water)	Increase / No Change	Consumers in systems that cease using uncovered finished water reservoirs (through covering or taking such reservoirs off-line) my have greater confidence in water quality. This may result in less averting behavior that reduces both out-of-pocket costs (e.g., purchase of bottled water) and opportunity costs (e.g., time to boil water).
Improving aesthetic water quality	Increase	Some technologies installed for this rule (e.g., ozone) are likely to reduce taste and odor problems.
Reducing risk from co-occurring and emerging pathogens	Increase	Although focused on removal of *Cryptosporidium* from drinking water, systems that change treatment processes will also increase removal of pathogens that the rule does not specifically regulate. Additional benefits will accrue.
Increased source water monitoring	Increase	The greater understanding of source water quality that results from monitoring may enhance the ability of plants to optimize treatment operations in ways other than those addressed in this rule.
Increased or decreased DBPs	Increase or Decrease	Systems that install chemical disinfection technologies like ozone may increase certain DBPs. Systems that install physical disinfection technologies like membranes or UV and reduce chemical disinfectant usage may reduce certain DBPs.

Benefit Type	Potential Effect on Benefits	Comments
Covering all finished water reservoirs	Increase	Although insufficient data were available to quantify benefits, the reduction of contaminants introduced through uncovered finished water reservoirs would produce positive public health benefits.

6. Cost Analysis

6.1 Introduction

This chapter presents estimates of the total national costs for the four LT2ESWTR regulatory alternatives. Total national costs include the costs of rule implementation, monitoring for bin classification, additional treatment, and future monitoring. These costs are summarized first, and then individual methodologies and cost details are provided. This chapter also summarizes per-household costs for all systems covered by the rule.

The estimated costs of this rule, as presented in this chapter, are highly dependent on the estimated occurrence of *Cryptosporidium* in source water. As discussed in Chapter 4, EPA uses three different occurrence data sets, the ICR, ICRSSL, and ICRSSM. Each has uncertainties surrounding its applicability to nationwide occurrence. As there is no data set that is clearly superior, separate cost analyses were conducted using each of them. To further reflect the uncertainty and variability of the occurrence data, this chapter calculates cost estimates corresponding to the 90 percent confidence bounds of each data set. Section 6.11 provides a full discussion on the uncertainty and variability associated with the cost estimates.

Section 6.1.1 describes the assumptions used to estimate national costs of the LT2ESWTR. The remaining sections detailed below present the estimated costs of the LT2ESWTR.

- 6.2 Rule Implementation Costs
  - 6.2.1 PWSs
  - 6.2.2 States and Other Primacy Agencies
- 6.3 Source Water Monitoring for Initial Bin Classification Costs
  - 6.3.1 PWSs
  - 6.3.2 State and Other Primacy Agency Costs
- 6.4 Treatment Costs
  - 6.4.1 Toolbox Options and Unit Costs
  - 6.4.2 Compliance Forecast and Technology Selection
  - 6.4.3 Capital and Annual Costs
- 6.5 Costs of Treatment for Unfiltered Plants
- 6.6 Costs for Benchmarking and Technology Reporting Requirements
- 6.7 Costs of Treatment for Uncovered Finished Water Reservoirs
  - 6.7.1 Unit Costs
  - 6.7.2 Compliance Forecast and Technology Selection
  - 6.7.3 Total Annual Treatment Costs
- 6.8 Future Source Water Monitoring
- 6.9 Summary of the National Costs of the LT2ESWTR
- 6.10 Household Costs
- 6.11 Summary of Uncertainties and Sensitivity Analyses
  - 6.11.1 *Cryptosporidium* Occurrence Data Sets
  - 6.11.2 Sensitivity Analysis of Influent Bromide Levels on Technology Selection for Filtered Plants
- 6.12 Unquantifiable Costs
- 6.13 Comparison of Regulatory Alternatives

Appendix D offers a comprehensive explanation of the laboratory and labor costs for rule implementation, *E. coli* and *Cryptosporidium* monitoring for initial bin classification, and future monitoring. Appendices E, F, and G support the cost estimates for filtered and unfiltered systems (unit costs, methodology for technology selection, and summary of technology selection, respectively). Appendix I presents unit costs for uncovered finished water reservoirs, and Appendix J summarizes the per-household cost estimation methodology. Appendix Q describes all cost model programs and files.

6.1.1 Cost Description and Assumptions

To estimate the total national costs of the rule, EPA estimated costs to be incurred by public water systems (PWSs) and by States or other Primacy Agencies. For PWSs, these include the costs of installing treatment, the costs to administer the program and understand the rule, and monitoring costs. State and Primacy Agency costs include estimates of the labor burdens that these agencies will face, such as training employees on the requirements of the LT2ESWTR, reviewing PWS reports, responding to inquiries, and record keeping.

EPA estimated costs for these activities using cost models, equipment price lists and quotes, wage rates from the Bureau of Labor Statistics, stakeholder inputs, and assumptions used in economic analyses performed for earlier drinking water rules. This section discusses the assumptions on discount rates, wage rates, laboratory fees, and uncertainty parameters. More details on cost assumptions and results are in Appendices D through J. EPA expresses costs as annualized values amortized over 25 years, based on the present value of the stream of costs that occur over time. All cost estimates are expressed in year 2003 dollars.

Systems Subject to Rule Provisions and Activities

The LT2ESWTR applies to all surface water systems and to systems that use ground water under the direct influence of surface water (GWUDI). These are classified as community water systems (CWSs), nontransient noncommunity water systems (NTNCWSs), or transient noncommunity water systems (TNCWSs), as described in Chapter 4. Unfiltered and filtered systems are subject to different rule provisions, as are systems with uncovered finished water reservoirs. It is estimated that all unfiltered systems will add treatment to meet the rule's requirements, and all systems with uncovered finished water reservoirs will cover their reservoirs or treat the discharge to inactivate viruses. See Chapter 4, sections 4.4 and 4.6 for baseline numbers of unfiltered systems and uncovered finished water reservoirs subject to the rule.

Exhibit 6.1 shows the estimated number of systems and plants that are subject to rule implementation, source water monitoring, treatment, and benchmarking costs. All nonpurchased systems will incur rule implementation costs. Plants achieving 5.5 log treatment of *Cryptosporidium* will incur neither treatment costs nor, possibly, source water monitoring costs, depending on when they meet the 5.5 log treatment with respect to LT2ESWTR promulgation.

EPA assumes no unfiltered plant currently achieves 2 log inactivation of *Cryptosporidium* as required by the LT2ESWTR; therefore, all unfiltered plants will incur costs for adding treatment. Filtered plants with source water monitoring results of 0.075 oocysts/L or greater will be required to provide additional treatment for *Cryptosporidium*. All systems with uncovered finished reservoirs must cover their reservoir or treat the effluent. Purchased systems do not have direct treatment costs and, thus, are not included in Exhibit 6.1 (unless they have uncovered reservoirs); however EPA recognizes that they will likely incur indirect costs through rate increases by the seller.

Exhibit 6.1: Number of Systems and Plants Expected to Incur Costs, Preferred Alternative

Dataset	Nonpurchased Systems and Plants								Systems with Uncovered Reservoirs
			Source Water Monitoring - Plants						
	System Size (population served)	Systems Incurring Implementation Costs	Initial *E. Coli* Monitoring	Initial *Crypto* Monitoring	Future *E. coli* Monitoring	Future *Crypto* Monitoring	Plants Adding Treatment		
		A	B	C	D	E	F		G
ICR	< 10,000	5,663	5,575	1,978	4,977	1,732	2,205		12
	≥ 10,000	1,493	1,733	1,762	1,184	1,184	677		69
	Total	7,156	7,308	3,741	6,161	2,916	2,882		81
ICRSSL	< 10,000	Same as ICR		1,285	5,237	1,171	1,428		Same as ICR
	≥ 10,000			1,762	1,379	1,379	440		
	Total			3,047	6,615	2,550	1,868		
ICRSSM	< 10,000	Same as ICR		1,555	5,181	1,409	1,729		Same as ICR
	≥ 10,000			1,762	1,306	1,306	531		
	Total			3,317	6,487	2,715	2,260		

Note: Detail may not add to totals due to independent rounding. Plants adding treatment in column F include purchased unlinked plants (see section 4.3.2).
Sources:
[A] Appendix D, Exhibit D.4, column A.
[B] Appendix D, Exhibit D.4, column D.
[C] ICR—Appendix D, Exhibit D.4, column F; ICRSSL—Appendix D, Exhibit D.6, column F; ICRSSM—Appendix D, Exhibit D.5, column F.
[D] ICR—Appendix D, Exhibit D.4, column I; ICRSSL—Appendix D, Exhibit D.6, column I; ICRSSM—Appendix D, Exhibit D.5, column I.
[E] ICR—Appendix D, Exhibit D.4, column J; ICRSSL—Appendix D, Exhibit D.6, column J.
[F] ICR—Appendix G, Exhibits G.37-G.39, column A; ICRSSL—Appendix G, Exhibit G.43-G.45, column A; ICRSSM—Appendix G, Exhibit G.49-G.51, column A. All include Exhibit 4.5, column C.
[G] Exhibit 4.23 and assuming one reservoir per system.

Scheduling and Discounting Assumptions for National Costs

Nominal costs for both non-treatment and treatment activities are of two kinds: (1) one-time costs that occur near the beginning of the rule implementation period, and (2) annual "steady-state" costs that systems and States/Primacy Agencies will incur after systems have made necessary changes to treatment and/or monitoring to comply with the LT2ESWTR. For the purposes of this Economic Analysis (EA), one-time and steady-state costs were projected over a 25-year time period to coincide with the estimated life span of capital equipment (typically estimated as 20 years for most technologies) and an average time lag of up to 5 years for technology installation after rule promulgation. Some portion of costs for the capital costs of technology provide benefits beyond the 25-year time horizon of this analysis. For example, for equipment installed in year 15, half of its useful life (and cost) is properly compared to benefits generated within the 25-year period of analysis, and half of it useful life (and cost) will generate benefits beyond this period. As a result, the proportion of costs that generate benefits after 25 years is deducted from the capital costs before being discounted into present values. The projected schedules for all rule activities are summarized in Appendix O.

As described previously in the Chapter 5 discussion of benefits, it is common practice to adjust benefits and costs to a present value[1] using a social discount rate so that they can be compared to one another. This process takes into account the time preference that society places on expenditures and allows comparison of cost and benefit streams that are variable over a given time period.[2] Similar to calculating the present value of benefits (see section 5.3.1.5), the present value of costs for any future period can be calculated using the following equation:

$$PV = V(t) / (1 + R)^t$$

Where: t = The number of years from the reference period
R = Social discount rate
V(t) = The cost occurring t years from the reference period

The present values presented in this EA are the sum of the PVs for each year.

There is much discussion among economists of the proper social discount rate to use for policy analysis. Therefore, for LT2ESWTR cost analyses, present value calculations are made using two social discount rates thought to best represent current policy evaluation methodologies, 3 and 7 percent. Historically, 3 percent is based on rates of return on relatively risk-free investments, as described in the *Guidelines for Preparing Economic Analyses* (USEPA 2000d). The rate of 7 percent is recommended by the Office of Management and Budget (OMB) as an estimate of "before-tax rate of return to incremental private investment" (USEPA 1996b). For any future cost, the higher the discount rate, the lower the present value. Specifically, a future cost (or stream of costs) evaluated at a 7 percent social discount rate will always result in a *lower* total present value cost than the same future cost evaluated at a 3 percent rate.

To allow evaluation on an annual basis, the total present value costs are annualized using the same social discount rates (3 and 7 percent) over 25 years. Unlike the total present value, the relationship between annualized costs at 3 and 7 percent is dependent on the time frame for annualization, as well as when the costs are incurred (as set forth in the schedule of rule activities, Appendix O, Exhibits O.7-O.9). When applying social discount rates to annualize costs, the higher (7 percent) discount rate will yield lower annualized costs if costs occur early in a period and the present value is annualized over fewer years (e.g., a 25-year stream of costs paid out or annualized over 5 years). Given a long enough time frame, the 7 percent annualized value will eventually be greater than the 3 percent annualized value. Thus, it is possible for the present value costs discounted at 7 percent to be lower than those discounted at 3 percent, and the annualized values to be opposite, with the value annualized at 7 percent to be higher than those annualized at 3 percent.

Labor Rates

For costing purposes, EPA estimates the labor needs and hourly labor rates of systems and States for two labor categories: managerial and technical. EPA recognizes that there may be significant variation in labor rates across all PWSs. However, the best estimates available for use in national estimates of the effect of drinking water rules are from *Labor Costs for National Drinking Water Rules*

---

[1] For purposes of analyses in this EA, all present value figures are presented at a year 2003 price level. Present value calculations are performed to the expected year of rule implementation (2005).

[2] See EPA's *Guidelines for Preparing Economic Analyses* (USEPA 2000d) for a full discussion of the use of social discount rates in the evaluation of policy decisions.

(USEPA, 2003b), which are used in this EA. The technical and managerial wage rates vary with system size and include fringe benefits. The technical and managerial wage rates (2003$) are shown in Exhibit 6.2.

Exhibit 6.2: Wage Rates by System Size

	System Size (Population Served)					
Loaded Wage Rate ($2003)	<100	100-499	500-3,299	3,300-9,999	10,000-99,999	≥100,000
Technical labor rate	$ 21.44	$ 23.09	$ 24.74	$ 25.34	$ 26.05	$ 31.26
Managerial labor rate	$ 44.36	$ 47.78	$ 51.20	$ 51.20	$ 51.20	$ 51.20
Labor Cost (per hour)	$ 21.44	$ 23.09	$ 24.74	$ 30.51	$ 31.08	$ 35.25

Notes: EPA estimates that systems with population greater than 3,300 use a combination of operators (technical) and engineers (managerial), with an 80/20 ratio between the two, respectively.

Source: Labor Costs for National Drinking Water Rules (USEPA 2003b).

To represent the composition of staff at PWSs of smaller sizes (e.g., systems serving fewer than 3,300 people), EPA uses only the technical rate. For systems serving 3,300 or more people, EPA uses a ratio of 80 percent technical labor to 20 percent managerial labor to arrive at a weighted labor rate of $30.51 for systems serving 3,301-10,000 people, $31.08 for systems serving 10,001-100,000 people, and $35.25 for systems serving greater than 100,000 people.

Labor costs attributable to States for administrative tasks are estimated using an average annual full time equivalent (FTE) labor cost, including overhead and fringe benefits, of $65,255 (2001$). This rate was established based on data from the 2001 State Drinking Water Needs Analysis (ASDWA 2001). For use in the LT2ESWTR EA analyses, the $65,255 annual rate was updated to a year 2003 level ($70,132) and converted to an hourly basis (1 FTE = 2,080 hours) to establish a State rate of $33.60 per hour.

Laboratory Fees

A laboratory fee, expressed as a cost per sample, is associated with *E. coli* and *Cryptosporidium* monitoring and with future monitoring for bin reclassification. Exhibit 6.3 summarizes the range of fees estimated from a survey of laboratories and EPA's experience during the ICR and ICRSSs. Cost calculations for this EA use the average laboratory cost for water sample analyses. Costs are calculated on a per-plant basis to be consistent with costs for treatment. Appendix D provides a more detailed derivation of the laboratory costs.

Some of the factors that could cause the cost per sample to differ from one system to another are regional variations in laboratory fees, the number of samples processed (quantity discounts) and laboratory capacity for *Cryptosporidium* analysis.

Exhibit 6.3: *E. coli* and *Cryptosporidium* Laboratory Costs

Analyte	Laboratory Cost Per Sample			Total Laboratory Cost per Plant
		Range		
	Average	Min	Max	
	A	B	C	D
Cryptosporidium	$ 530	$ 389	$ 713	$13,767
E. coli				
Utility Laboratory	21	12	38	$546
Commercial Laboratory	70	60	85	$1,820

Source: Appendix D, described in sections D.4.1 and D.4.2.
[A] *Cryptosporidium* - Exhibit D.14a, column F; *E. coli* - Exhibit D.12, columns F and I.
[B] and [C] *Cryptosporidium* - DynCorp (2002); *E. coli* - DynCorp (2000).
[D] Column [A] multiplied by the number of samples (26) (biweekly samples for *E. coli*, and 24 regular samples for *Cryptosporidium* plus 2 spiked samples).

6.2 Rule Implementation Costs

This section presents the estimated costs for PWSs and States/Primacy Agencies to perform administrative activities associated with the LT2ESWTR. These cost estimates are the same for all regulatory alternatives.

6.2.1 PWSs

All nonpurchased surface water and GWUDI systems subject to the LT2ESWTR (including filtered and unfiltered systems) will incur one-time costs for implementation activities that include time for staff to read the rule and become familiar with its provisions and for training employees on rule requirements. The technical and managerial labor rates, as presented in section 6.1.1, were used along with estimates of labor hours, to calculate rule implementation costs for all systems. Labor rates used to estimate implementation costs vary by activity and system size. Costs for systems serving up to 3,300 people are based on only the technical rate. For those systems serving at least 3,300 people, costs are based on an assumed 80/20 split between technical and managerial labor rates. Labor hour estimates are based on EPA's experience with previous rules.

6.2.2 States and Other Primacy Agencies

State and other Primacy Agency implementation activities include:

- Adopting the regulation and developing the program
- Training State or other Primacy Agency staff
- Training PWS staff and providing technical assistance
- Updating the data management system

To estimate implementation costs to States/Primacy Agencies, the number of FTEs per activity is multiplied by the number of labor hours per FTE, the cost per labor hour, and the number of States/Primacy Agencies.

EPA estimates the number of FTEs required per activity based on previous experience with other rules. In estimating State/Primacy Agency costs, a labor rate of $33.60 is assumed (see section 6.1.1). The number of States and territories includes the 50 states, six territories (American Samoa, Commonwealth of the Northern Marianas, Guam, Palau, Puerto Rico, and the Virgin Islands), and the Navajo Nation, for a total of 57 entities.

Exhibit 6.4 summarizes the estimated implementation costs for PWSs and States to comply with the LT2ESWTR. Implementation costs are the same for all rule options. In Appendix D, Exhibits D.10 and D.11 provide detailed estimates of hours and calculations for implementation costs by system size (Appendix D costs are undiscounted; discounted costs are shown in Appendix O).

Exhibit 6.4: Estimated Costs of Implementation, Present Value— Discounted at 3 and 7 Percent, Preferred Alternative ($Millions, 2003$)

System / State	3 Percent	7 Percent
< 10,000	$ 1.12	$ 1.04
≥ 10,000	$ 0.39	$ 0.38
System Total	$ 1.51	$ 1.42
State Total	$ 7.66	$ 7.52

Note: Detail may not add to totals due to independent rounding.
Sources:
System costs: Appendix O, Exhibit O.11a and O.14a, Column A.
State costs: Appendix O, Exhibit O.10a and O.13a, Column A.

6.3 Source Water Monitoring for Initial Bin Classification Costs

6.3.1 PWSs

Source water monitoring costs are estimated on a per-plant basis. Purchased plants are assumed not to treat source water and not to have any monitoring costs. There are three types of monitoring that plants may be required to conduct—turbidity, *E. coli*, and *Cryptosporidium*. Source water turbidity is a water quality parameter that most plants measure frequently for operational control. Also, to meet the SWTR, IESWTR, and LT1ESWTR requirements, most water systems have turbidity analysis equipment in house and their operators are experienced in its use. Thus, EPA assumes that the incremental turbidity monitoring burden associated with the LT2ESWTR is negligible.

For large and medium systems, all are required to conduct monthly *E. coli* and *Cryptosporidium* monitoring for 2 years to determine initial bin classification. If systems achieve, or will achieve at the time treatment is required, 5.5 log *Cryptosporidium* removal/inactivation, they are not required to conduct source water monitoring. (See Exhibits 4.5 and 4.11 for the baseline number of unfiltered and filtered plants conducting monitoring, respectively.)

Small systems, except those achieving at least 5.5 log *Cryptosporidium* removal/inactivation, must conduct bi-weekly *E.coli* monitoring for 1 year. Systems exceeding the following levels must monitor semi-monthly for *Cryptosporidium*:

- Annual mean > 10 *E.coli*/100 mL for lakes and reservoirs

- Annual mean > 50 *E.coli*/100 mL for flowing streams

To estimate source water monitoring costs for small systems, this EA assumes that all systems (except those achieving 5.5 log treatment) will conduct *E. coli* monitoring and only those predicted to require additional treatment (from the binning assignment prediction discussed in section 4.5.4) will monitor *Cryptosporidium* in their source water (see Appendix D, Exhibit D.4 for a calculation of plants conducting *E.coli* and *Cryptosporidium* monitoring). EPA will continue to investigate the use of a surrogate for determining source water microbial quality, in order to reduce the cost burden on these systems. If a reliable indicator is identified, EPA will issue guidance for system monitoring. The costs in this chapter may, therefore, be an overestimate of actual costs.

From the modeled *Cryptosporidium* occurrence distributions, EPA estimated the percentage of plants that would fall into treatment bins for each rule option. Exhibit 6.5 presents the annualized monitoring costs based on the modeled *Cryptosporidium* occurrence distributions. Appendix D provides an explanation of how these costs are developed.

6.3.2 State and Other Primacy Agency Costs

Because EPA will directly manage the data collection for initial source water monitoring of large and medium systems, States/Primacy Agencies are predicted not to incur any costs for these activities. They will, however, incur costs from the small system initial monitoring requirement. The delayed start of small system monitoring will allow some States to assume primacy for that effort. To estimate State/Primacy Agency costs, the number of FTEs required per activity is multiplied by the number of labor hours per FTE, the State/Primacy Agency labor hour cost, and the number of States or Primacy Agencies. Exhibit 6.5 presents the estimated total cost incurred by States/Primacy Agency for initial source water monitoring (see Appendix D, Exhibit D.17, for the derivation of costs).

Exhibit 6.5: Cost Estimates for Initial Source Water Monitoring, Present Value—Discounted at 3 and 7 Percent, Preferred Alternative ($Millions, 2003$)

System Size	ICR Mean	ICR 5th %ile	ICR 95th %ile	ICRSSL Mean	ICRSSL 5th %ile	ICRSSL 95th %ile	ICRSSM Mean	ICRSSM 5th %ile	ICRSSM 95th %ile
3 Percent									
< 10,000	$ 33.79	$ 32.11	$ 36.63	$ 25.24	$ 22.02	$ 27.44	$ 28.57	$ 26.36	$ 30.43
≥ 10,000	$ 25.22	$ 25.22	$ 25.22	$ 25.22	$ 25.22	$ 25.22	$ 25.22	$ 25.22	$ 25.22
Total	$ 59.01	$ 57.33	$ 61.86	$ 50.46	$ 47.24	$ 52.66	$ 53.79	$ 51.58	$ 55.66
7 Percent									
< 10,000	$ 29.05	$ 27.64	$ 31.45	$ 21.85	$ 19.13	$ 23.70	$ 24.65	$ 22.79	$ 26.22
≥ 10,000	$ 23.38	$ 23.38	$ 23.38	$ 23.38	$ 23.38	$ 23.38	$ 23.38	$ 23.38	$ 23.38
Total	$ 52.42	$ 51.01	$ 54.82	$ 45.22	$ 42.50	$ 47.07	$ 48.02	$ 46.17	$ 49.60

Notes: Detail may not add to totals due to independent rounding.
Includes laboratory costs, labor costs, and reporting costs.
Sources: All data from Appendix O, and from Alternative A3.
At 3 percent:
Mean: Sum of columns B, C, and D from Exhibits O.11a (ICR), O.11d (ICRSSM), and O.11g (ICRSSL)
5th percentile: Sum of columns B, C, and D from Exhibits O.11b (ICR), O.11e (ICRSSM), and O.11h (ICRSSL)
95th percentile: Sum of columns B, C, and D from Exhibits O.11c (ICR), O.11f (ICRSSM), and O.11i (ICRSSL)
At 7 percent:
Mean: Sum of columns B, C, and D from Exhibits O.14a (ICR), O.14d (ICRSSM), and O.14g (ICRSSL)
5th percentile: Sum of columns B, C, and D from Exhibits O.14b (ICR), O.14e (ICRSSM), and O.14h (ICRSSL)
95th percentile: Sum of columns B, C, and D from Exhibits O.14c (ICR), O.14f (ICRSSM), and O.14i (ICRSSL)

6.4 Treatment Costs

As shown in Chapter 4, filtered plants make up the majority of surface water and GWUDI plants subject to the LT2ESWTR. Costs of treatment associated with these plants make up most of the costs associated with the LT2ESWTR. This section reviews the cost methodology and total costs for the Preferred Regulatory Alternative as follows:

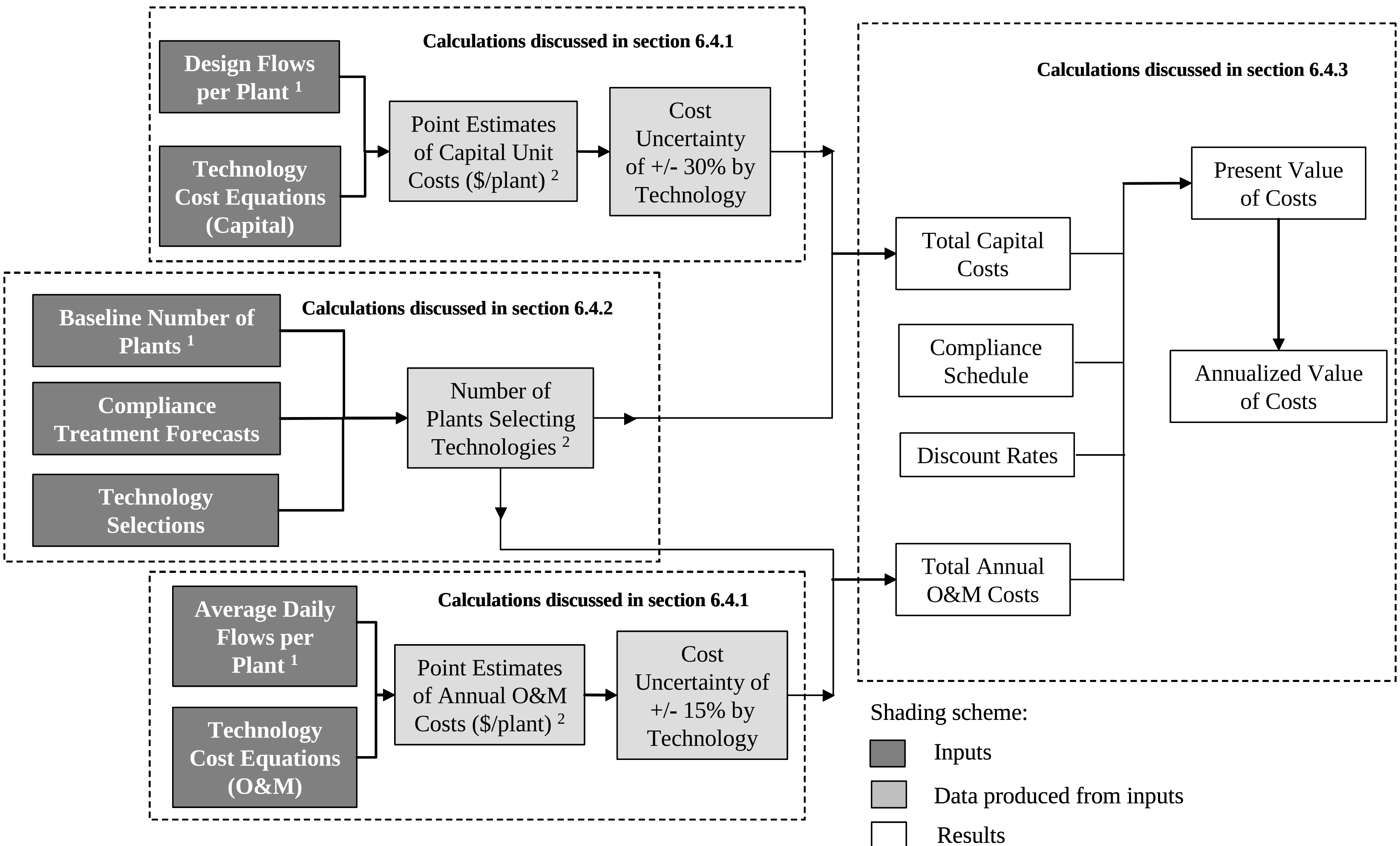
6.4.1 Discusses the technologies and describes how plant unit costs ($/plant) are derived.

6.4.2 Presents the compliance and technology selection forecasts.

6.4.3 Describes how total capital investment and annualized costs are estimated for each size category and rule option.

Treatment costs are calculated by estimating the number of plants that will be adding treatment technologies, then multiplying these estimates by the unit costs ($/plant) of the selected technologies. Although individual information is not available on every plant, assumptions are made about the percentages of plants nationwide that will select each technology. Capital improvement costs are converted to present values and are then annualized using the discount rates presented in section 6.1.1. Exhibit 6.6 provides an overview of the methodology used to generate national treatment costs.

Exhibit 6.6: Methodology for Estimating Treatment Costs



[1] Baseline information is discussed in Chapter 4.
[2] Capital unit costs, annual O&M costs, and number of plants selecting technologies are also used in the derivation of household cost distributions. See section 6.9 and Appendix J for further discussion.

6.4.1 Toolbox Options and Unit Costs

Under the LT2ESWTR, systems will have a "toolbox" of treatment and management options to select from to meet their bin requirements (listed in Exhibit 1.2). This section describes those options that plants will most likely select to meet the LT2ESWTR requirements and the typical conditions under which the selected technologies may be installed. The derivation of per plant capital costs and annual O&M costs for each technology is also discussed. Unit cost data for each technology for CWS plants are presented in Appendix E.

Exhibit 6.7 summarizes the technologies considered for estimating benefits and costs of the LT2ESWTR. Note, some toolbox options are not considered in this analysis and therefore not included in the Exhibit 6.7. The following section briefly describes each of the options not included and provides reasons why they were not considered. Section 6.5.1.2 discusses the technologies that were considered for this EA.

6.4.1.1 Toolbox Options Not Considered in the Cost Analysis

Changing Sources

Plants may avoid adding treatment by connecting to a nearby water system or changing to a source of water that has lower *Cryptosporidium* concentrations. EPA estimates that approximately 22 percent of small systems are located in metropolitan areas where distances between potential connecting water systems may allow interconnection at reasonable costs (USEPA 2000f). Changing the water source may also be possible, although EPA has no information on the number of systems that may have less contaminated sources available to them. Even if EPA could estimate how many systems might choose these options, the costs for both are highly variable. Costs for connecting to another system involve costs for new pipes and facilities, and for those consolidating with another water system, as well as costs associated with merging management capabilities. Costs for changing to another water source would depend on the new source and the system. Costs could include such items as drilling a new well, installation of new piping, and new treatment facilities or adaptation of existing ones to handle different source quality. The costs for both of these options would be highly system-dependent and are difficult to predict. For these reasons, these toolbox options were not considered in these cost estimates.

Intake Changes

Relocating the intake and managing the timing or level of withdrawal are all toolbox options. The purpose of these options is to change the location or timing of withdrawal of water from the source in order to draw from those locations and at those times when *Cryptosporidium* concentrations are lower. These options may cost little compared to adding treatment, especially for systems drawing from reservoirs. The costs would depend on the existing intake structures and the nature of the source. It is unknown how many systems could likely take advantage of such strategies and how much reduction they might achieve. Because of this uncertainty, these options were not considered in this LT2ESWTR analysis.

Chlorine Dioxide

Cryptosporidium can be inactivated by chlorine dioxide; however, the operational and water quality conditions are challenging to meet. The disinfection capability of chlorine dioxide rapidly diminishes as water temperature decreases, as reflected by the high contact time (CT) requirements below 10 degrees Celsius. Chlorine dioxide when added to water forms chlorite, a regulated disinfection byproduct, thus limiting the dose. It also degrades relatively rapidly, which limits the allowable contact time.

EPA used SWAT (see Section 4.2.3) to predict the percent of plants that could achieve 0.5 log removal or treatment while not exceeding the chlorite MCL. The results showed only a few percent could achieve this credit. Therefore, this EA assumes no systems will be able to use chlorine dioxide to comply with *Cryptosporidium* inactivation requirements.

The rule does provide chlorine dioxide and ozone CT requirements for 0.25 log credit; and thus, allowing the combination of the two disinfectants to receive 0.5 log credit (no other toolbox options have presumed credits of 0.25 log or an increment of 0.25 log). Due to the high cost of installing two technologies and the limitations on their use, EPA did not evaluate this option for receiving 0.5 log credit, but recognizes some systems may elect this option.

Performance Studies

Some plants may have filtration processes that achieve a higher level of *Cryptosporidium* removal across their treatment train than assumed by the LT2ESWTR. Plants may conduct performance studies of their treatment process to demonstrate to the State that the required level of *Cryptosporidium* removal or inactivation is being achieved. The number of systems is unknown, but likely very low, that could demonstrate a higher level of treatment on a consistent basis. Also, the cost of such studies could be higher than implementing another toolbox option.

The toolbox options that were omitted from the costs analysis may be less expensive than the technologies considered and, therefore, the costs presented here may be overestimated. Cost uncertainties for this analysis are summarized in section 6.12.

6.4.1.2 Technologies Considered for the LT2ESWTR Cost Analysis

Exhibit 6.7 shows technologies that were included in the cost analysis for the LT2ESWTR. The second column summarizes the condition(s) under which the technology use is constrained in this EA. Plants may be constrained from installing a technology for various reasons. During the Small Surface Water Delphi process, industry experts and the Technical Work Group (TWG) identified limitations in the use of several technologies. A more extensive explanation of these groups and their conclusions can be found in the *Stage 2 DBPR Economic Analysis* (USEPA 2003b).

The third column in Exhibit 6.7 identifies the conditions for which cost estimates are developed. To capture the variation in costs, many technologies are evaluated over a range of possible influent water qualities and operating conditions. For the purposes of estimating the costs of the LT2ESWTR, the TWG selected the water quality and operating parameters to capture the "normal" circumstances under which plants may use the technology. EPA does not assume that all systems would be designed or operated under these conditions, but that the cost equations generate capital and O&M costs that are typical for the range of system types and sizes. While these assumptions simplify the true variety of operating conditions, EPA believes they are adequate to enable reasonable estimates of national costs.

EPA recognizes that similar systems may experience different capital or O&M costs due to site-specific factors. Inputs to unit costs such as water quality conditions, labor rates, and land costs can be highly variable and increase the system-to-system variability in unit costs. In developing the unit cost estimates, there is insufficient information to fully characterize what the distributions of this variability will be on a national scale for all of the treatment technologies and all possible conditions.

Instead, the unit costs are developed as average or representative estimates of what these unit costs will be on a national basis. That is, in developing unit costs, design criteria for the technologies are selected to represent typical, or average, conditions for the universe of systems. As a result, there is uncertainty inherent in these unit cost estimates reflecting the fact that they are based on independent assumptions with supporting data and vendor quotes, where available, rather than on a detailed aggregation of State, regional, or local estimates based on actual field conditions. In this EA, uncertainty in these national average unit costs factors is characterized as follows:

- Capital costs: triangular distribution of +/- 30%
- O&M costs: triangular distribution of +/- 15%

These estimates were developed by EPA and reflect information presented by the National Drinking Water Advisory Council (2001) in its review of the national cost estimation methodology for the Arsenic Rule. EPA believes that the uncertainties in capital and O&M costs for a given technology are independent of one another, and that uncertainties across all technologies are independent.

The final column in Exhibit 6.7 provides the source for the unit costs. The unit costs are derived from equations and other information in the Technology and Cost document (USEPA 2003a), and are revised to incorporate labor rates from *Labor Costs for National Drinking Water Rules* (USEPA, 2003b). Unit costs presented in Appendix E are based on labor rates presented in Exhibit 6.2, and are in 2003$. For some technologies, unit costs were provided by the FACA committee and its TWG in June 2000 as part of the Stage 2 M-DBP negotiation process or are estimated from earlier EPA rules.

In most cases, technology unit costs are specified for single average daily and design flows for nine system size categories. In reality, there will be a range of unit costs for a category, relative to the range of flows. EPA believes, however, that using a mean unit cost ($/plant) in each category, derived from mean flow data, provides an accurate representation of total national costs. For technologies that are a combination of two or more unit processes (e.g., cartridge filters with ozone), the technology unit costs are simply assumed to be the sum of the costs for each unit process. This may result in the overestimation of "combined" technology options since some economies of scale are expected when such combined technologies are implemented.

Exhibit 6.7: Toolbox Options Considered for the LT2ESWTR

Technology	Constraints[1]	Water Quality and Operational Parameters	Source of Unit Cost[2] in T&C Document
Bag Filtration	Not practical for systems serving more than 10,000 people	Bag replacement four times per year	Figures D-19 and D-20
Cartridge Filtration	Not practical for systems serving more than 10,000 people	Cartridge replacement twice per year	Figures D-21 and D-22
Combined Filter Performance	None	None	Figures D-30 and D-31
Bank Filtration	Not practical for systems serving fewer than 10,000 people	None	Figure D-23
Microfiltration/ Ultrafiltration (MF/UF)	None	0.3 NTU, 10°C, disposal of reject stream to sewer	Figures D-17 and D-18
Ozone (O_3)	Not practical for systems serving 500 people or fewer	Concentration for 0.5, 1.0, and 2.0 log of *Cryptosporidium* inactivation determined by SWAT analyses.	Figure D-11 through Figure D-16
Secondary Filter (SF)	Not practical for systems serving 500 people or fewer	None	Figures D-24 and D-25
UV [3]	None	Median water quality parameters: UV_{254} = 0.051cm^{-1}, turbidity = 0.1 NTU, alkalinity = 60 mg/L as $CaCO_3$, hardness = 100 mg/L as $CaCO_3$	Figures D-7 and D-8
Watershed Control (WC)	Not practical for systems serving 10,000 people or fewer	None	Figures D-28 and D-29

[1]Constraints identified by the TWG and the Small Surface Water Delphi Group (USEPA 2003a).
[2]Unit costs ($/plant) for CWSs provided in Appendix E for each technology shown.
[3]Patent fee of $0.015/1,000 gallons included in household costs, see section 6.10 for rationale.

6.4.2 Compliance Forecast and Technology Selection

Three key inputs are required to estimate the technologies plants will add to comply with LT2ESWTR:

1. The percent of plants that must make a treatment change to meet the LT2ESWTR requirements.

2. The treatment technologies these plants have in place prior to implementation of the rule.

3. The treatment technologies these plants are predicted to select to comply with the rule.

These inputs, coupled with baseline data presented in Chapter 4, provide an estimate of the number of filtered plants that will use each technology to meet the requirements of the LT2ESWTR. Input 1 above is largely a result of classifying systems into treatment "bins" based on initial source-water *Cryptosporidium* monitoring (see section 3.3.1). The *Cryptosporidium* occurrence distributions derived from the ICR, ICRSSL, and ICRSSM (see section 4.2) are used to determine the bin assignments for all sizes of systems, yielding three sets of bin assignments for each rule alternative.

The second input accounts for plants that already have some of the toolbox technologies in place and will be able to obtain credit for *Cryptosporidium* treatment without any additional costs or obtain a portion of their required treatment credit. Therefore, the existing technologies cannot be considered as a possible technology selection for these plants. To accommodate the two treatment baseline scenarios, two separate technology selection forecasts are used for plants that already have toolbox technologies in place and those that do not. These two forecasts follow the same methodology as described below, with the former omitting the existing technologies from the selection process.

The overall methodology used to develop the technology selection forecast in the third input is based on the “least-cost principle.” EPA assumes that the cost of the rule is best estimated by assuming that drinking water plants will select the least expensive technology or combination of technologies available to meet the treatment requirements of a given action bin. EPA recognizes not all plants may not be able to implement certain technologies because of site-specific conditions. Therefore, the technology selections are limited by maximum use percentages. Appendix F details the methodology for technology selection forecast, including assumptions for estimating maximum use percentages.

Exhibit 6.8 shows the selections for the Preferred Alternative, derived from the mean ICR, ICRSSL, and ICRSSM occurrence distributions. Appendix G provides results for all regulatory alternatives and sensitivity analyses. In many cases, the least costly technology results in higher levels of *Cryptosporidium* inactivation or removal than required for that bin (this is always the case when UV is selected). Although direct filtration plants have 0.5 log higher bin requirements than conventional and other filtration plants, no additional treatment is estimated for them. The 0.5 log higher requirement for those plants is adequately addressed by the higher levels of *Cryptosporidium* treatment achieved by the selected technologies.

Exhibit 6.8: Technology Selection Forecast for Filtered Plants

Technology Selections[1]	Data Set[2]			Technology Selections[1]	Data Set[2]		
	ICR	ICRSSL	ICRSSM		ICR	ICRSSL	ICRSSM
Bag Filter 1.0 Log	1,523	1,219	1,421	Ozone 0.5 Log	27	21	25
Cartridge Filter 2.0 Log	209	20	58	Ozone 1.0 Log	18	14	16
Combined Filter Performance 0.5 Log	16	12	14	Ozone 2.0 Log	10	3	4
In-bank Filtration 1.0 Log	6	5	6	Secondary Filter 1.0 Log	0	0	0
MF/UF 2.5 Log	37	13	18	UV 2.5 Log	979	503	641
				WS Control 0.5 Log	0	0	0

Notes:
[1]Selection includes non-purchased plants in CWSs, NTNCWSs, and TNCWSs adding treatment; and purchased plants that could not be linked with their sellers. Some plants select more than one technology to meet the bin requirements.
[2]Forecasts from the mean occurrence distributions. Forecasts from 95th and 5th percentile distributions presented in Appendix G.
Source: Appendix G; ICR data from Exhibits G.37-39; ICRSSL data from Exhibits G.43-45; ICRSSM data from Exhibits G.49-51.

6.4.3 Capital and Annual Costs

To estimate the treatment costs for filtered plants, the technology unit costs (capital and O&M) are multiplied by the number of plants within each size category predicted to install each technology. The O&M costs are costs that systems incur yearly to maintain system performance. The capital costs are adjusted to account for the life-span of the capital equipment, assumed to be 20 years. The methodology for projecting and discounting costs is as follows:

- Project all undiscounted costs (capital and O&M) over a 25-year time horizon based on the rule implementation schedule in Appendix O.
- Calculate total present value costs using social discount rates of 3 and 7 percent (see section 6.1.1 for a discussion of these rates).
- Annualize the costs over 25 years using the same social discount rates.

Appendix O, Exhibit O.2 shows the schedule of implementation used to determine when systems will install the equipment.

The treatment costs for CWS, NTNCWS, and TNCWS plants are calculated separately since each type has different population-per-system averages, producing different mean flows (see Exhibit 4.4a) and, thus, different mean plant unit costs. These costs are summed across technologies and size categories to estimate the total treatment costs for LT2ESWTR. Exhibit 6.9 shows the mean and 90 percent confidence bound estimates for the Preferred Alternative based on the ICR, ICRSSL, and ICRSSM occurrence distributions.

Exhibit 6.9: Treatment Costs for Filtered Systems, Discounted at 3 and 7 Percent, Preferred Alternative ($Millions, 2003$)

System Size (Population Served)	Capital - Present Value			O & M - Annualized			Total - Annualized		
	Mean	5th %ile	95th %ile	Mean	5th %ile	95th %ile	Mean	5th %ile	95th %ile
	A	B	C	D	E	F	G	H	I
ICR									
3 Percent									
<10K	$ 82.64	$ 64.16	$ 104.23	$ 4.41	$ 3.68	$ 5.25	$ 9.15	$ 7.37	$ 11.24
>10k	$ 930.88	$ 734.43	$ 1,181.51	$ 26.95	$ 22.82	$ 31.80	$ 80.40	$ 65.00	$ 99.65
Total	$ 1,013.52	$ 798.59	$ 1,285.74	$ 31.35	$ 26.51	$ 37.05	$ 89.56	$ 72.37	$ 110.88
7 Percent									
<10K	$ 61.03	$ 47.38	$ 76.97	$ 3.63	$ 3.04	$ 4.33	$ 8.87	$ 7.10	$ 10.94
>10k	$ 756.28	$ 596.62	$ 959.92	$ 23.72	$ 20.09	$ 27.99	$ 88.62	$ 71.28	$ 110.36
Total	$ 817.30	$ 644.00	$ 1,036.90	$ 27.35	$ 23.13	$ 32.32	$ 97.48	$ 78.39	$ 121.29
ICRSSL									
3 Percent									
<10K	$ 42.16	$ 28.04	$ 55.67	$ 2.32	$ 1.67	$ 2.87	$ 4.74	$ 3.28	$ 6.06
>10k	$ 543.39	$ 365.33	$ 712.22	$ 14.09	$ 10.35	$ 17.20	$ 45.30	$ 31.33	$ 58.10
Total	$ 585.56	$ 393.37	$ 767.90	$ 16.41	$ 12.02	$ 20.06	$ 50.04	$ 34.61	$ 64.16
7 Percent									
<10K	$ 31.14	$ 20.70	$ 41.12	$ 1.91	$ 1.38	$ 2.36	$ 4.58	$ 7.10	$ 10.94
>10k	$ 441.34	$ 296.69	$ 578.50	$ 12.39	$ 9.10	$ 15.13	$ 50.27	$ 71.28	$ 110.36
Total	$ 472.48	$ 317.40	$ 619.61	$ 14.30	$ 10.48	$ 17.49	$ 54.85	$ 78.39	$ 121.29
ICRSSM									
3 Percent									
<10K	$ 53.77	$ 39.88	$ 68.22	$ 2.94	$ 2.36	$ 3.50	$ 6.02	$ 4.65	$ 7.41
>10k	$ 674.22	$ 505.63	$ 850.51	$ 17.94	$ 14.62	$ 21.13	$ 56.66	$ 43.66	$ 69.97
Total	$ 727.99	$ 545.51	$ 918.73	$ 20.87	$ 16.98	$ 24.63	$ 62.68	$ 48.31	$ 77.39
7 Percent									
<10K	$ 39.71	$ 29.45	$ 50.38	$ 2.42	$ 1.94	$ 2.88	$ 5.83	$ 7.10	$ 10.94
>10k	$ 547.63	$ 410.66	$ 690.86	$ 15.78	$ 12.86	$ 18.59	$ 62.77	$ 71.28	$ 110.36
Total	$ 587.34	$ 440.11	$ 741.24	$ 18.20	$ 14.81	$ 21.47	$ 68.60	$ 78.39	$ 121.29

Note: Detail may not add to totals due to independent rounding.

Sources: Appendix O.
[A]-[C] Exhibit O.12 (3%) and O.15 (7%); Columns A-C.
[D]-[F] Exhibit O.18 (3%) AND O.21 (7%); Columns D-F.
[G]-[I] Exhibit O.18 (3%) AND O.21 (7%); Sum of columns A and D, B and E, and C and F.

6.5 Costs of Treatment for Unfiltered Plants

As summarized in Chapter 1, the LT2ESWTR requires all unfiltered plants to achieve 2 log *Cryptosporidium* inactivation if their source water concentration is less than or equal to 1 oocyst per 100 liters, and 3 log inactivation if it is greater than 1 oocyst per 100 liters. UV is the least expensive technology that can achieve the required log inactivation of *Cryptosporidium* and, therefore, the most likely to be installed. However, as with filtered systems, EPA estimated that a small percentage of the plants would elect to install a technology more expensive than UV due to the configuration of existing equipment or other factors. Ozone is the next cheapest technology that will meet the inactivation requirements, and therefore is projected to be used by plants that cannot use UV. Due to the high concentrations of ozone necessary to inactivate *Cryptosporidium*, EPA estimated that ozone can achieve only 2.0 log inactivation and all systems that are required to obtain 3.0 log inactivation are assumed to use UV. Although the toolbox lists UV as achieving 2.5 log *Cryptosporidium* inactivation, studies have shown that it can achieve much greater inactivation at the standard drinking water dose of 40 mJ/cm^2 (Clancy et al. 2000; Craik et al. 2001). MF/UF was considered as a substitute for UV in this analysis, but is much more expensive than these technologies, especially for larger systems.

Unit costs for UV and ozone and the conditions under which they can be used are the same as for the filtered plants[3] (section 6.5). Ozone unit costs are for an ozone concentration that provides 2.0 log of *Cryptosporidium* inactivation.

All unfiltered plants must meet the requirements of the LT2ESWTR; therefore, 100 percent of such plants will add technology. The following assumptions were used in developing the technology selection forecast for plants needing 2.0 log *Cryptosporidium* inactivation:

- 100 percent of very small systems will use UV.

- 90 percent of other plants will be able to install UV (the least expensive of the two technologies).

- 10 percent of other plants will add ozone.

Consistent with assumptions for filtered systems, very small plants were also assumed to be unable to use ozone. This is because of the high level of operator attention and training required to operate and maintain an ozone system. Because of the high costs for alternatives like MF/UF for very small plants, the analysis assumes that all these plants would find a way to use UV. EPA believes this to be a reasonable assumption because small plants have less existing infrastructure that might limit their technology selection. Exhibit 6.10 summarizes the treatment costs at 3 and 7 percent discount rates.

[3]EPA incorporated project costs for New York City's planned UV system due to the extraordinarily large size of their water system in comparison to all other systems, which are adequately represented by the unit costs.

Exhibit 6.10: Treatment Costs for Unfiltered Systems, Discounted at 3 and 7 Percent, Preferred Alternative ($Millions, 2003$)

System Size (Population Served)	Capital - Present Value			O & M - Annualized			Total - Annualized		
	Mean	5th %ile	95th %ile	Mean	5th %ile	95th %ile	Mean	5th %ile	95th %ile
	A	B	C	D	E	F	G	H	I
3 Percent									
<10K	$ 5.69	$ 4.82	$ 6.57	$ 0.28	$ 0.25	$ 0.30	$ 0.60	$ 0.53	$ 0.67
>10k	$ 407.27	$ 325.03	$ 488.60	$ 2.09	$ 1.90	$ 2.27	$ 25.47	$ 20.57	$ 30.33
Total	$ 412.96	$ 329.86	$ 495.16	$ 2.36	$ 2.16	$ 2.56	$ 26.08	$ 21.10	$ 31.00
7 Percent									
<10K	$ 4.20	$ 3.56	$ 4.85	$ 0.23	$ 0.21	$ 0.24	$ 0.59	$ 0.52	$ 0.66
>10k	$ 335.56	$ 267.78	$ 402.58	$ 1.85	$ 1.68	$ 2.01	$ 30.64	$ 24.66	$ 36.55
Total	$ 339.76	$ 271.35	$ 407.43	$ 2.07	$ 1.89	$ 2.25	$ 31.23	$ 25.18	$ 37.21

Note: Detail may not add to totals due to independent rounding.

Sources: Appendix O.
[A]-[C] Exhibit O.12 (3%) and O.15 (7%); Columns G-I.
[D]-[F] Exhibit O.18 (3%) and O.21 (7%); Columns J-L.
[G]-[I] Exhibit O.18 (3%) and O.21 (7%); Sum of columns G and J, H and K, and I and L.

6.6 Costs of Disinfection Profiling and Benchmarking and of Technology Reporting

The disinfection profiling and benchmarking requirement was introduced in the IESWTR and LT1ESWTR. In the LT2ESWTR, it requires any system proposing a change to its disinfection process to complete an evaluation of the existing process and consult with the State/Primacy Agency about how the proposed change will affect disinfection performance. To estimate costs for this provision of the rule, EPA assumes the systems selecting UV and ozone will require time to evaluate data and consult with the State. Appendix D provides further detail on the derivation of costs for systems and for States. Exhibit 6.11 presents the estimated costs for systems to develop a disinfection profile, calculate a benchmark, and consult with the State.

Exhibit 6.11: Disinfection Profiling and Benchmarking Estimated Costs, Present Value–Discounted at 3 and 7 Percent, Preferred Alternative ($Millions, 2003$)

System Size	ICR			ICRSSL			ICRSSM		
	Mean	Confidence Bounds		Mean	Confidence Bounds		Mean	Confidence Bounds	
		5th %ile	95th %ile		5th %ile	95th %ile		5th %ile	95th %ile
3 Percent									
< 10,000	$ 0.06	$ 0.05	$ 0.06	$ 0.03	$ 0.03	$ 0.04	$ 0.04	$ 0.04	$ 0.04
> 10,000	$ 0.07	$ 0.07	$ 0.08	$ 0.05	$ 0.04	$ 0.05	$ 0.06	$ 0.05	$ 0.06
Total	$ 0.13	$ 0.12	$ 0.14	$ 0.08	$ 0.07	$ 0.09	$ 0.09	$ 0.08	$ 0.10
7 Percent									
< 10,000	$ 0.04	$ 0.04	$ 0.05	$ 0.02	$ 0.02	$ 0.03	$ 0.03	$ 0.03	$ 0.03
> 10,000	$ 0.06	$ 0.05	$ 0.06	$ 0.04	$ 0.03	$ 0.04	$ 0.04	$ 0.04	$ 0.05
Total	$ 0.10	$ 0.09	$ 0.11	$ 0.06	$ 0.05	$ 0.07	$ 0.07	$ 0.07	$ 0.08

Note: Detail may not add to totals due to independent rounding.
Sources: Appendix O; Exhibit O.11 (3%) and O.14 (7%); Column H.

Systems required to meet additional *Cryptosporidium* treatment will also have to report compliance monitoring data, depending on the toolbox option implemented. EPA assumes UV, ozone, bank filtration, and microfiltration technologies will impose additional burden for reporting compliance. Exhibit 6.12 presents the estimated costs for systems to conduct the reporting activities. Appendix D, Exhibits D.21–D.23 for systems and Exhibits D.18–D.20 for States/Primacy Agencies, show the derivation of system and States/Primacy Agency costs and total costs for technology compliance reporting.

Exhibit 6.12: Technology Reporting Estimated Costs, Annualized at 3 and 7 Percent, Preferred Alternative ($Millions, 2003$)

System Size	ICR Mean	ICR Confidence Bounds 5th %ile	ICR Confidence Bounds 95th %ile	ICRSSL Mean	ICRSSL Confidence Bounds 5th %ile	ICRSSL Confidence Bounds 95th %ile	ICRSSM Mean	ICRSSM Confidence Bounds 5th %ile	ICRSSM Confidence Bounds 95th %ile
3 Percent									
< 10,000	$ 0.36	$ 0.32	$ 0.39	$ 0.21	$ 0.19	$ 0.22	$ 0.24	$ 0.22	$ 0.26
≥ 10,000	$ 0.48	$ 0.44	$ 0.53	$ 0.31	$ 0.25	$ 0.35	$ 0.37	$ 0.33	$ 0.41
Total	$ 0.83	$ 0.76	$ 0.92	$ 0.52	$ 0.44	$ 0.57	$ 0.61	$ 0.55	$ 0.66
7 Percent									
< 10,000	$ 0.30	$ 0.26	$ 0.32	$ 0.17	$ 0.15	$ 0.18	$ 0.20	$ 0.18	$ 0.21
≥ 10,000	$ 0.41	$ 0.38	$ 0.45	$ 0.27	$ 0.22	$ 0.30	$ 0.32	$ 0.29	$ 0.35
Total	$ 0.71	$ 0.64	$ 0.78	$ 0.44	$ 0.37	$ 0.49	$ 0.52	$ 0.47	$ 0.56

Note: Detail may not add to totals due to independent rounding.

Sources: Appendix O; Exhibit O.17 (3%) and O.20 (7%); Column I.

6.7 Costs of Treatment for Uncovered Finished Water Reservoirs

As part of the LT2ESWTR, systems with uncovered finished water reservoirs have the options to cover the reservoirs or to provide disinfection downstream of the reservoir. Disinfection alternatives must achieve at least 2 log of *Cryptosporidium*, 3 log *Giardia*, and 4 log of virus inactivation. To develop national cost estimates for systems to comply with this provision of the LT2ESWTR, unit costs for each treatment alternative and the percentage of systems selecting each alternative are estimated for the inventory of systems having uncovered finished water reservoirs (presented in Chapter 4). This section summarizes the methodology for developing the unit costs of reservoir covers and disinfection. Appendix I provides further details on the derivation of unit costs. The basis for estimating the number of systems that select each alternative is also discussed in this section, followed by the presentation of national cost estimates for this provision of the rule.

6.7.1 Unit Costs

There are two types of reservoir covers—fixed and floating. Fixed covers are commonly constructed of concrete, steel, or aluminum. Floating covers are flexible membrane structures generally made of polypropylene or similar material. The unit costs for fixed covers are estimated from information provided in the Uncovered Finished Water Reservoirs Guidance Manual (USEPA 1999c). The unit costs for floating covers were estimated by obtaining vendor quotes (detailed in Appendix I). They are both based on the estimated surface area of a reservoir and the average cost of materials.

Systems have the option to disinfect the water leaving the reservoir instead of installing a cover. A review of available disinfection options showed that the combination of UV and gaseous chlorine is the least-cost option to achieve the required *Cryptosporidium*, *Giardia*, and virus inactivation. Unit costs of gas chlorination presented in Appendix I are a function of flow and include the costs of typical process equipment and the chemical building. Unit costs for UV are the same as those used for filtered and unfiltered treatment plants.

6.7.2 Compliance Forecast and Technology Selection

The technology selection methodology for the uncovered finished water reservoirs also uses a least-cost approach. For systems with reservoir capacities of 10 million gallons (MG) or less, covering is the least expensive alternative and all of this size are assumed to install covers. The technology selection for the remaining reservoirs is split between installing covers and disinfecting the effluent. To meet the disinfection requirements, a combination of UV and chlorine is the least expensive option for achieving virus, *Giardia*, and *Cryptosporidium* inactivation requirements. However, the ability of a system to use booster chlorination depends on its current residual disinfectant type. Approximately 50 percent of all surface water systems are predicted to use chloramination following implementation of the Stage 2 DBPR. Adding chlorine to water treated with chloramines can cause quality problems; therefore, a maximum of 50 percent of systems were assumed to add booster chlorination after the reservoir.

Because the technology selection is based on least costs, and fixed-cover costs are the most expensive treatment option considered, no systems were assumed to install fixed covers. EPA recognizes that some systems may select fixed covers for other reasons, but the incremental costs are not attributable to this rule.

Systems will also incur costs for reporting the presence of an uncovered finished water reservoir to the Primacy Agency and for submitting a plan to either cover or treat the reservoir. Costs for reporting are covered in detail in Appendix D.

6.7.3 Total Annual Treatment Costs

Total annual treatment costs are calculated by multiplying the number of reservoirs in a category by the percent selecting a technology and the unit cost for that technology. Exhibit 6.13a summarizes the costs for all systems with uncovered finished water reservoirs to comply with the rule. Exhibit 6.13b shows the reporting costs for systems to report to the Primacy Agency.

Exhibit 6.13a: Cost for Systems with Uncovered Finished Water Reservoirs, Annualized at 3 and 7 Percent ($Millions, 2003$)

System Size (Population Served)	Annualized Cost at 3%			Annualized Cost at 7%		
	Capital	O&M	Total	Capital	O&M	Total
<10,000	$ 0.01	$ 0.00	$ 0.01	$ 0.01	$ 0.00	$ 0.02
≥10,000	$ 6.52	$ 3.73	$ 10.24	$ 9.39	$ 3.68	$ 13.07
Total	$ 6.53	$ 3.73	$ 10.26	$ 9.40	$ 3.68	$ 13.08

Note: Detail may not add to totals due to independent rounding.
Sources: Appendix O, Exhibits O.18a (3%) and O.21a (7%), Columns N and Q.

Exhibit 6.13b: Reporting Cost for Systems with Uncovered Finished Water Reservoirs, Annualized at 3 and 7 Percent ($Millions, 2003$)

System Size (Population Served)	Annualized Cost at 3%	Annualized Cost at 7%
<10,000	$ 0.0002	$ 0.0002
≥10,000	$ 0.0011	$ 0.0016
Total	$ 0.0012	$ 0.0018

Note: Detail may not add to totals due to independent rounding.

Sources: Appendix O, Exhibits O.17a (3%) and O.20a (7%), Column J.

6.8 Future Source Water Monitoring

Six years after initial bin classification, filtered plants will be required to conduct a second round of monitoring to reassess source water conditions for bin assignments. EPA will evaluate new analytical methods and surrogate indicators of *Cryptosporidium* in the interim. While the costs of monitoring are likely to change in the 6 years following rule promulgation, it is difficult to predict how they will change. In the absence of other information, it was assumed that the laboratory costs would be the same as for the initial monitoring. All plants that conduct initial monitoring are assumed to conduct future monitoring as well, except for those systems that achieve 5.5 log *Cryptosporidium* treatment credit. Exhibit 6.14 shows the costs for future monitoring. Costs vary among the *Cryptosporidium* occurrence data sets because the numbers of plants that add technologies and achieve 5.5 log treatment credit differ and the number of small plants triggered into *Cryptosporidium* monitoring differ. Confidence bounds represent the low (5th percentile) and high (95th percentile) occurrence distributions for each data set. Appendix D, Exhibits D.30-D.35 show the calculations for the cost estimates.

Exhibit 6.14: Future Monitoring Cost Estimates, Present Value–Discounted at 3 and 7 Percent, Preferred Alternative ($Millions, 2003$)

System Size	ICR			ICRSSL			ICRSSM		
	Mean	Confidence Bounds		Mean	Confidence Bounds		Mean	Confidence Bounds	
		5th %ile	95th %ile		5th %ile	95th %ile		5th %ile	95th %ile
3 Percent									
< 10,000	$ 22.71	$ 21.86	$ 24.40	$ 17.74	$ 15.52	$ 19.23	$ 19.92	$ 18.47	$ 21.13
≥ 10,000	$ 13.20	$ 13.63	$ 12.50	$ 15.37	$ 16.14	$ 14.84	$ 14.55	$ 15.09	$ 14.10
Total	$ 35.91	$ 35.49	$ 36.89	$ 33.11	$ 31.66	$ 34.07	$ 34.48	$ 33.57	$ 35.23
7 Percent									
< 10,000	$ 13.79	$ 13.28	$ 14.79	$ 10.82	$ 9.49	$ 11.72	$ 12.13	$ 11.26	$ 12.85
≥ 10,000	$ 8.85	$ 9.14	$ 8.38	$ 10.31	$ 10.82	$ 9.95	$ 9.76	$ 10.12	$ 9.45
Total	$ 22.63	$ 22.42	$ 23.17	$ 21.13	$ 20.32	$ 21.67	$ 21.89	$ 21.38	$ 22.30

Note: Detail may not add to totals due to independent rounding.
Includes laboratory costs, labor costs, and reporting costs.
Sources: Appendix O, Exhibits O.11 (3%) and O.14 (7%), Sum of columns E, F, and G.

6.9 Summary of the National Costs of the LT2ESWTR

This section combines the cost estimates described in the previous sections to summarize the total national cost of the rule. Costs are broken out in several ways: by type of system or plant subject to rule provisions, by system size, and by nature of the cost (one-time or annual). All costs presented in this section are for the Preferred Regulatory Alternative for the LT2ESWTR. Cost estimates for the other regulatory alternatives are presented in section 6.13.

Exhibit 6.15 summarizes the estimated total initial capital and one-time costs of the LT2ESWTR, which include costs of rule implementation and all monitoring activities. Costs are presented for the means of the three occurrence distributions. Exhibit 6.16 follows with annualized costs and includes confidence bounds for each occurrence data set to show the full range of estimates. As can be seen in Exhibit 6.15, treatment costs comprise most of the costs of the rule. Exhibit 6.17a and 6.17b, therefore, provide further detail of treatment costs–a breakdown by system size for all three occurrence distributions (ICR, ICRSSL, and ICRSSM), including confidence bounds, discounted at 3 percent and 7 percent.

Exhibit 6.15: Initial Capital and One-Time Costs, Undiscounted, Preferred Alternative ($Millions, 2003$)

	Serving < 10,000 People			Serving ≥ 10,000 People			All Systems		
Type of Cost	ICR	ICRSSL	ICRSSM	ICR	ICRSSL	ICRSSM	ICR	ICRSSL	ICRSSM
Total									
National (System + State)							$2,104.32	$ 1,526.27	$ 1,719.41
System									
System Total	$ 214.30	$ 132.32	$ 157.93	$ 1,869.74	$ 1,373.81	$ 1,541.30	$2,084.04	$ 1,506.13	$ 1,699.23
Treatment	$ 140.74	$ 76.26	$ 94.75	$ 1,706.86	$ 1,208.24	$ 1,376.73	$1,847.60	$ 1,284.50	$ 1,471.48
Implementation	$ 1.19	$ 1.19	$ 1.19	$ 0.39	$ 0.39	$ 0.39	$ 1.59	$ 1.59	$ 1.59
Initial Monitoring	$ 38.03	$ 28.27	$ 32.07	$ 26.77	$ 26.77	$ 26.77	$ 64.80	$ 55.04	$ 58.84
Second Monitoring	$ 33.47	$ 26.05	$ 29.30	$ 18.01	$ 20.97	$ 19.86	$ 51.48	$ 47.02	$ 49.16
Benchmarking	$ 0.07	$ 0.04	$ 0.05	$ 0.08	$ 0.06	$ 0.07	$ 0.16	$ 0.10	$ 0.11
Tech Reporting	$ 0.65	$ 0.37	$ 0.43	$ 0.74	$ 0.49	$ 0.58	$ 1.39	$ 0.86	$ 1.01
Uncovered Reservoirs	$ 0.14	$ 0.14	$ 0.14	$ 116.88	$ 116.88	$ 116.88	$ 117.03	$ 117.03	$ 117.03
State									
State Total							$ 20.28	$ 20.15	$ 20.19
Implementation							$ 7.77	$ 7.77	$ 7.77
Initial Monitoring							$ 5.98	$ 5.98	$ 5.98
Second Monitoring							$ 6.18	$ 6.18	$ 6.18
Benchmarking							$ 0.09	$ 0.06	$ 0.07
Tech Reporting							$ 0.27	$ 0.17	$ 0.19
Uncovered Reservoirs							$ 0.00	$ 0.00	$ 0.00

Notes: Detail may not add to totals due to independent rounding.
Sources: All data from Appendix O, and from Alternative A3.
System:8
Treatment: Sum of columns B and H from Exhibits O.6a (ICR), O.6b (ICRSSM), and O.6c (ICRSSL)
Implementation: Column A from Exhibits O.5a (ICR), O.5d (ICRSSM), and O.5g (ICRSSL)
Initial Monitoring: Sum of columns B, C, and D from Exhibits O.5a (ICR), O.5d (ICRSSM), and O.5g (ICRSSL)
Second Monitoring: Sum of columns E, F, and G from Exhibits O.5a (ICR), O.5d (ICRSSM), and O.5g (ICRSSL)
Benchmarking: Column H from Exhibits O.5a (ICR), O.5d (ICRSSM), and O.5g (ICRSSL)
Tech Reporting: Column I from Exhibits O.5a (ICR), O.5d (ICRSSM), and O.5g (ICRSSL)
Uncovered Reservoirs: Column N from Exhibits O.6a (ICR), O.6b (ICRSSM), and O.6c (ICRSSL)
State:
Implementation: Column A from Exhibits O.4a (ICR), O.4d (ICRSSM), and O.4g (ICRSSL)
Initial Monitoring: Sum of columns B and C from Exhibits O.4a (ICR), O.4d (ICRSSM), and O.4g (ICRSSL)
Second Monitoring: Sum of columns D and E from Exhibits O.4a (ICR), O.4d (ICRSSM), and O.4g (ICRSSL)
Benchmarking: Column F from Exhibits O.4a (ICR), O.4d (ICRSSM), and O.4g (ICRSSL)
Tech Reporting: Column G from Exhibits O.4a (ICR), O.4d (ICRSSM), and O.4g (ICRSSL)

Exhibit 6.16: Annualized Total Costs–Discounted at 3 and 7 Percent, Preferred Alternative ($Millions, 2003$)

	ICR			ICRSSL			ICRSSM		
		Confidence Bounds			Confidence Bounds			Confidence Bounds	
	Mean	5th %ile	95th %ile	Mean	5th %ile	95th %ile	Mean	5th %ile	95th %ile
	3%								
National	$ 133.42	$ 111.05	$ 160.00	$ 92.88	$ 72.11	$ 112.17	$ 105.90	$ 86.30	$ 125.74
System Total	$ 132.27	$ 109.91	$ 158.83	$ 91.78	$ 71.03	$ 111.07	$ 104.79	$ 85.20	$ 124.62
State Total	$ 1.15	$ 1.14	$ 1.17	$ 1.09	$ 1.08	$ 1.10	$ 1.11	$ 1.10	$ 1.12
	7%								
National	$ 150.48	$ 125.12	$ 180.61	$ 106.77	$ 83.21	$ 128.83	$ 120.93	$ 98.58	$ 143.61
System Total	$ 149.07	$ 123.72	$ 179.19	$ 105.42	$ 81.87	$ 127.47	$ 119.56	$ 97.22	$ 142.23
State Total	$ 1.41	$ 1.39	$ 1.42	$ 1.35	$ 1.34	$ 1.36	$ 1.37	$ 1.36	$ 1.38

Notes: Detail may not add to totals due to independent rounding.
Sources: All data from Appendix O, and from Alternative A3.
System (at 3 percent):
Mean: Sum of column J from Exhibits O.17a (ICR), O.17d (ICRSSM), and O.17g (ICRSSL) and column T from Exhibits O.18a (ICR), O.18b (ICRSSM), and O.18c (ICRSSL)
5th percentile: Sum of column J from Exhibits O.17b (ICR), O.17e (ICRSSM), and O.17h (ICRSSL) and column S from Exhibits O.18a (ICR), O.18b (ICRSSM), and O.18c (ICRSSL)
95th percentile: Sum of column J from Exhibits O.17c (ICR), O.17f (ICRSSM), and O.17i (ICRSSL) and column U from Exhibits O.18a (ICR), O.18b (ICRSSM), and O.18c (ICRSSL)
System (at 7 percent):
Mean: Sum of column J from Exhibits O.20a (ICR), O.20d (ICRSSM), and O.20g (ICRSSL) and column T from Exhibits O.18a (ICR), O.18b (ICRSSM), and O.18c (ICRSSL)
5th percentile: Sum of column J from Exhibits O.20b (ICR), O.20e (ICRSSM), and O.20h (ICRSSL) and column S from Exhibits O.18a (ICR), O.18b (ICRSSM), and O.18c (ICRSSL)
95th percentile: Sum of column J from Exhibits O.20c (ICR), O.20f (ICRSSM), and O.20i (ICRSSL) and column U from Exhibits O.18a (ICR), O.18b (ICRSSM), and O.18c (ICRSSL)
State (at 3 percent):
Mean: Column H from Exhibits O.16a (ICR), O.16d (ICRSSM), and O.16g (ICRSSL)
5th percentile: Column H from Exhibits O.16b (ICR), O.16e (ICRSSM), and O.16h (ICRSSL)
95th percentile: Column H from Exhibits O.16c (ICR), O.16f (ICRSSM), and O.16i (ICRSSL)
State (at 7 percent):
Mean: Column H from Exhibits O.19a (ICR), O.19d (ICRSSM), and O.19g (ICRSSL)
5th percentile: Column H from Exhibits O.19b (ICR), O.19e (ICRSSM), and O.19h (ICRSSL)
95th percentile: Column H from Exhibits O.19c (ICR), O.19f (ICRSSM), and O.19i (ICRSSL)

Exhibit 6.17a: Annualized Treatment Costs by System Size, Preferred Alternative, 3 Percent Discount Rate ($Millions, 2003$)

System Size (Population Served)	Capital - Present Value			O & M - Annualized			Total - Annualized		
	Mean	5th %ile	95th %ile	Mean	5th %ile	95th %ile	Mean	5th %ile	95th %ile
	A	B	C	D	E	F	G	H	I
ICR									
<100	$ 5.0	$ 3.9	$ 6.3	$ 0.3	$ 0.3	$ 0.4	$ 0.6	$ 0.5	$ 0.8
100-499	$ 7.0	$ 5.6	$ 8.8	$ 0.5	$ 0.4	$ 0.6	$ 0.9	$ 0.7	$ 1.1
500-999	$ 4.9	$ 3.9	$ 6.1	$ 0.3	$ 0.3	$ 0.4	$ 0.6	$ 0.5	$ 0.7
1,000-3,299	$ 19.1	$ 14.9	$ 23.8	$ 1.2	$ 1.0	$ 1.5	$ 2.3	$ 1.9	$ 2.8
3,300-9,999	$ 52.4	$ 40.7	$ 65.7	$ 2.3	$ 1.9	$ 2.7	$ 5.3	$ 4.3	$ 6.5
10,000-49,999	$ 221.4	$ 176.5	$ 279.3	$ 7.3	$ 6.3	$ 8.6	$ 20.0	$ 16.4	$ 24.7
50,000-99,999	$ 145.8	$ 114.7	$ 185.5	$ 3.6	$ 3.0	$ 4.2	$ 11.9	$ 9.6	$ 14.8
100,000-999,999	$ 419.3	$ 331.4	$ 530.2	$ 11.3	$ 9.6	$ 13.3	$ 35.4	$ 28.7	$ 43.7
1,000,000+	$ 551.6	$ 436.9	$ 675.2	$ 6.8	$ 5.8	$ 8.0	$ 38.5	$ 30.9	$ 46.7
Total	$ 1,426.5	$ 1,128.4	$ 1,780.9	$ 33.7	$ 28.7	$ 39.6	$ 115.6	$ 93.5	$ 141.9
ICRSSL									
<100	$ 3.0	$ 2.0	$ 3.9	$ 0.2	$ 0.1	$ 0.2	$ 0.3	$ 0.2	$ 0.4
100-499	$ 4.0	$ 2.7	$ 5.2	$ 0.2	$ 0.2	$ 0.3	$ 0.5	$ 0.3	$ 0.6
500-999	$ 2.8	$ 1.9	$ 3.6	$ 0.2	$ 0.1	$ 0.2	$ 0.3	$ 0.2	$ 0.4
1,000-3,299	$ 10.4	$ 7.2	$ 13.4	$ 0.7	$ 0.5	$ 0.8	$ 1.3	$ 0.9	$ 1.6
3,300-9,999	$ 27.8	$ 19.1	$ 36.1	$ 1.3	$ 1.0	$ 1.6	$ 2.9	$ 2.1	$ 3.7
10,000-49,999	$ 134.5	$ 92.3	$ 174.4	$ 4.3	$ 3.2	$ 5.2	$ 12.0	$ 8.5	$ 15.2
50,000-99,999	$ 88.8	$ 60.3	$ 116.1	$ 2.0	$ 1.5	$ 2.4	$ 7.1	$ 5.0	$ 9.1
100,000-999,999	$ 250.4	$ 171.3	$ 325.7	$ 6.1	$ 4.6	$ 7.3	$ 20.5	$ 14.4	$ 26.0
1,000,000+	$ 476.8	$ 366.4	$ 584.7	$ 3.8	$ 3.0	$ 4.6	$ 31.2	$ 24.0	$ 38.1
Total	$ 998.5	$ 723.2	$ 1,263.1	$ 18.8	$ 14.2	$ 22.6	$ 76.1	$ 55.7	$ 95.2
ICRSSM									
<100	$ 3.7	$ 2.7	$ 4.6	$ 0.2	$ 0.2	$ 0.3	$ 0.4	$ 0.3	$ 0.5
100-499	$ 4.9	$ 3.7	$ 6.2	$ 0.3	$ 0.3	$ 0.4	$ 0.6	$ 0.5	$ 0.7
500-999	$ 3.4	$ 2.6	$ 4.2	$ 0.2	$ 0.2	$ 0.2	$ 0.4	$ 0.3	$ 0.5
1,000-3,299	$ 12.9	$ 9.7	$ 16.1	$ 0.8	$ 0.7	$ 1.0	$ 1.6	$ 1.2	$ 1.9
3,300-9,999	$ 34.6	$ 26.0	$ 43.7	$ 1.6	$ 1.3	$ 1.9	$ 3.6	$ 2.8	$ 4.5
10,000-49,999	$ 164.7	$ 125.1	$ 205.9	$ 5.3	$ 4.4	$ 6.2	$ 14.7	$ 11.5	$ 18.0
50,000-99,999	$ 108.5	$ 81.4	$ 136.8	$ 2.5	$ 2.0	$ 2.9	$ 8.7	$ 6.7	$ 10.7
100,000-999,999	$ 306.9	$ 231.7	$ 385.5	$ 7.6	$ 6.3	$ 8.9	$ 25.2	$ 19.6	$ 31.0
1,000,000+	$ 501.5	$ 392.6	$ 610.8	$ 4.7	$ 3.9	$ 5.4	$ 33.5	$ 26.4	$ 40.5
Total	$ 1,141.0	$ 875.4	$ 1,413.9	$ 23.2	$ 19.1	$ 27.2	$ 88.8	$ 69.4	$ 108.4

Note: Detail may not add to totals due to independent rounding.
Sources: Appendix O.
[A]-[C] Exhibit O.12, Columns G-I.
[D]-[F] Exhibit O.18, Columns J-L.
[G]-[I] Exhibit O.18, Sum of columns G and J, H and K, and I and L.

Exhibit 6.17b: Annualized Treatment Costs by System Size, Preferred Alternative, 7 Percent Discount Rate ($Millions, 2003$)

System Size (population served)	Capital - Present Value			O & M - Annualized			Total - Annualized		
	Mean	5th %ile	95th %ile	Mean	5th %ile	95th %ile	Mean	5th %ile	95th %ile
	A	B	C	D	E	F	G	H	I
ICR									
<100	$ 3.7	$ 2.9	$ 4.6	$ 0.3	$ 0.2	$ 0.3	$ 0.6	$ 0.5	$ 0.7
100-499	$ 5.2	$ 4.1	$ 6.5	$ 0.4	$ 0.3	$ 0.5	$ 0.8	$ 0.7	$ 1.0
500-999	$ 3.6	$ 2.9	$ 4.5	$ 0.3	$ 0.2	$ 0.3	$ 0.6	$ 0.5	$ 0.7
1,000-3,299	$ 14.1	$ 11.0	$ 17.6	$ 1.0	$ 0.9	$ 1.2	$ 2.2	$ 1.8	$ 2.7
3,300-9,999	$ 38.7	$ 30.0	$ 48.6	$ 1.9	$ 1.6	$ 2.2	$ 5.2	$ 4.2	$ 6.4
10,000-49,999	$ 172.8	$ 137.7	$ 218.0	$ 6.3	$ 5.4	$ 7.4	$ 21.1	$ 17.2	$ 26.1
50,000-99,999	$ 118.1	$ 93.0	$ 150.3	$ 3.1	$ 2.7	$ 3.7	$ 13.3	$ 10.7	$ 16.6
100,000-999,999	$ 345.9	$ 273.3	$ 437.3	$ 10.1	$ 8.6	$ 11.8	$ 39.8	$ 32.0	$ 49.4
1,000,000+	$ 455.0	$ 360.4	$ 556.9	$ 6.1	$ 5.1	$ 7.1	$ 45.1	$ 36.1	$ 54.9
Total	$1,157.1	$ 915.3	$ 1,444.3	$ 29.4	$ 25.0	$ 34.6	$ 128.7	$ 103.6	$ 158.5
ICRSSL									
<100	$ 2.2	$ 1.5	$ 2.9	$ 0.1	$ 0.1	$ 0.2	$ 0.3	$ 0.2	$ 0.4
100-499	$ 2.9	$ 2.0	$ 3.8	$ 0.2	$ 0.1	$ 0.2	$ 0.5	$ 0.3	$ 0.6
500-999	$ 2.0	$ 1.4	$ 2.6	$ 0.1	$ 0.1	$ 0.2	$ 0.3	$ 0.2	$ 0.4
1,000-3,299	$ 7.7	$ 5.3	$ 9.9	$ 0.5	$ 0.4	$ 0.7	$ 1.2	$ 0.9	$ 1.5
3,300-9,999	$ 20.5	$ 14.1	$ 26.7	$ 1.1	$ 0.8	$ 1.4	$ 2.9	$ 2.0	$ 3.6
10,000-49,999	$ 105.0	$ 72.0	$ 136.1	$ 3.7	$ 2.8	$ 4.5	$ 12.7	$ 8.9	$ 16.1
50,000-99,999	$ 72.0	$ 48.9	$ 94.1	$ 1.7	$ 1.3	$ 2.1	$ 7.9	$ 5.5	$ 10.2
100,000-999,999	$ 206.6	$ 141.3	$ 268.7	$ 5.4	$ 4.1	$ 6.5	$ 23.1	$ 16.2	$ 29.6
1,000,000+	$ 393.3	$ 302.2	$ 482.3	$ 3.4	$ 2.6	$ 4.1	$ 37.2	$ 28.6	$ 45.4
Total	$ 812.2	$ 588.7	$ 1,027.0	$ 16.4	$ 12.4	$ 19.7	$ 86.1	$ 62.9	$ 107.9
ICRSSM									
<100	$ 2.7	$ 2.0	$ 3.4	$ 0.2	$ 0.2	$ 0.2	$ 0.4	$ 0.3	$ 0.5
100-499	$ 3.6	$ 2.7	$ 4.6	$ 0.3	$ 0.2	$ 0.3	$ 0.6	$ 0.4	$ 0.7
500-999	$ 2.5	$ 1.9	$ 3.1	$ 0.2	$ 0.1	$ 0.2	$ 0.4	$ 0.3	$ 0.5
1,000-3,299	$ 9.5	$ 7.2	$ 11.9	$ 0.7	$ 0.6	$ 0.8	$ 1.5	$ 1.2	$ 1.8
3,300-9,999	$ 25.6	$ 19.2	$ 32.3	$ 1.4	$ 1.1	$ 1.6	$ 3.6	$ 2.8	$ 4.4
10,000-49,999	$ 128.5	$ 97.6	$ 160.7	$ 4.5	$ 3.7	$ 5.3	$ 15.6	$ 12.1	$ 19.1
50,000-99,999	$ 87.9	$ 65.9	$ 110.9	$ 2.2	$ 1.8	$ 2.5	$ 9.7	$ 7.4	$ 12.1
100,000-999,999	$ 253.2	$ 191.1	$ 318.0	$ 6.8	$ 5.6	$ 7.9	$ 28.5	$ 22.0	$ 35.2
1,000,000+	$ 413.6	$ 323.8	$ 503.8	$ 4.2	$ 3.4	$ 4.8	$ 39.7	$ 31.2	$ 48.1
Total	$ 927.1	$ 711.5	$ 1,148.7	$ 20.3	$ 16.7	$ 23.7	$ 99.8	$ 77.7	$ 122.3

Notes: Detail may not add to totals due to independent rounding.
Sources: Appendix O.
[A]-[C] Exhibit O.15, Columns G-I.
[D]-[F] Exhibit O.21; Columns J-L.
[G]-[I] Exhibit O.21; Sum of columns G and J, H and K, and I and L.

6.10 Household Costs

EPA assumes that systems will pass some or all of the costs of a new regulation on to their customers in the form of rate increases. These rate increases will include interest costs and patent costs that are not included in cost estimates shown in other sections. Household costs, which are in units of *$ per household per year*, are estimated in this chapter to provide a measure of the increase in water bills that may result from the LT2ESWTR. Exhibit 6.18 presents the mean expected increases in yearly household costs by system size, system type, and occurrence data set, for those systems subject to the rule. (Appendix J, Exhibit J.4 presents household cost estimates for those systems predicted to make treatment changes.)

These costs incorporate the expenses of rule implementation (e.g., reading and understanding the rule), initial and future monitoring for bin classification, covering or treating effluent from uncovered finished water reservoirs, treatment changes, benchmarking, and compliance reporting. A detailed description of the derivation of per-household costs is in Appendix J. Per-household costs for uncovered finished water reservoirs are determined by taking the costs for fixing the reservoirs from section 6.8 and assigning them to systems as described in section 4.6.

To annualize capital costs for the purposes of determining the costs to households, EPA uses different discount rates for private and public systems and for systems of different sizes. The discount rate differences between systems represent the different borrowing sources each type of system has available to it, differences in risk, and expectations regarding inflation. The rates vary from 5.20 to 6.27 percent depending on system size and ownership, and are summarized in Appendix J, Exhibit J.1. Per-household costs also include costs for royalty payments on the use of UV light (described below).

For each system size category, the unit costs for treatment in dollars per thousand gallons is then multiplied by the annual per-household usage rate to obtain their contribution to per-household costs. Although rule implementation and monitoring represent relatively small, one-time costs, they have been included in the analysis to provide a complete distribution of the potential per-household cost increase.

Calgon Carbon Corporation holds a patent (No. 6,129,893) for "A method for prevention of *Cryptosporidium* oocysts and similar organisms in water by irradiating the water with ultraviolet light in a range of 200 to 300 nm in concentrations of about 10 mJ/cm^2 to about 175 mJ/cm^2." This patent applies to systems using medium-pressure mercury vapor lamps to inactivate *Cryptosporidium*. EPA also understands that Calgon has applied for a continuation in part to extend coverage of the patent to low-pressure mercury vapor lamps and to lower UV concentrations. Calgon is charging a license fee of $0.015/1,000 gallons treated to water producers using UV under conditions covered by the patent. This cost was added to the unit cost of UV in the per-household cost calculations. It was not used in the national cost estimates because it represents a transfer payment involving no net use of resources.

For purchased systems that are linked to larger, nonpurchased systems, the per-household costs are calculated using the unit costs of the larger system; however, they are reported within the size category distributions for the purchased system. Household costs for these purchased systems are based on the per-household usage rates appropriate for the retail system and not for the system selling that wholesales water. This reflects the fact that although purchased systems will not face increased costs from adding their own treatment, whatever costs the wholesale utility incurs would likely be passed on as higher water costs.

Exhibit 6.18: Summary of Annual Per-Household Cost[1] Increases, Preferred Alternative ($/Year)

System Type/Size	Households	Mean	Median	90th Percentile	95th Percentile	Percent of Systems with Household Cost Increase < $12	Percent of Systems with Household Cost Increase < $120
ICR							
All CWS	68,857,992	$2.59	$0.21	$6.43	$9.97	96.49%	99.99%
CWS ≤ 10,000	5,587,602	$4.14	$0.56	$9.97	$14.79	91.19%	99.88%
CWS < 500	158,900	$13.09	$3.86	$28.66	$53.60	63.20%	98.87%
ICRSSL							
All CWS	68,857,992	$1.67	$0.09	$6.37	$6.42	97.96%	100.00%
CWS ≤ 10,000	5,587,602	$2.49	$0.36	$6.60	$9.37	96.46%	99.94%
CWS < 500	158,900	$8.58	$2.91	$17.44	$29.01	72.61%	99.50%
ICRSSM							
All CWS	68,857,992	$1.97	$0.09	$6.37	$6.85	97.47%	99.99%
CWS ≤ 10,000	5,587,602	$3.00	$0.49	$7.02	$11.39	95.19%	99.93%
CWS < 500	158,900	$10.10	$2.90	$26.24	$35.97	68.73%	99.31%
ICR - High							
All CWS	68,857,992	$2.84	$0.21	$6.43	$9.97	96.09%	99.99%
CWS ≤ 10,000	5,587,602	$4.58	$0.61	$11.50	$15.30	90.22%	99.86%
CWS < 500	158,900	$7.21	$2.91	$16.81	$26.25	75.79%	99.80%
ICRSSL - Low							
All CWS	68,857,992	$1.42	$0.03	$5.65	$6.42	98.37%	100.00%
CWS ≤ 10,000	5,587,602	$2.06	$0.23	$6.58	$7.47	97.21%	99.96%
CWS < 500	158,900	$14.42	$4.79	$30.00	$54.42	62.07%	98.58%

Note:
[1]Annualized at discount rates varied by system size and ownership (see Appendix J, Exhibit J.2).
[2]Households served by systems subject to the LT2ESWTR.
Source: Appendix J, Exhibit J.3.

EPA estimates that all households served by surface and GWUDI sources will face some increase in costs due to implementation of the LT2ESWTR (except for those few that have already installed 5.5 log of treatment for *Cryptosporidium*; see Chapter 4 for a summary of households served by systems subject to various LT2ESWTR provisions). Of all the households subject to the rule, 24 to 35 percent are projected to incur costs for adding treatment, depending on the *Cryptosporidium* occurrence data set used. Approximately 95 percent of the households potentially subject to the rule are connected to systems serving at least 10,000 people; these systems will experience the smallest increases in costs, due to economies of scale. Over 90 percent of all households will face an annual cost increase of less than 7 dollars.

6.11 Summary of Uncertainties and Sensitivity Analyses

As described throughout this chapter, uncertainty and variability are inherent in developing national cost estimates. EPA addresses these issues by using probability distributions of key variables, conducting the analysis for multiple data sets, and analyzing specific variables of the model to determine how sensitive is their effect on national estimates. This section first discusses the uncertainties in the national cost estimates and then provides sensitivity analyses to demonstrate how the national estimates can fluctuate as certain parameters are changed.

Exhibit 6.19 below presents a summary of the uncertainties, references to the section or appendix where the issue is discussed, and estimates the effects that each may have on national costs.

Exhibit 6.19: Summary of Uncertainties Affecting LT2ESWTR Cost Estimates

Source of Uncertainty	Section with Full Discussion of Uncertainty	Effect on Cost Estimates		
		Under-estimate	Over-estimate	Under or Over Estimate
Occurrence data used to predict plant bin assignments	4.5.3 Appendix O			X
All systems are charged the same laboratory fee for *Cryptosporidium* monitoring	6.1.1			X
Unit costs developed for typical system conditions, where site-specific factors often drive costs and treatment selections[1]	6.4.1			X
Single flow rate used to evaluate unit costs within each of 9 size categories	6.4.1			X
Potentially lower-cost treatments or toolbox options not considered	6.4.1		X	
Economies of scale not considered for combined treatment technologies	6.4.1		X	
Inability to link all purchased systems with their suppliers	4.3.2		X	
Number of systems achieving credit for technologies in place	4.5.1, Appendix A		X	

[1]Source water quality and plant building or existing infrastructure may inhibit the use of a technology or cause decreased or increased capital and O&M costs.

Of the uncertainties in Exhibit 6.19, those affecting (1) the number of plants predicted to add treatment, and (2) the technology selection will have the greatest effect on the LT2ESWTR national cost estimates. Section 6.11.1 discusses the effect of the occurrence estimates; and Section 6.11.2 provides sensitivity analyses on source water quality.

The uncertainty surrounding unit costs is significant. EPA addresses this uncertainty by assigning a range of unit costs—±30 percent for capital costs and ±15 percent for O&M costs. Although actual costs incurred by a plant implementing a given technology may be substantially higher or lower than implied by this uncertainty, this analysis is concerned with national estimates. The unit costs represent mean estimates for a given size and technology, which is appropriate to use for estimating national costs, as one would expect the variability imposed by site-specific factors to have similar effects in both directions of lower or higher costs. For example, some metropolitan systems may incur extraordinarily high costs due to land cost, while some others may incur extraordinarily low costs because they have the space available to install the required infrastructure in their existing facility.

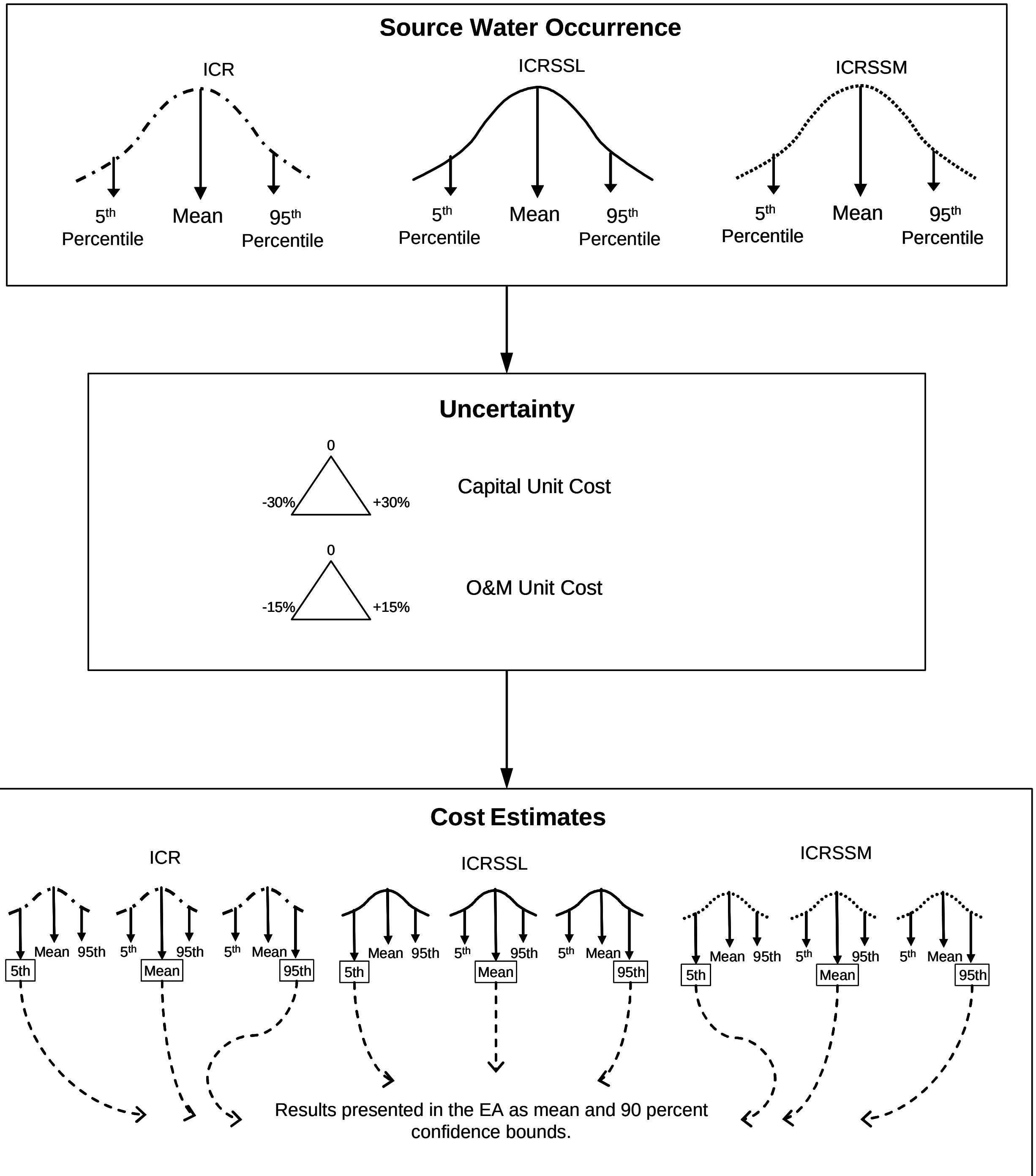
6.11.1 *Cryptosporidium* Occurrence Data Sets

The source water occurrence of *Cryptosporidium* has much uncertainty due to the nonuniform distribution of the oocysts in a body of water, limitations in analytical methods, and atypical weather or source water contamination events. EPA recognized these issues with the ICR and ICRSS data and modeled likely distributions of national *Cryptosporidium* occurrence. However, the model results still present a significant amount of uncertainty. To show how the national estimate may vary depending on the source water *Cryptosporidium* concentrations, all costs were estimated for mean values and 90 percent confidence bounds of each occurrence data set, resulting in nine occurrence estimates.

The results presented throughout this chapter show mean, 5th percentile, and 95th percentile values for each data set. The cost model also incorporates uncertainty in capital and O&M unit costs by estimating a mean, 5th percentile, and 95th percentile value for each occurrence distribution. The result is 27 estimates of treatment costs (implementation, monitoring, and reporting costs do not incorporate uncertainty of the unit costs). The confidence bounds of treatment and total national costs presented in Exhibits 6.15, 6.16, and 6.17 are the 5th percentile cost of the 5th percentile occurrence distribution and the 95th percentile cost of the 95th percentile occurrence distribution, or the low of the low and high of the high, for each of the ICR, ICRSSL, and ICRSSM data sets (see Exhibit 6.20).

The 95th percentile of the ICR data set represents the highest occurrence estimate and the 5th percentile of the ICRSSL data set represents the lowest occurrence estimate. From the national total annualized costs presented in Exhibit 6.16, the ICR 95th percentile is $159 million and the ICRSSL 5th percentile is $71 million (discounted at 3 percent). The sensitivity of the cost estimate to the uncertainty of *Cryptosporidium* occurrence is shown by the comparison of cost estimates between ICR and ICRSSL data sets. The mean national cost estimate between these data sets varies by roughly a factor of two.

Exhibit 6.20: Cost Model Estimates by Occurrence Distributions and Unit Cost Uncertainty



6.11.2 Sensitivity Analysis of Influent Bromide Levels on Technology Selection for Filtered Plants

Bromide in the treatment plant influent can limit ozone use due to the byproduct formation of bromate. In the LT2ESWTR least cost-modeling approach, ozone is selected after UV disinfection and a few other technologies, depending on system size and log treatment credit required. EPA conducted a sensitivity analysis to evaluate how the technology selection, and thus national cost estimate, would change if more plants had source water bromide concentrations that restricted the use of ozone.

The ICR database includes plant influent bromide concentrations for July 1997 through December 1998. Bromide levels vary from year to year and are highest during drought periods. There is concern that ICR bromide data were not collected during a drought period and, thus, do not accurately reflect the maximum influent levels that plants would use when designing their ozonation systems. For the standard conditions used in the main cost analysis, maximum use percentages for ozone reflect the SWAT analysis using influent bromide equivalent to the values reported in the ICR (USEPA 2003b). EPA conducted another SWAT analysis in which the influent bromide concentrations for each plant were increased by 50 parts per billion (ppb). Those results provided a maximum use percent of ozone for the LT2ESWTR decision tree, under high influent bromide levels. Exhibit 6.21 compares the number of plants selecting UV and ozone and the filtered plant treatment cost estimates for each technology selection (standard and influent bromide increased by 50 ppb). Technology selection constraints on ozone use have little impact on annual costs. Appendix G presents technology selection forecasts that reflect the three occurrence data sets and an increased source water bromide concentration for all regulatory alternatives.

Exhibit 6.21: Sensitivity of Technology Selection to Influent Bromide Concentration for Filtered Plants

	Standard Condition (Influent Bromide as reported in ICR)			Influent Bromide Increased by 50 ppb		
	ICR	**ICRSSL**	**ICRSSM**	**ICR**	**ICRSSL**	**ICRSSM**
	A	B	C	D	E	F
Number of Plants Converting to Ozone	54	38	45	41	32	37
Total Annual Treament Cost ($ Millions, 2003$)						
3 Percent	$90	$50	$63	$103	$56	$71
7 Percent	$97	$55	$69	$112	$62	$77

Sources:
"Number of Plants Converting to Ozone" Appendix G, Exhibits G.37-48; Row - Total Plants; Columns H-J.
"Treatment Cost (Annual)" Appendix O, Exhibits O.18 and O.21; Column B and E, Total rows for Rule Alternative A3 and Rule Alternative A3 UV90-10B.

6.12 Unquantified Costs

EPA has quantified all of the major costs for this rule and has provided uncertainty analyses to bound the over- or underestimates in the mean cost values. Some cost effects are unquantifiable, however, because of a lack of information. One such cost effect on systems that must comply with several rules at the same time. This analysis took into consideration compliance with the Stage 2 DBPR, the LT1ESWTR, and the IESWTR. It did not, however take into account other rules that are or will be promulgated before this rule. These include the Arsenic Rule, the Ground Water Rule, and the Filter Backwash Recycling Rule. Although most of these will not affect surface water sources, they may limit the use of alternative sources. The rules affecting ground water could affect the GWUDI systems in the LT2ESWTR. There could be lower-costs for some systems if technologies they install for this rule also achieve reductions in other contaminants. There could be unquantifiable savings in monitoring and implementation costs for complying with several rules at once. There are also unquantifiable savings associated with some of the treatment and management strategies listed in section 6.5.1.1 that were not included in this analysis, but that may be less expensive than the treatment technologies which were evaluated.

Another cost not quantified is that of systems merging to comply with this rule. Although mergers could make compliance easier or treatment costs lower (due to economies of scale) for many small systems, it is difficult to tell how many mergers would result from this rule and how many would occur because of other factors. Costs would also be difficult to quantify. There could be savings because of economies of scale, but there could also be increases because of additional capital costs to connect the systems.

Other toolbox options that were not quantified included source water intake management and performance studies. These measures may prove cheaper than the technologies considered in the analyses, so their inclusion would result in lower-costs. The cost savings are difficult to quantify, however, because the effectiveness and applicability of these options is unknown.

6.13 Comparison of Regulatory Alternatives

Exhibits 6.22a-b provide a summary of the annualized present value of filtered plant costs for each regulatory alternative, for each data set, using 3 and 7 percent discount rates, based on a 25-year period of analysis. They do not include costs to unfiltered plants and uncovered finished water reservoirs because regulatory requirements to these entities do not change among regulatory alternatives.

Exhibit 6.22a: Comparison by Regulatory Alternative of Total Costs, Annualized at 3 Percent for Filtered Plants ($Millions, 2003$)

System Size (Population Served)	ICR			ICRSSL			ICRSSM		
	Mean	Confidence Bounds		Mean	Confidence Bounds		Mean	Confidence Bounds	
		5th %ile	95th %ile		5th %ile	95th %ile		5th %ile	95th %ile
Preferred Alternative									
<10K	$ 9.15	$ 7.37	$ 11.24	$ 4.74	$ 3.28	$ 6.06	$ 6.02	$ 4.65	$ 7.41
≥10k	$ 80.40	$ 65.00	$ 99.65	$ 45.30	$ 31.33	$ 58.10	$ 56.66	$ 43.66	$ 69.97
Total	$ 89.56	$ 72.37	$ 110.88	$ 50.04	$ 34.61	$ 64.16	$ 62.68	$ 48.31	$ 77.39
Alternative 1									
<10K	$ 38.47	$ 33.40	$ 43.51	$ 38.47	$ 33.40	$ 43.51	$ 38.47	$ 33.40	$ 43.51
≥10k	$ 323.67	$ 292.12	$ 355.30	$ 323.67	$ 292.12	$ 355.30	$ 323.67	$ 292.12	$ 355.30
Total	$ 362.14	$ 325.51	$ 398.81	$ 362.14	$ 325.51	$ 398.81	$ 362.14	$ 325.51	$ 398.81
Alternative 2									
<10K	$ 13.84	$ 11.59	$ 17.26	$ 9.09	$ 6.76	$ 11.41	$ 10.62	$ 8.50	$ 12.93
≥10k	$ 101.19	$ 85.02	$ 126.04	$ 65.86	$ 47.90	$ 83.33	$ 78.24	$ 62.15	$ 95.34
Total	$ 115.03	$ 96.61	$ 143.30	$ 74.96	$ 54.66	$ 94.74	$ 88.86	$ 70.65	$ 108.26
Alternative 4									
<10K	$ 4.53	$ 3.63	$ 5.66	$ 2.12	$ 1.44	$ 2.87	$ 2.94	$ 2.26	$ 3.68
≥10k	$ 32.78	$ 25.61	$ 41.17	$ 13.00	$ 8.76	$ 17.94	$ 18.99	$ 14.26	$ 24.10
Total	$ 37.31	$ 29.24	$ 46.83	$ 15.11	$ 10.21	$ 20.81	$ 21.93	$ 16.51	$ 27.77

Sources: Appendix O, Exhibits O.18, Column B and E.

Exhibit 6.22b: Comparison by Regulatory Alternative of Total Costs, Annualized at 7 Percent for Filtered Plants ($Millions, 2003$)

System Size (Population Served)	ICR			ICRSSL			ICRSSM		
	Mean	Confidence Bounds		Mean	Confidence Bounds		Mean	Confidence Bounds	
		5th %ile	95th %ile		5th %ile	95th %ile		5th %ile	95th %ile
Preferred Alternative									
<10K	$ 8.87	$ 7.10	$ 10.94	$ 4.58	$ 3.16	$ 5.89	$ 5.83	$ 4.47	$ 7.21
≥10k	$ 88.62	$ 71.28	$ 110.36	$ 50.27	$ 34.56	$ 64.77	$ 62.77	$ 48.10	$ 77.87
Total	$ 97.48	$ 78.39	$ 121.29	$ 54.85	$ 37.71	$ 70.66	$ 68.60	$ 52.57	$ 85.08
Alternative 1									
<10K	$ 37.35	$ 32.18	$ 42.51	$ 37.35	$ 32.18	$ 42.51	$ 37.35	$ 32.18	$ 42.51
≥10k	$ 351.05	$ 315.08	$ 387.08	$ 351.05	$ 315.08	$ 387.08	$ 351.05	$ 315.08	$ 387.08
Total	$ 388.41	$ 347.26	$ 429.59	$ 388.41	$ 347.26	$ 429.59	$ 388.41	$ 347.26	$ 429.59
Alternative 2									
<10K	$ 13.43	$ 11.19	$ 16.83	$ 8.81	$ 6.51	$ 11.10	$ 10.29	$ 8.19	$ 12.59
≥10k	$ 110.64	$ 92.44	$ 138.46	$ 72.20	$ 52.18	$ 91.81	$ 85.73	$ 67.68	$ 104.96
Total	$ 124.07	$ 103.63	$ 155.28	$ 81.01	$ 58.69	$ 102.91	$ 96.03	$ 75.87	$ 117.55
Alternative 4									
<10K	$ 4.37	$ 3.49	$ 5.49	$ 2.04	$ 1.38	$ 2.78	$ 2.84	$ 2.17	$ 3.57
≥10k	$ 36.15	$ 28.02	$ 45.64	$ 14.26	$ 9.54	$ 19.79	$ 20.87	$ 15.54	$ 26.63
Total	$ 40.52	$ 31.51	$ 51.13	$ 16.30	$ 10.93	$ 22.58	$ 23.71	$ 17.71	$ 30.20

Sources: Appendix O, Exhibits O.21, Column B and E.

7. Economic Impact Analysis

7.1 Introduction

As part of the rulemaking process, EPA is required to address the direct and indirect burdens that the LT2ESWTR may place on certain types of governments, businesses, and populations. This chapter presents the analyses performed by EPA in accordance with the following 12 Federal mandates:

1. The Regulatory Flexibility Act (RFA) of 1980, as amended by the Small Business Regulatory Enforcement Fairness Act (SBREFA) of 1996.
2. Analysis of small system affordability to determine variance technologies in accordance with Section 1415(e)(1) of the 1996 Safe Drinking Water Act (SDWA) Amendments.
3. Feasible technologies available to all systems as required by Section 1412(b)(4)(E) of the 1996 SDWA Amendments.
4. Technical, financial, and managerial capacity assessment as required by Section 1420(d)(3) of the 1996 Amendments to SDWA.
5. Paperwork Reduction Act (a separate Information Collection Request document contains the complete analysis).
6. Unfunded Mandates Reform Act (UMRA) of 1995.
7. Executive Order 13175 (Consultation and Coordination with Indian Tribal Governments).
8. Impacts on sensitive subpopulations as required by Section 1412(b)(3)(c)(i) of the 1996 SDWA Amendments.
9. Executive Order 13045 (Protection of Children from Environmental Health Risks and Safety Risks).
10. Executive Order 12898 (Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations).
11. Executive Order 13132 (Federalism).
12. Executive Order 13211 (Actions Concerning Regulations That Significantly Affect Energy Supply, Distribution, or Use).

Many of the requirements and executive orders listed above call for an explanation of why the rule is necessary, the statutory authority for the rule, and the primary objectives that the rule is intended to achieve (refer to Chapter 2 for more information regarding the objectives of the rule). More specifically, they are designed to assess the financial and health effects of the rule on sensitive, low-income, and Tribal populations as well as on small systems. The chapter also examines how much additional capacity systems will need to meet LT2ESWTR requirements and whether there are existing, feasible technologies and treatment techniques available to meet rule requirements.

7.2 Regulatory Flexibility Act and Small Business Regulatory Enforcement Fairness Act

The RFA generally requires an agency to prepare a regulatory flexibility analysis for any rule subject to notice and comment rulemaking requirements under the Administrative Procedure Act or other statute, unless the Agency certifies that the rule will not have a significant economic impact on a substantial number of small entities (5 U.S.C. 603(a)). Small entities include small businesses, small organizations, and small governmental jurisdictions.

The RFA provides default definitions for each type of small entity, discussed in more detail in Appendix H. Small entities are defined as: (1) a small business as defined by the Small Business Administration's (SBA) regulations at 13 CFR 121.201; (2) a small governmental jurisdiction that is a government of a city, county, town, school district, or special district with a population of less than 50,000; and (3) a small organization that is any "not-for-profit enterprise that is independently owned an operated and is not dominant in the field." However, the RFA also authorizes an agency to use alternative definitions for each category of small entity that "are appropriate to the activities of the Agency after proposing the alternative definition(s) in the *Federal Register* and taking comment" (5 U.S.C. §601(3)-(5)). In addition, to establish an alternative small business definition, agencies must consult with SBA's Chief Counsel for Advocacy. In assessing the impacts of the LT2ESWTR on small entities, EPA considered small entities to be PWSs serving 10,000 or fewer persons, which is the cut-off level specified by Congress in the 1996 Amendments to SDWA for small system flexibility provisions.

EPA conducted a screening analysis to determine if the LT2ESWTR would have a significant economic impact on a substantial number of small entities (see Appendix H). In this analysis, EPA evaluated the potential economic impact of the rule on small entities by comparing annualized compliance costs as a percentage of annual revenues[1] for different small-entity classifications. Chapter 4 of this EA provides data on small entities potentially subject to the LT2ESWTR, and Chapter 6 discusses actions systems would need to take to comply with the rule and their associated costs. Using information from these two chapters, along with additional information from the Safe Drinking Water Information System (SDWIS), the Community Water System Survey (CWSS), and the U.S. Census, EPA conducted a quantitative analysis of small system impacts resulting from the rule.

After considering the economic impacts of the LT2ESWTR on small entities based on the information presented in Appendix H, EPA certifies that the LT2ESWTR will not have a significant economic impact on a substantial number of small entities. The small entities directly regulated by the LT2ESWTR are small businesses, small organizations, and small governmental jurisdictions.

EPA has determined that 152 small entities, which are 2.3 percent of all small entities affected by the LT2ESWTR, will experience an impact of 1 percent or greater of average annual revenues. Majority of those systems, 105 of 152, will experience an impact between 1.0% and 1.5% of average annual revenues. Twenty eight systems will experience an impact between 1.5 % and 2.0% of average revenues. The Agency has determined that the remaining 18 small entities, which are 0.3 percent of all small entities subject to the LT2ESWTR, will experience an impact of 3 percent or greater of average annual revenues.

EPA is certifying that the LT2ESWTR will not lead to significant economic impacts for a substantial number of small entities, and, therefore is not required by the RFA, as amended by SBREFA, to conduct a final regulatory flexibility analysis (FRFA). Nevertheless, EPA has tried to reduce the impact of this rule on small systems.

Summary of the SBREFA Process

The RFA, as amended by SBREFA, and Section 203 of UMRA require EPA to provide small governments with an opportunity for timely and meaningful participation in the regulatory development process. EPA provided stakeholders, including small governments, with several opportunities to provide input on the LT2ESWTR. For example, EPA conducted three conference calls to solicit feedback and

---

[1] Revenue information was used whenever available. When it was not available, different measures, such as sales or annual operating expenditures, were used.

information from the Small Entity Representatives (SERs) on issues regarding LT2ESWTR impacts on small systems. SERs included small system operators, local government officials, and small nonprofit organizations.

During the first call, held on January 28, 2000, EPA presented an overview of the SDWA, as amended in 1996 and SBREFA. Issues and schedules for the LT2ESWTR rules were also discussed. The second call was held on February 25, 2000. EPA presented the stakeholders with an overview of the EPA regulatory development process and background on the development of the Stage 2 Microbial-Disinfectants/Disinfection Byproduct (M-DBP) Rules, particularly regarding health risks, issues and options identified by the Federal Advisory Committees Act (FACA) Committee, and Disinfection Byproduct (DBP) and microbial occurrence in small systems. The third meeting was held on April 7, 2000. EPA presented SERs with a cost estimate and an impact analysis for selected regulatory options. In addition, EPA presented SERs with schedules for the FACA and SBREFA processes.

These three conference calls generated a wide range of information, issues, and technical input from SERs. To provide SERs with a foundation for commenting on these rules, EPA gave them extensive background information. In general, the SERs were concerned about the impact of these rules on small water systems (because of their small staff and limited budgets); small systems' ability to acquire the technical and financial capability to implement this rule's requirements; maintaining the flexibility to tailor requirements to their needs; and general limitations of small systems. The Agency used the feedback received during these meetings in developing the LT2ESWTR. EPA also mailed a draft version of the preamble to the attendees of these meetings.

The Agency convened a Small Business Advocacy Review (SBAR) Panel, in accordance with the RFA as amended by SBREFA, to address small entity concerns, including those of small local governments. EPA convened the SBAR Panel after completing the consultation meetings with SERs on the LT2ESWTR. Eight of the small entities represented small governments. SERs' concerns were provided to the SBAR Panel when the panel convened on April 25, 2000.

7.3 Small-System Affordability

Section 1415(e)(1) of SDWA applies to most rules and allows States to grant variances to small water systems in lieu of complying with a maximum contaminant level (MCL) if EPA determines that no nationally affordable compliance technologies exist for that system size/water quality combination. The system must then install an EPA-listed variance treatment technology (Section 1412(b)(15)) that makes progress toward the MCL, if not necessarily reaching it. Section 1415(e)(6)(B) of SDWA, however, applies to the LT2ESWTR and states that a variance shall not be available under the above-noted subsection for a "national primary drinking water regulation for a microbial contaminant (including a bacterium, virus, or other organism) or an indicator or treatment technique for a microbial contaminant." This EA does not identify affordable compliance technologies or variance treatment technologies because the LT2ESWTR is a regulation to control a microbial contaminant.

7.4 Feasible Treatment Technologies for All Systems

In accordance with Section 1412(b)(4)(E) of the 1996 SDWA Amendments, EPA examined whether there were existing, feasible technologies and treatment techniques available that would allow systems to meet the LT2ESWTR requirements. EPA determined that filtered systems of all sizes could meet the LT2ESWTR requirements using ultraviolet light (UV). In addition, small systems could potentially meet the requirements using bag or cartridge filtration, while medium and large systems could use ozone. According to the toolbox of treatment techniques (described in Chapter 6), UV can achieve 3 log reduction of *Cryptosporidium*, bag and cartridge filtration may achieve up to a 2 log reduction, and ozone can achieve 2 log reduction. In fact, many small systems are predicted to choose cartridge filtration or UV as treatment techniques.

The LT2ESWTR requires unfiltered systems to use two disinfectants to meet *Cryptosporidium*, *Giardia*, and virus inactivation requirements, in which one disinfectant meets the full inactivation requirement of at least one of the three pathogens. Considering studies that show UV can achieve greater reduction of *Cryptosporidium* and *Giardia* at relatively low doses and chlorine can easily meet the virus inactivation requirement, it is feasible for unfiltered systems to achieve the two disinfectant requirement.

All uncovered finished water reservoirs can meet the LT2ESWTR requirements by covering their reservoirs or treating the effluent.

7.5 Effect of Compliance with the LT2ESWTR on the Technical, Managerial, and Financial Capacity of Public Water Systems

Section 1420(d)(3) of SDWA, as amended, requires that, in promulgating a National Primary Drinking Water Regulation (NPDWR), the Administrator shall include an analysis of the likely effect of compliance with the regulation on the technical, managerial, and financial (TMF) capacity of PWSs. The following analysis fulfills this statutory obligation by identifying the incremental impact that the LT2ESWTR will have on the TMF of regulated water systems. Analyses presented in this document reflect only the impact of new or revised requirements, as established by the LT2ESWTR; the impacts of previously established requirements on system capacity are not considered.

Overall water system capacity is defined in *Guidance on Implementing the Capacity Development Provisions of the Safe Drinking Water Act Amendments of 1996* (USEPA 1998c) as the ability to plan for, achieve, and maintain compliance with applicable drinking water standards. Capacity encompasses three components: technical, managerial, and financial. Technical capacity is the operational ability of a water system to meet SDWA requirements. Key issues of technical capacity include:

- Source water adequacy—Does the system have a reliable source of water with adequate quantity? Is the source generally of good quality and adequately protected?

- Infrastructure adequacy—Can the system provide water that meets SDWA standards? What is the condition of its infrastructure, including wells or source water intakes, treatment and storage facilities, and distribution systems? What is the infrastructure's life expectancy? Does the system have a capital improvement plan?

- Technical knowledge and implementation—Are the system's operators certified? Do the operators have sufficient knowledge of applicable standards? Can the operators effectively implement this technical knowledge? Do the operators understand the system's technical and operational characteristics? Does the system have an effective O&M program?

Managerial capacity is the ability of a water system's managers to make financial, operating, and staffing decisions that enable the system to achieve and maintain compliance with SDWA requirements. Key issues include:

- Ownership accountability—Are the owners clearly identified? Can they be held accountable for the system?

- Staffing and organization—Are the operators and managers clearly identified? Is the system properly organized and staffed? Do personnel understand the management aspects of regulatory requirements and system operations? Do they have adequate expertise to manage water system operations (i.e., to conduct implementation, monitor for *E. coli* and *Cryptosporidium*, install treatment, and cover or disinfect reservoir discharge to meet the LT2ESWTR requirements)? Do personnel have the necessary licenses and certifications?

- Effective external linkages—Does the system interact well with customers, regulators, and other entities? Is the system aware of available external resources, such as technical and financial assistance?

Financial capacity is a water system's ability to acquire and manage sufficient financial resources to allow the system to achieve and maintain compliance with SDWA requirements. Key issues include:

- Revenue sufficiency—Do revenues cover costs?

- Creditworthiness—Is the system financially healthy? Does it have access to capital through public or private sources?

- Fiscal management and controls—Are adequate books and records maintained? Are appropriate budgeting, accounting, and financial planning methods used? Does the system manage its revenues effectively?

7.5.1 Requirements of the LT2ESWTR

This capacity analysis is presented only for the Preferred Alternative, although EPA took similar considerations into account in the selection of the Preferred Alternative over the other alternatives. This process led to the incorporation of less expensive rule features for systems having fewer capabilities. For example, there is a possibility that a better, less burdensome indicator test for *Cryptosporidium* can be developed based on the results of the source water monitoring conducted by large systems. If that is the case, the burden on small systems will be less than that estimated here. Further, the schedule for small systems to begin monitoring is 2 years after large systems. This time extension may increase familiarity with these tests and perhaps lower the costs of laboratory analysis. Beyond the design of the rule, the options available for small systems to comply were factored into the decision tree of available technologies. The decision tree is discussed in detail in Chapter 6 and Appendix F.

This capacity analysis is based on the ICR occurrence data set. Analysis of the ICR data set predicts the highest level of *Cryptosporidium* occurrence and, therefore, the greatest challenges that water systems may face. Although two other data sets are available (ICR Supplemental Survey data for medium systems (ICRSSM) and ICR Supplemental Survey data for large systems (ICRSSL)), these project that fewer plants will need additional treatment and project fewer technical, financial, and managerial challenges. EPA used the ICR data set to develop the most conservative capacity impact analysis.

The LT2ESWTR establishes five new requirements that may affect the TMF capacity of affected PWSs:

1. Monitoring for *E. coli* (first or second round)

2. Monitoring for *Cryptosporidium* (first or second round)

3. Installing treatment (filtered systems)

4. Installing treatment (unfiltered systems)

5. Covering or disinfecting reservoir discharge

In addition, personnel from systems regulated under the LT2ESWTR will need to familiarize themselves with the rule and its requirements.

7.5.2 Systems Subject to the LT2ESWTR

The LT2ESWTR will apply to all PWSs that treat surface water or GWUDI. However, because systems purchasing surface water or GWUDI may incur costs through rate increases, EPA estimates that the LT2ESWTR may affect 5,378 CWSs, 766 NTNCWSs and 2,091 TNCWSs—8,235 filtered systems and 60 unfiltered systems in all (see Exhibits 4.3 and 4.5). While most will not, some systems may require increased TMF capacity to comply with the new requirements, or will need to tailor their compliance approaches to match their capacities. Refer to section 7.5.4 for a detailed discussion of the changes in TMF capacity for small and large systems.

7.5.3 Impact of the LT2ESWTR on System Capacity

The estimates presented in Exhibit 7.1 reflect the anticipated impact of the LT2ESWTR on system capacity based on the expected measures that systems will be required to adopt. The extent of the expected impact of a particular requirement on system capacity is estimated using a scale of 0-5, where 0 represents a requirement that is not expected to have any impact, 1 represents a requirement that is expected to have a minimal impact, and 5 represents a requirement that is expected to have a very significant impact on system capacity. Criteria used to develop the scores and associated impacts are discussed further in section 7.5.4.

Impacts are assessed separately for small systems (Exhibit 7.1a) and for large systems (Exhibit 7.1b). This distinction is necessary because most large systems will face fewer challenges in implementing the rule than most small systems. For both large and small systems, EPA evaluated the capacity impact of each requirement on those systems affected by that particular requirement. For example, EPA only evaluated the impact of the *Cryptosporidium* monitoring requirement on small systems that are required to monitor for *Cryptosporidium* as a consequence of the results of their *E. coli* monitoring. In many cases, the requirements only affect a small percentage of systems/plants. The exhibits, therefore, also display the number of systems and percent of systems/plants (of the subset of small or large systems/plants) estimated to be affected by each specific requirement.

Exhibit 7.1a: Estimated Impacts of the LT2ESWTR on Small Systems' Technical, Managerial, and Financial Capacity

(0 = no impact, 1 = minimal impact, and 5 = very significant impact)

Requirement	Number and Percent of Small Plants	Technical Capacity			Managerial Capacity			Financial Capacity		
		Source Water Adequacy	Infrastructure Adequacy	Technical Knowledge & Implementation	Ownership Accountability	Staffing & Organization	Effective External Linkages	Revenue Sufficiency	Credit Worthiness	Fiscal Mgmt. & Controls
Familiarization with requirements of the rule	5,663 (100.0%)[1]	0	0	1	0	1	0	0	0	0
Monitoring for *E. coli* (first and second round)	5,575 (97%)[2]	0	0	1	1	0	0	1	0	0
Monitoring for *Cryptosporidium* (first and second round)	1,978 (34%)[2]	0	0	2	1	0	1	3	0	2
Installation of treatment (filtered plants) (Bins 2 and 3)	2,069 (36%)	0	2	4	2	2	2	4	3	2
Installation of treatment (filtered plants) (Bin 4)	136 (2%)	0	4	4	2	3	3	5	4	3
Installation of treatment (unfiltered plants)	38 (0.6%)	2	4	4	3	3	3	5	4	5
Cover or disinfect reservoir discharge[1]	12 (0.2%)	0	4	3	2	3	3	5	4	3

[1]Number and percent of small systems.
[2]This cell contains only the number and percentage of plants expected to be affected by first-round monitoring requirements. The number of plants participating in the second round of monitoring is expected to be smaller. The rankings for capacity for monitoring include both the first and second rounds.
Note: To analyze the impact of these requirements on system capacity, the requirements believed to have the most and least impact on affected systems (i.e., the installation of treatment by plants placed into Bin 4, and familiarization with the requirements of the rule, respectively), were analyzed first, as described in section 7.5.4. These initial analyses were then used as the basis against which the relative impacts of the remaining requirements were assessed. The impact estimates developed for each requirement were also compared to the Stage 2 DBPR to ensure cross-rule consistency and enable cross-rule comparisons. Analysis is based on data modeled from the ICR data set, because that data set predicts the highest level of occurrence and, therefore, the greatest challenges systems will face.

Source: Number and percent of plants/systems impacted by each requirement are derived from systems serving #10,000 (Exhibit 6.2). Number and percent of small plants making treatment changes from Appendix G, Exhibits G.37–G.39 and unfiltered systems are derived from Exhibit 4.5. Number of systems required to cover or disinfect reservoir discharge are derived from Exhibit 4.25. Impact on capacity is determined relative to previous regulations based on the cost and number of systems/plants that require additional capacity to comply with each requirement, as described in section 7.5.4.

Exhibit 7.1b: Estimated Impacts of the LT2ESWTR on Large Systems' Technical, Managerial, and Financial Capacity

(0 = no impact, 1 = minimal impact, and 5 = very significant impact)

Requirement	Number and Percent of Large Plants	Technical Capacity			Managerial Capacity			Financial Capacity		
		Source Water Adequacy	Infrastructure Adequacy	Technical Knowledge & Implementation	Ownership Accountability	Staffing & Organization	Effective External Linkages	Revenue Sufficiency	Credit Worthiness	Fiscal Mgmt. & Controls
Familiarization with requirements of the rule[1]	1,493 (100%)	0	0	1	0	1	0	0	0	0
Monitoring for *E. coli* (first and second round)	1,733 (98%)[2]	0	0	1	1	0	0	0	0	0
Monitoring for *Cryptosporidium* (first and second round)	1,762 (99.6%)[2]	0	0	2	1	0	1	1	0	1
Installation of treatment (filtered plants) (Bins 2-4)	654 (33%)	0	3	3	2	3	2	2	2	2
Installation of treatment (unfiltered plants)	25 (0.4%)	2	3	4	3	3	3	3	2	3
Cover or disinfect reservoir discharge[1]	69 (5%)	0	3	4	2	1	2	3	2	3

[1]Number and percent of large systems.
[2]This cell contains only the number and percentage of plants expected to be affected by first-round monitoring requirements. The number of plants participating in the second round of monitoring is expected to be smaller. The rankings for capacity for monitoring include both the first and second rounds.
Note: To analyze the impact of these requirements on system capacity, the requirements believed to have the most and least impact on affected systems (i.e., the installation of treatment by plants placed into Bin 4, and familiarization with the requirements of the rule, respectively), were analyzed first, as described in section 7.5.4. These initial analyses were then used as the basis against which the relative impacts of the remaining requirements were assessed. The impact estimates developed for each requirement were also compared to the Stage 2 DBPR to ensure cross-rule consistency and enable cross-rule comparisons. Analysis is based on data modeled from the ICR data set, because that data set predicts the highest level of occurrence and, therefore, the greatest challenges systems will face.

Source: Number and percent of plants/systems impacted by each requirement are derived from systems serving #10,000 (Exhibit 6.2). Number and percent of large filtered plants making treatment changes from Appendix G, Exhibits G.37–G.39 and unfiltered systems are derived from Exhibit 4.5. Number of systems required to cover or disinfect reservoir discharge are derived from Exhibit 4.25. Impact on capacity is determined relative to previous regulations based on the cost and number of systems/plants that require additional capacity to comply with each requirement, as described in section 7.5.4.

7.5.4 Derivation of the LT2ESWTR Scores

EPA developed a 5-point scoring system to analyze the impact compliance with all new regulations will have on the technical, managerial, and financial capacity of PWSs. For each regulation, it is necessary to complete the following steps:

1. Determine the type and number of PWSs to which the regulation applies

2. List all of the requirements of the regulation

3. Determine the type and number of PWSs to which each requirement applies

4. Evaluate the impact of each requirement on the capacity of affected PWSs

The determination of the universe of affected systems and the evaluation of the capacity impact of individual requirements requires the use of the cost and technical information contained in SDWIS, EAs developed for other rules, information collection requests, and other supporting documentation for the rule. These data sources are also used to develop a qualitative description of the expected response of affected systems to each requirement.

The overall evaluation of the impact of a requirement on the affected systems, presented in Exhibit 7.1, is determined by the impact of each requirement on nine sub-categories of capacity—three sub-categories under each of the broader divisions of technical, managerial, and financial capacity. Within these sub-categories, a professional engineer with extensive water system experience reviewed the costs, number of systems affected, and complexity of each requirement. After estimating the technical, managerial, and financial impacts within each sub-category, the professional engineer assigned the scores using best professional judgment. Costs were considered cumulatively for each requirement for small and large systems. This score reflects the additional capacity that systems will need to develop to comply with each requirement. Due to a lack of available information on operating budgets, this analysis does not include a quantitative component.

To ensure the ability to make cross-rule comparisons, to standardize the assignment of numerical scores, and to minimize the subjectivity of the scoring system, the requirements made on systems by the regulation in question are compared to the requirements of those regulations for which capacity impact analyses have already been conducted (e.g., Ground Water Rule, and LT1ESWTR). Similar requirements were assigned similar impact scores.

These group assignments are reviewed by the EPA Rule Manager and other EPA staff cognizant of small system issues to ensure that they accurately reflect the cumulative impact of the rule requirements on system capacity. Any disagreements over the assignments are discussed. The EPA Rule Manager and other EPA staff discuss the rationale for the disagreement and evaluate whether the assignments need to be adjusted. EPA adjusts the assignments only after review of the rule support documents and an analysis of the expected system response to the rule requirements.

Small Water Systems (Those Serving 10,000 or Fewer People)

Most small systems will likely face only a minimal challenge to their technical and managerial capacity as a result of efforts to familiarize themselves with LT2ESWTR and comply with the requirements for monitoring of *E. coli* (Exhibit 7.1a). Systems monitoring for *Cryptosporidium*, however, will require additional assistance. In addition, systems with source waters that trigger them to monitor for *Cryptosporidium* will need to pay higher sampling costs since these systems have not previously performed the strict sampling protocols that are part of EPA's approved analytical method. To meet these challenges, it is likely that systems will need to develop or enhance linkages with technical and financial assistance providers (including State extension agents).

Exhibit 7.1a indicates that installation of some new treatment technologies will pose significant challenges to small systems' technical, managerial, and financial capacity; the less the current level of treatment, the greater the impact will be. As with *Cryptosporidium* monitoring, the development and enhancement of external linkages will be very important to systems that must install new equipment. Technical and financial assistance providers can help systems analyze their needs as well as the trade-offs between cost and health protection. In addition, they may be able to assist systems in finding the funding necessary to install and operate new equipment.

The requirement to obtain additional log-removal credits will likely challenge, to a significant degree, the financial capacity of some of the small systems affected. This is especially true since those systems may not have included the costs associated with complying with the LT2ESWTR in their long-term financial plans. Incurring these costs will tend to reduce a system's credit rating since it will be forced to direct more of its revenue to new equipment, and systems (or entities owning the systems) may be required to issue bonds or obtain loans. It is also evident from Exhibit 7.1a that the impacts of the LT2ESWTR on the capacity of systems assigned to Bins 2 to 4 will be similar.

The scores presented in Exhibit 7.1 apply to those (relatively few) systems most heavily affected. For example, of the very small systems (serving 500 or fewer people) that are required to add treatment technologies to comply with the requirements of Bins 2 and 3, 10 percent or fewer are predicted to install UV (see Appendix F). Of those very small systems that are predicted to require an additional 2.5 log treatment (as required by Bin 4), all must install UV. UV requires little involvement for the operator since UV can be monitored on-line. Only systems with the capability to handle this technology are expected to use it. The rest will be able to rely on low-cost, uncomplicated bag and cartridge filters.

Small plants serving between 500 and 10,000 people may install microfiltration or ultrafiltration (MF/UF) to comply; however, fewer than one-third of 1 percent of those requiring treatment are expected to choose MF/UF. MF/UF requires a daily integrity test during which finished water production must be interrupted, so only those few systems that have the capability would make such a choice. For those in Bin 4, only 1 percent are projected to use MF/UF, with 90 percent using UV and the rest using combinations of technologies.

Those few systems that do not now filter their water will be required to provide an additional 2 or 3 log disinfection under LT2ESWTR. In many cases, the financial capacity of these systems will be affected since they may need to revise their budgeting process to account for new capital and O&M expenses.

Systems that rely entirely on purchased water will experience negligible technical and managerial impacts, if any. The responsibility for implementing the necessary changes inherent in LT2ESWTR will fall upon those systems that sell water to other systems, not those that purchase it. The latter will not be responsible for implementing any technical changes and will only experience economic effects associated with their supplier's compliance with LT2ESWTR. Issues of sufficient revenue may arise; however, any additional costs that result will eventually be passed on to consumers, resulting in little effect on small purchased systems.

Finally, the TMF capacity of small systems required to cover a reservoir or to provide post-reservoir disinfection will be affected to approximately the same degree as the capacity of those filtered systems that must install additional treatment based on their action bin. In both cases, system staff will need to learn to operate and maintain new equipment. System management will need to ensure the presence of adequately trained staff and will need to explain the need for the additional equipment to customers and rate boards. The systems also will face significant new costs, potentially requiring adjustments to the rate structure, billing practices, and capital planning practices.

The overall impacts on small systems' technical, managerial, and financial capacity will vary. Monitoring and familiarization with new rules will have no significant effects on small systems, with the exception of moderate revenue constraints on those systems that need to implement monitoring for *Cryptosporidium*. It should be noted that all second-round monitoring will impose reduced impacts. The largest impacts will occur as a result of attaining 2.5 log treatment levels, covering uncovered reservoirs, or disinfecting reservoir discharge.

Large Water Systems (Those Serving at Least 10,000 People)

Large regulated systems will likely not face more than a minimal challenge to their technical and managerial capacity as a result of efforts to familiarize themselves with the LT2ESWTR and monitor for *E. coli* (Exhibit 7.1b). The three monitoring requirements established under the LT2ESWTR, however, vary substantially in their impact on system capacity. While measuring turbidity levels and monitoring coliforms will have a minimal effect, monitoring for *Cryptosporidium* may require increased system management, technical assistance, and cost of sampling. However, even the largest monitoring impacts will not be very significant. Those systems serving more than 100,000 people have already upgraded to meet *Cryptosporidium* monitoring needs (and collected such samples under the ICR); therefore, systems serving between 10,000 and 100,000 people will experience the majority of monitoring impacts.

Exhibit 7.1b shows that the installation of new treatment technology will pose moderate challenges to large systems' technical, managerial, and financial capacity. As with *Cryptosporidium* monitoring, the development and enhancement of external linkages will be very important to systems that must install new equipment.

The requirement to obtain additional log-removal credits will likely challenge the financial capacity of systems only to a small degree. Incurring costs might reduce a system's credit rating since it will be forced to direct more of its revenue to new equipment, and may be required to issue bonds or obtain loans. The LT2ESWTR will have essentially similar impacts on the capacity of large systems assigned to different action bins because similar technologies are expected to be installed in spite of varying requirements.

Large systems that rely on purchased water will experience only minimal impacts since the responsibility of meeting the requirements of LT2ESWTR will fall primarily on systems selling water. Systems purchasing water will experience only those economic effects associated with their supplier's compliance with LT2ESWTR and any additional costs will ultimately be applied to consumers. Therefore, the LT2ESWTR will have little effect on large systems purchasing water.

The capacity of systems required to install a cover or to provide post-reservoir disinfection will be affected to a greater degree than the capacity of those filtered systems that must install additional treatment. In both cases, system staff will need to learn how to operate and maintain new equipment. System management will need to ensure the presence of adequately trained staff and will need to explain the need for the additional equipment to customers and rate boards. Additionally, the systems will face significant new costs that could require adjustments to rate structures, billing practices, and capital planning methods.

Overall, EPA assumed that large systems will have the technical, financial, and managerial capacity to implement LT2ESWTR requirements based on the scale and complexity of their operations. The nature of their operations generally assures that they have access to the technical and managerial expertise to carry out all activities required by the LT2ESWTR. It is also generally easier for large systems to fund capital improvements than small systems, since costs can be spread over a larger customer base, making them smaller on a per-household basis.

7.6 Paperwork Reduction Act

The information collection requirements for the LT2ESWTR have been submitted for approval to the Office of Management and Budget (OMB) under the Paperwork Reduction Act, 44 U.S.C. 3501 *et seq.* The information collected as a result of this rule will allow the States/Primacy Agencies and EPA to determine appropriate requirements for specific systems and evaluate compliance with the rule.

The Paperwork Reduction Act requires EPA to estimate the burden on PWSs and States/Primacy Agencies of complying with the rule. Burden means the total time, effort, and financial resources required to generate, maintain, retain, disclose, or provide information to or for a Federal agency. This burden includes the time needed to conduct these activities:

- Review instructions
- Develop, acquire, install, and employ technology and systems for the purposes of collecting, validating, verifying, processing, maintaining, and disclosing information
- Adjust the existing ways to comply with any previously applicable instructions and requirements
- Train personnel to respond to information collected
- Search data sources
- Complete and review the collection of information
- Transmit or otherwise disclose the information

For the first 3 years after publication of the final LT2ESWTR in the *Federal Register*, the major information requirements pertain to implementation activities for States/Primacy Agencies and PWSs, covering uncovered finished water reservoirs, monitoring activities for large systems, and preparation for monitoring activities by small systems. The information collection requirements are mandatory under Part 141 of the NPDWRs. The calculation of LT2ESWTR information collection burden and costs can be found in the *Information Collection Request for the Long Term 2 Enhanced Surface Water Treatment Rule* (USEPA 2004b).

The total burden associated with LT2ESWTR requirements over the 3 years covered by the Information Collection Request is 423,886 hours, an average of 141,295 hours per year. The total cost over the 3-year clearance period is $34.1 million, an average of $11.4 million per year (simple average over 3 years). (These estimates are based on modeled results of the ICR *Cryptosporidium* occurrence data set.) EPA assumes that the systems affected by the LT2ESWTR have already purchased the basic equipment required for monitoring and reporting. Therefore, there are no capital start–up costs associated with information collection under this rule. The average burden per response (i.e., the amount of time needed for each activity that requires a collection of information) is 0.63 hours; the average cost per response is $50.35. Exhibit 7.2 provides a summary of the results of the Information Collection Request calculations.

Exhibit 7.2: Average Annual Burden Hours and Costs for the LT2ESWTR Information Collection Request

	Burden Hours	Labor Cost	Capital Cost	Non-Labor Cost	Average Annual Cost
Water Systems					
Implementation	19,236	$ 529,252	$ -	$ -	$ 529,252
E. coli monitoring	15,337	$ 317,941	$ -	$ 1,492,548	$ 1,810,489
Cryptosporidium monitoring	5,216	$ 144,370	$ -	$ 5,523,681	$ 5,668,051
Reporting	7,390	$ 209,252	$ -	$ -	$ 209,252
States and Territories					
Implementation	77,064	$ 2,589,722	$ -	$ -	$ 2,589,722
Reporting	16,796	$ 564,427	$ -	$ -	$ 564,427
Total	**141,295**	**$ 4,363,363**	**$ -**	**$ 7,016,230**	**$11,379,592**

Note: Data represent burden and cost for only the 3-year ICR clearance period. Data are based on nominal (or undiscounted) values. Detail may not add due to independent rounding.

Source: *Information Collection Request for the Long Term 2 Enhanced Surface Water Treatment Rule* (USEPA 2004a).

7.7 Unfunded Mandates Reform Act

The UMRA of 1995, Public Law 104-4, consists of four Titles and numerous sections. Sections 201 through 205 of Title II, entitled "Regulatory Accountability and Reform,"are relevant to the LT2ESWTRand are discussed in this section. Title II, Section 201 of the UMRA, requires 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 generally must prepare a written statement, including a cost-benefit analysis, for proposed and final rules with "Federal mandates" that may result in expenditures by State, Local, and Tribal governments, in the aggregate, or by the private sector, of $100 million or more in any 1 year. Section 203 requires the Agency to establish a small government agency plan before establishing any regulatory requirements that may significantly or uniquely affect small governments.

Section 204 of the UMRA requires the Agency to develop an effective process to permit elected officers of State, Local, and Tribal governments to provide meaningful and timely input in the development of regulatory proposals that contain significant Federal intergovernmental mandates. Finally, Section 205 generally requires EPA to identify and consider a reasonable number of regulatory alternatives and adopt the least costly, most cost-effective, or least burdensome alternative that achieves the objectives of the rule before promulgating a rule for which a written statement is needed under Section 202. The provisions of Section 205 do not apply when they are inconsistent with applicable law. Moreover, Section 205 allows EPA to adopt an alternative other than the least costly, most cost-effective, or least burdensome alternative if the Administrator publishes with the final rule an explanation why that alternative was not adopted.

EPA has determined that this rule contains a Federal mandate that 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, as shown in Exhibit 7.3.

Exhibit 7.3: Annualized Value of Public and Private Costs for the LT2ESWTR (Annualized at 3 and 7 Percent)

	Range of Annualized Costs (Million$, 2003$)								
	3% Discount Rate			7% Discount Rate			Percent of Total Cost		
Publicly Owned PWS Costs	$57.4	-	$82.7	$65.9	-	$88.6	61.8%	-	62.0%
State Costs	$1.1	-	$1.2	$1.4	-	1.4	1.2%	-	0.9%
Tribal Costs	$0.1	-	$0.2	$0.2	-	$0.3	0.2%	-	0.2%
Total Public Costs	**$58.6**	**-**	**84.1**	**$67.4**	**-**	**90.3**	**63.1%**	**-**	**63.0%**
Total Private Costs	**$34.3**	**-**	**49.4**	**$39.3**	**-**	**60.2**	**36.9%**	**-**	**37.0%**
Total Costs	**$92.9**	**-**	**$133.4**	**$106.8**	**-**	**150.5**	**100.0%**	**-**	**100.0%**

Note: The ranges reflect the difference between the ICRSSL (lowest) and ICR (highest) modeled *Cryptosporidium* occurrence distributions. The percentages of total cost in the last column were calculated only for the 3 percent discount rate. Detail may not add due to independent rounding.

Source: "Publicly owned PWS costs" are from the total system cost in Exhibit 6.4, multiplied by the proportion of PWSs that are publicly owned according to SDWIS. "State costs" are from Exhibit 6.4. "Tribal costs" are from Exhibit 7.9 for the high end of each range in this exhibit and are assumed to represent the same proportion of total costs in the low end of the range. "Total private costs" include costs for all privately owned PWSs and are calculated by subtracting total public costs from total costs.

Thus, the LT2ESWTR is subject to the requirements of Sections 202 and 205 of UMRA, and EPA is obligated to prepare a written statement addressing the following items:

- The authorizing legislation
- Benefit-cost analysis, including an analysis of the extent to which the costs of State, Local and Tribal governments will be paid for by the Federal government
- Estimates of future compliance costs and disproportionate budgetary effects
- Macroeconomic effects
- A summary of EPA's consultation with State, Local, and Tribal governments and their concerns, including a summary of the Agency's evaluation of those comments and concerns
- Identification and consideration of regulatory alternatives and the selection of the least costly, most cost-effective, or least burdensome alternative that achieves the objectives of the rule

The legislative authority for the LT2ESWTR is discussed in Chapter 2. The remaining items are discussed below, but are also addressed in other chapters of this EA, such as Chapters 3 and 6.

7.7.1 Social Benefits and Costs

The social benefits are those that accrue primarily to the public through increased protection from illness and potential death caused by exposure to microbial pathogens in drinking water. To assign a monetary value to the reductions in illness, EPA used a cost-of-illness measure. This is considered to be a lower-bound estimate of actual benefits because it does not include the pain and discomfort associated with the illness. Mortalities were valued using a value of statistical life estimate consistent with EPA policy. Chapter 5 presents the benefits analysis, which includes both qualitative and monetized benefits of improvements to health and safety. The potential nonquantifiable benefits may include reduced risks to sensitive subpopulations, reduced outbreak risks and response costs, reduced risk-averting behavior (e.g., boiling tap water or purchasing bottled water), reduced risk from co-occurring pathogens, increased source water monitoring, increased regulation of unfiltered systems, and covering or treating finished water reservoirs. In addition, certain nonhealth-related benefits may exist, such as enhanced aesthetic water quality. The estimated annualized quantified benefit for the traditional cost of illness (COI) for the Preferred Alternative of the LT2ESWTR using a 3-percent discount rate ranges from $335 to $1,341 million (or $272 to $1,089 million using a 7-percent discount rate) (Exhibit 7.4). Similarly, the estimated annualized quantified benefit using the enhanced COI ranges from $458 to $1,853 million (or $371 to $1,501 million using a 7-percent discount rate).

Measuring the social costs of the rule requires identifying affected entities by ownership (public or private), considering regulatory alternatives, calculating regulatory compliance costs, and estimating any disproportionate impacts. Chapter 6 of this document details the cost analysis performed for the LT2ESWTR. Under the Preferred Alternative, the likely compliance scenario is expected to result in total annualized costs of approximately $93 to $133 million using a 3-percent discount rate (or $107 to $150 million using a 7-percent discount rate). Exhibit 7.4 summarizes the range of annualized costs and benefits for each regulatory alternative.

Exhibit 7.4: Total Annualized Benefits and Costs of Regulatory Alternatives ($Millions, 2003$)

Regulatory Alternative	Enhanced COI Range of Annualized Benefits (3%)	Traditional COI Range of Annualized Benefits (3%)	Enhanced COI Range of Annualized Benefits (7%)	Traditional COI Range of Annualized Benefits (7%)	Range of Annualized Costs (3%)	Range of Annualized Costs (7%)
Alternative A1	$558 - $1,895	$403 - $1,369	$452 - $1,534	$327 - $1,112	$403	$436
Alternative A2	$489 - $1,871	$356 - $1,353	$396 - $1,515	$289 - $1,099	$123 - $163	$139 - $182
Alternative A3 (Preferred Alternative)	$458 - $1,853	$335 - $1,341	$371 - $1,501	$272 - $1,089	$93 - $133	$107 - $150
Alternative A4	$405 - $1,753	$299 - $1,273	$328 - $1,421	$243 - $1,034	$57 - $81	$68 - $93

Source: Benefits from Exhibits 5.28a-b. Costs from Exhibit 6.16.

Various Federal programs exist to provide financial assistance to State, Local, and Tribal governments in complying with this rule. The Federal government provides funding to States that have primary enforcement responsibility for their drinking water programs through the Public Water Systems Supervision (PWSS) Grants Program. States may use these funds to develop primacy programs or to contract with other State agencies to assist in the development or implementation of their primacy programs. However, they may not use these funds to contract with regulated entities (i.e., water systems). States may use PWSS Grants to set up and administer a State program that includes such activities as public education, testing, training, technical assistance, development and administration of a remediation grant and loan or incentive program (excluding the actual grant or loan funds), or other regulatory or nonregulatory measures.

Additional funding is available from other programs administered by EPA or other Federal agencies. These include EPA's Drinking Water State Revolving Fund (DWSRF), the U.S. Department of Agriculture's Rural Utilities' Loan and Grant Program, and the Department of Housing and Urban Development's Community Development Block Grant (CDBG) Program.

SDWA authorizes the EPA Administrator to award capitalization grants to States, which in turn can provide low-cost loans and other types of assistance to eligible PWSs. The DWSRF assists PWSs with financing the costs of infrastructure needed to achieve or maintain compliance with SDWA requirements. Each State has considerable flexibility to determine the design of its DWSRF Program and to direct funding toward its most pressing compliance and public health protection needs. States may also, on a matching basis, use up to 10 percent of their DWSRF allotments for each fiscal year to assist in running the State drinking water program. In addition, States have the flexibility to transfer a portion of funds from their Clean Water State Revolving Fund accounts to their DWSRF accounts.

A State can use the financial resources of the DWSRF to assist small systems. In fact, a minimum of 15 percent of a State's DWSRF grant must be used to provide infrastructure loans to systems serving 10,000 or fewer people. Two percent of the State's grant is set-aside funding that can only be used to provide technical assistance to small systems. In addition, up to 14 percent of the State's grant may be used to provide technical, managerial, and financial assistance to all system sizes. For small systems that are disadvantaged, up to 30 percent of a State's DWSRF may be used for increased loan subsidies. Tribes have separate set-aside funding that they can use under the DWSRF.

In addition to the DWSRF, money is available from the Department of Agriculture's Rural Utility Service (RUS) and Housing and Urban Development's CDBG Program. RUS provides loans, loan guarantees, and grants to improve, repair, or construct water supply and distribution systems in rural areas and towns with a population of up to 10,000 people. In fiscal year 2003, RUS had over $1.5 billion of available funds for water and environmental programs. Also, three sources of funding exist under the CDBG program to finance building and improvements of public facilities such as water systems. These include: 1) direct grants to communities with populations over 200,000; 2) direct grants to States, which in turn are awarded to smaller communities, rural areas, and coloñas in Arizona, California, New Mexico, and Texas; and 3) direct grants to U.S. territories and trusts. The CDBG budget for fiscal year 2003 totaled over $4.4 billion.

7.7.2 Disproportionate Budgetary Effects

UMRA is intended to reduce the burden on State, Local, and Tribal governments of Federal mandates that are not accompanied by adequate Federal funding. Section 202 of UMRA requires an analysis of possible disproportionate budgetary effects of certain classes of rules, in which LT2ESWTR falls.[2] Such an analysis is required if EPA determines that accurate estimates are reasonably feasible. The specific concern is disproportionate budgetary effects of the LT2ESWTR upon certain areas or industries:

- Any particular regions of the United States
- Any particular State, Local, or Tribal government
- Urban or rural or other types of communities
- Any segment of the private sector

This EA has considered how best to interpret and comply with these requirements. The remainder of this section describes ways to consider these requirements, whether meaningful data can be provided, and whether accurate estimates are possible. The general conclusion for this section, however, is that there are little basis and insufficient data to make accurate estimates of budgetary impacts that differ among groups, regions, governments, types of communities, or segments of the private sector. Further, from all of the Agency's analysis and consultations, the Agency believes the rule will treat similarly situated systems (in terms of size, water quality, available data, installed technology, and presence of uncovered finished reservoirs) in similar (proportionate) ways, without regard to geographic location, type of community, or segment of industry. The LT2ESWTR is a rule whose requirements are proportional to risk. In this analysis, the estimates of occurrence are different only for filtered and unfiltered systems, reflecting the judgment that differentiation along these other specific characteristics (regions, type of government, and so forth) is not possible with the available data. Although some groups may have differing budgetary effects as a result of the LT2ESWTR, those costs are proportional to the need for additional monitoring and the risk posed by *Cryptosporidium* occurrence.

Most of the following analyses begin with national data and then disaggregate those data, when possible, using other measures. Because the data and estimates are national in scope, breakouts by region or other parameters tend to be merely proportional extensions based on a characteristic, not "bottom-up" estimates of actual differences among types of systems, communities, or economic sectors. Thus, the analyses may not reveal true differences attributable to the impacts of the rule alternatives on various regions. Local conditions at each regulated entity will drive the actual cost impacts of the rule (e.g., the level of *Cryptosporidium* in the source water) and these data are not available. In fact, the LT2ESWTR

[2] "...[T]he agency shall prepare a written statement containing. . . (3) estimates by the agency, if and to the extent that the agency determines that accurate estimates are reasonably feasible, of. . . (B) any disproportionate budgetary effects of the Federal mandate upon any particular regions of the nation or particular State, Local, or Tribal government, urban or rural or other types of communities, or particular segments of the private sector..."

requires most systems to test their water to determine the impact of the rule on their system, a process that, in time, could generate that information.

When considering disproportionate impacts, it is necessary to consider whom the LT2ESWTR affects. The rule, by definition, covers some communities and a segment of the private sector. Most of those communities and PWSs that use surface water or GWUDI and those having uncovered finished water reservoirs will incur some costs. Communities and PWSs that use only ground water or have no uncovered finished water reservoirs will avoid these costs, although they may have to comply with other rules to which surface water systems may not be subject. In an economic sense, these differences between communities and utilities do not disadvantage one group over the other because the systems are not in a national market that allows for direct competition for customers. In general, those systems are better considered local natural monopolies.

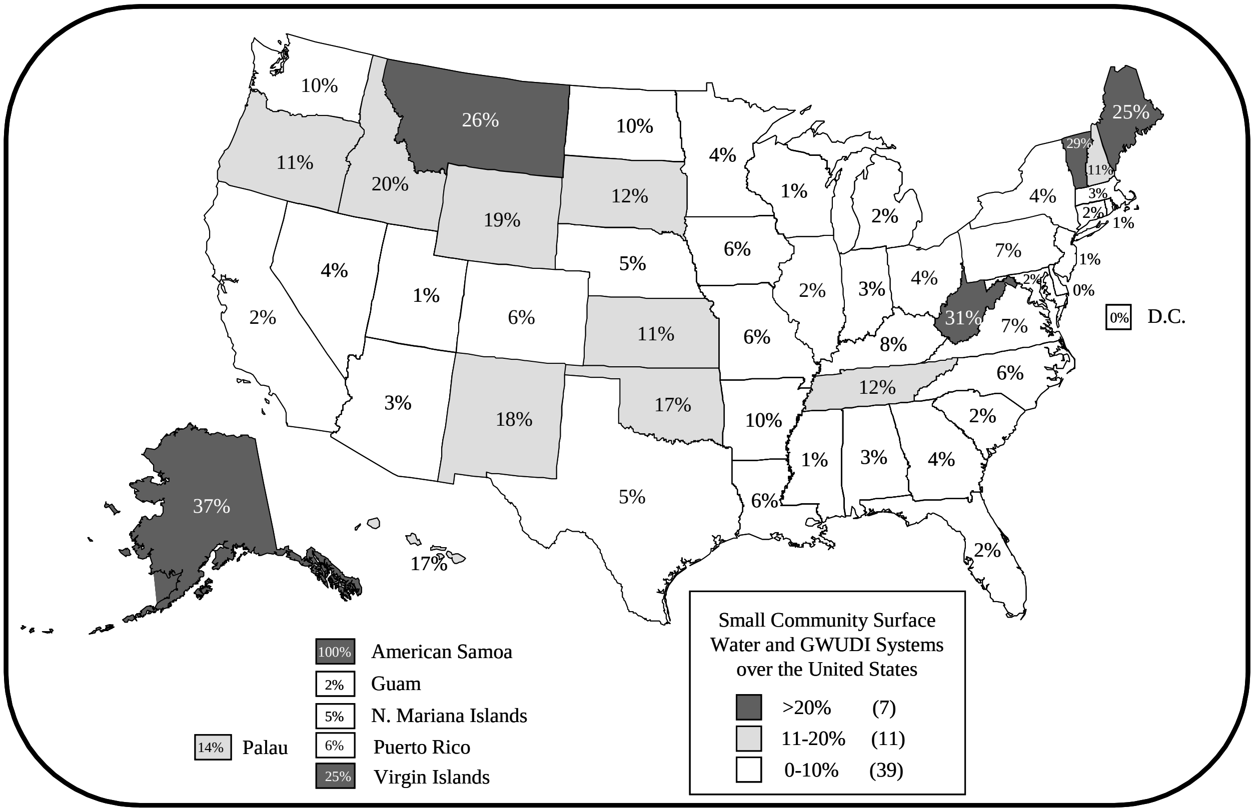
Regions

There are no specific data available that suggest that the compliance costs and other effects of LT2ESWTR will cause disproportionate budgetary effects by region. LT2ESWTR is a national mandate and applies uniformly to all States. These effects will be felt at the system level, with most systems primarily facing monitoring, rather than treatment, costs. Some contaminants in drinking water are distributed unevenly across regions. The data available on the occurrence of *Cryptosporidium*, however, indicate that it is prevalent nationwide. More data on *Cryptosporidium* occurrence will become available after the monitoring required by the rule is completed.

Although *Cryptosporidium* levels do not show strong regional patterns, it is still possible that budgetary effects could differ between regions. There is no direct measure of potential budgetary impacts by regions, but proxy measures are considered. One possible proxy for potential regional impacts is the projection that smaller systems will be subject to greater impacts on their financial capacity (including revenue sufficiency) (Exhibit 7.1a) and that small systems will face greater budgetary pressures, particularly if installing treatment, because of economies of scale (this effect is seen in higher average household costs for those served by small PWSs). Regions have varying proportions of small, medium, and large systems that supply public water. To the extent that some regions are more dependent on small systems, the regions as a whole could be considered more likely to face greater impacts on budgets of many small entities, even if there is no "regional budget."

To show what proxy measures based on dependency on small systems might reveal, two measures are used. The first is the percent of the population of a State that is served by small, rather than large, systems. Exhibit 7.5 indicates that the States that have more dependence on small water systems tend to be lower-population States such as Vermont, West Virginia, and Alaska. Most relevant to this analysis, no regional patterns are apparent.

Exhibit 7.5: Percent of Population of CWSs Served by Small Surface and GWUDI Systems by State



Source: Appendix M.

The second proxy measure used is the absolute number of small systems. Not surprisingly, this tends to correlate with high total population, with New York, California, and Texas among the largest. Again, no regional patterns are evident.

This analysis concludes that accurate estimates are not reasonably feasible, but significant regional impacts are not expected. Further, tests with proxy measures support the conclusion of no regional disproportionate budgetary impacts.

State, Local, or Tribal Governments

There is no expectation that there will be disproportionate budgetary effects upon State, Local, or Tribal governments. Costs are expected to be proportional to the risk *Cryptosporidium* occurrence poses, even if unevenly distributed among systems and perhaps types of systems. Furthermore, there are no accurate estimates to address the differing budgetary effects of LT2ESWTR on State, Local or Tribal governments.

There are few data available that bear on this issue. Exhibit 7.3 breaks out national-level costs for public PWSs, Tribal costs, and State costs, but only allocates costs to these categories rather than revealing any disproportionate impacts on the budgets of these groups. Exhibits 7.5 and 7.6 imply that State impacts will be larger to the extent that States contain a greater proportion of small systems. Even using dependence on small systems as a measure, an accurate distribution of potential impacts will not be available until after the monitoring phase is complete.

Urban and Rural

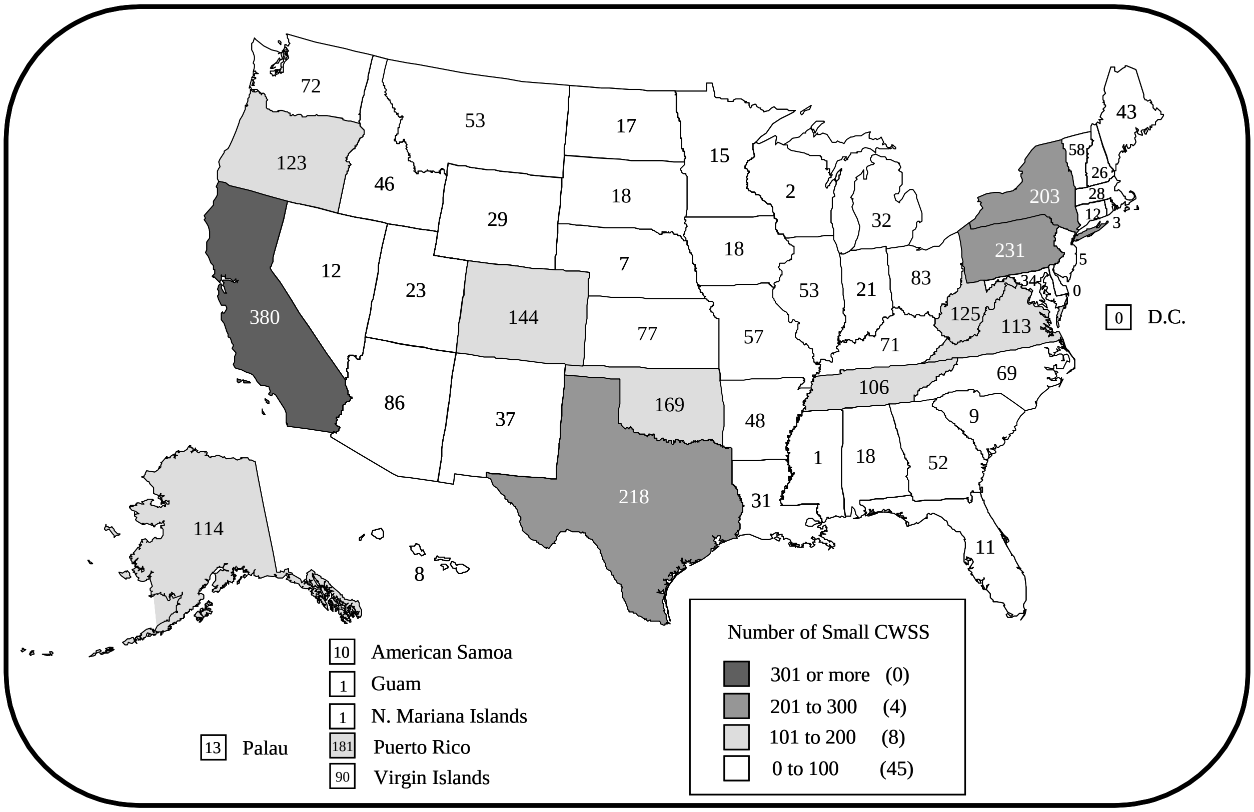
There are no data that distinguish between the budgetary effects of LT2ESWTR on urban versus rural areas, and there is no expectation that one kind of area will pay disproportionately higher costs than the other.

The only data available that may be relevant are the cost differences that are expected to exist between small and larger systems. The analyses in this EA, based on the *Technologies and Costs Document* (USEPA 2003a), estimate that there are economies of scale: as the population served increases, average costs of service decrease. If it is assumed that rural systems are smaller than urban systems, the latter may face smaller per-household costs than rural systems. However, this variation does not imply an effect that is disproportionate to risk. The variations in costs will not predominantly fall along the lines of population served (although population served can be used as a proxy), but will specifically depend on which treatment bin a water system is assigned to—depending on the level of treatment that systems' water needs. Further, many large systems are suburban systems, and many systems sell water to other, sometimes rural, systems. Again, there is no expectation of disproportionate budgetary impact, based on the design of the rule and known patterns of occurrence, and accurate estimates are not now feasible.

Segments of the Private Sector

Only one segment of the private economy is directly affected by this rule—drinking water providers. Section 7.5 discusses the budgetary impacts on this sector. An indirect indicator of the reasonableness of the cost of the LT2ESWTR is the agreement achieved by the Stage 2 M-DBP FACA Committee on major rule elements. Based on this agreement, the budgetary impact could not disproportionately affect drinking water providers since it is explicitly proportionate to risk.

Exhibit 7.6: Number of Small Surface and GWUDI Systems by State



Source: Appendix M.

7.7.3 Macroeconomic Effects

Under UMRA Section 202, EPA is required to estimate the potential macroeconomic effects of the regulation. These include effects on productivity, economic growth, full employment, and creation of Gross Domestic Product (GDP) (USEPA 2000d). Macroeconomic effects tend to be measurable in nationwide econometric models only if the economic impact of the regulation reaches 0.25 percent to 0.5 percent of GDP. In 2003, real GDP was $10,321 billion (U.S. Department of Commerce BEA 2004a); thus, a rule would have to cost at least $26 billion annually to have a measurable effect. A regulation with a smaller aggregate effect is unlikely to have any measurable impact, unless it is highly focused on a particular geographic region or economic sector. The LT2ESWTR should not have a measurable effect on the national economy; the total annualized costs for the Preferred Regulatory Alternative range from $93 to $133 million to $107 to $150 million using a 3 and 7 percent discount rate, respectively. Using these annualized figures as a measure, the annual cost of the LT2ESWTR is an insignificant fraction of a $26 billion annual cost that would be considered a measurable macroeconomic impact. Thus, annualized LT2ESWTR costs measured as a percentage of the national GDP will only decline over time as GDP grows.

7.7.4 Consultation with Small Governments

Before the Agency establishes any regulatory requirements that may significantly or uniquely affect small governments, including Tribal governments, it must have developed, under Section 203 of UMRA, a small government agency plan. The plan must provide for the notification of potentially affected small governments, enabling officials of affected small governments to have meaningful and timely input in the development of EPA regulatory proposals with significant Federal intergovernmental mandates and informing, educating, and advising small governments on compliance with the regulatory requirements. EPA consulted with small governments to address impacts of regulatory requirements in the LT2ESWTR that might significantly or uniquely affect small governments. A variety of stakeholders, including small governments, were provided with several opportunities to participate early in the regulatory development process, as described in section 7.2.

7.7.5 Consultation with State, Local, and Tribal Governments

Section 204 of UMRA requires the Agency to develop an effective process to permit elected officers of State, Local, and Tribal governments (or their designated authorized employees) to provide meaningful and timely input in the development of regulatory proposals that contain significant Federal intergovernmental mandates. Consistent with these provisions, EPA held consultations with affected governmental entities prior to proposal of the rule, as described in sections 7.2 and 7.8. EPA conducted four outreach conference calls, discussed in section 7.2, and contacted each of the 12 Native American Drinking Water State Revolving Fund Advisors to invite them, and representatives of their organizations, to participate in the meetings. In addition to the conference calls, EPA presented the LT2ESWTR at several health, environmental, and Native American conferences.

Representatives from State, Local, and Tribal governments were also involved in the development of the Agreement in Principle, which was created early in the regulatory process. EPA provided the Association of State Drinking Water Administrators (ASDWA) with an opportunity to comment before officially proposing the LT2ESWTR. EPA accepted comments from ASDWA and other Federal Advisory Committee Act (FACA) members, such as the National League of Cities (NLC), on a draft of the LT2ESWTR posted on its web site and, to the extent possible, comments were incorporated into the rule.

In addition to these efforts, EPA will educate, inform, and advise small systems, including those run by small governments, about the LT2ESWTR requirements. The Agency is developing plain-English guidance that will explain what actions a small entity must take to comply with the rule. Also, the Agency has developed fact sheets that concisely describe various aspects and requirements of the LT2ESWTR. Additional details on Tribal involvement in the rulemaking process can be found in section 7.8.

7.7.6 Regulatory Alternatives Considered

As required under Section 205 of UMRA, EPA considered several regulatory alternatives and numerous methods to identify systems most at risk to microbial contamination. Chapter 3 provides a detailed discussion of these alternatives. EPA chose the Preferred Regulatory Alternative because it provided substantial benefits at an acceptable level of costs. In addition, the FACA Committee recommended the Preferred Regulatory Alternative in the Stage 2 M-DBP Agreement in Principle.

7.7.7 Impacts on Small Governments

EPA has determined that this rule contains no regulatory requirements that might significantly or uniquely affect small governments. As described in section 7.2, EPA has certified that this rule will not have a significant economic impact on a substantial number of small entities. Estimated annual expenditures by small systems for the LT2ESWTR range from \$4.7 to \$9.2 million at a 3 percent discount rate. While the treatment requirements of the LT2ESWTR apply uniformly to both small and large

PWSs, large systems will bear most of the total costs of compliance with the rule. This is because large systems treat a majority of the drinking water that originates from surface water sources.

7.8 Indian Tribal Governments

Executive Order 13175, entitled "Consultation and Coordination with Indian Tribal Governments" (65 FR 67249; November 9, 2000), requires EPA to develop "an accountable process to ensure meaningful and timely input by Tribal officials in the development of regulatory policies that have Tribal implications." The Executive Order defines "policies that have Tribal implications" to include regulations that have "substantial direct effects on one or more Indian Tribes, on the relationship between the Federal government and the Indian Tribes, or on the distribution of power and responsibilities between the Federal government and Indian Tribes."

Under Executive Order 13175, EPA may not issue a regulation that has Tribal implications, that imposes substantial direct compliance costs, and that is not required by statute, unless the Federal government provides the funds necessary to pay the direct compliance costs incurred by Tribal governments, or EPA consults with Tribal officials early in the process of developing the proposed regulation and develops a Tribal summary impact statement.

EPA has concluded that this rule may have Tribal implications, because it may impose substantial direct compliance costs on Tribal governments. There are 93 Tribal water systems serving a population of 82,216 (see Exhibit 7.7). As presented in Exhibit 7.9a, they will bear an annualized cost of $227,365, at a 3 percent discount rate, to implement this rule ($334,265 at a 7 percent discount rate). Accordingly, EPA provides a Tribal summary impact statement as required by Section 5(b) of Executive Order 13175. The Federal government will not specifically provide the funds necessary to pay costs for Tribal systems associated with the LT2ESWTR because EPA consulted with Tribal officials early in the process of developing the regulation.

Exhibit 7.7: Numbers of Indian Tribal Public Water Systems Using Surface Water Sources

System Size (Population Served)	Number of Systems
Community Water Systems	
≤ 100	16
101 - 500	40
501 - 1000	11
1,001 - 3,300	13
3,301 - 10,000	4
Nontransient Noncommunity Water Systems	
≤ 100	2
101 - 500	1
1,001 - 3,300	1
Transient Noncommunity Water Systems	
≤ 100	1
101 - 500	2
1,001 - 3,300	1
10,001 - 50,000	1

Source: EPA SDWIS Database, September 2004.

EPA consulted with Tribal officials in a variety of ways to permit them to have meaningful and timely input into development of the LT2ESWTR. Tribes were able to have long-term input in the rule by participating in the Federal Advisory Committee. During the Las Vegas EPA/Inter-Tribal Council of Arizona in February 1999, a number of Tribal representatives requested that the All Indian Pueblo Council (AIPC) representative be the FACA representative for Federal Tribes, given his knowledge of drinking water systems. Approximately 20 Tribes are associated with the AIPC.

In addition to obtaining FACA Tribal input, EPA presented the LT2ESWTR at three conferences: the 16th Annual Consumer Conference of the National Indian Health Board, the National Tribal Environmental Council's Annual Conference in April 2000, and the EPA/Inter-Tribal Council of Arizona, Inc. Tribal consultation meeting. Over 900 attendees representing Tribes from across the country attended the National Indian Health Board's Consumer Conference, and representatives from over 100 Tribes attended the annual conference of the National Tribal Environmental Council. Finally, representatives from 15 Tribes participated at the EPA/Inter-Tribal Council of Arizona meeting. At the first two conferences, an EPA representative conducted two workshops on their drinking water program and upcoming regulations, including the LT2ESWTR. The presentation materials and meeting summary were sent to over 500 Tribes and Tribal organizations.

EPA distributed fact sheets describing the requirements of the LT2ESWTR and requested Tribal input at an annual EPA Tribal meeting in San Francisco and a Native American Water Works Association meeting in Scottsdale, Arizona. EPA also worked through its Regional Indian Coordinators and the National Tribal Operations Committee to mail fact sheets on the LT2ESWTR to all of the Federally recognized Tribes in November 2000.

After reviewing the fact sheets, a few Tribes requested more information and expressed concern about having to implement too many regulations. They were also concerned about infrastructure costs and the lack of funding attached to the rule. In response to a Tribal representative's comments, EPA explained the health protection benefits associated with the LT2ESWTR, which some members of the Tribal Caucus also noted. EPA directed Tribes to the Agreement in Principle on the EPA Web site for more information.

On January 24, 2002, EPA held a teleconference for Tribal representatives as another step in Tribal consultation. Prior to the teleconference, EPA send invitations to all Federally-recognized Tribes, along with fact sheets explaining the rule. Twelve Tribal representatives and four regional Tribal Program Coordinators attended the teleconference, requested further explanation of the rule, and expressed concerns about funding sources. EPA explained that capital projects related to the rule would rank high on lists of current funding sources due to the health risks associated with *Cryptosporidium*. Tribes also called EPA after the teleconference to provide additional feedback.

Tribal Summary Impact Statement

EPA performed an analysis to estimate the impact of the LT2ESWTR on Tribal systems. EPA has identified 93 Indian Tribal systems that might be subject to the LT2ESWTR. As seen in Exhibit 7.7, all but one Tribal system is classified as small (serving 10,000 or fewer people).

EPA has estimated the costs for Indian Tribal systems to comply with the LT2ESWTR, based on the assumption that the percentages of systems expected to incur costs for each size category will be the same for Tribal systems as for systems nationwide. The costs for Tribal systems are calculated in two steps. First, the number of Indian Tribal systems in each size category is multiplied by the percentage of systems nationally in each size category expected to incur costs for various rule activities (e.g., *E. coli* monitoring, *Cryptosporidium* monitoring, additional treatment). Second, the average cost of each rule requirement is multiplied by the number of Tribal systems expected to incur costs.

Exhibit 7.8 shows the percentage of systems expected to incur costs in various categories based on the ICR *Cryptosporidium* occurrence data set. For example, EPA projects that among systems serving 10,000 or fewer people, 34.3 percent would be triggered into monitoring for *Cryptosporidium* and 86.3 percent would conduct future *E. coli* monitoring. Among systems serving more than 10,000 people, 99.6 percent of plants would monitor for *Cryptosporidium* and 67.0 percent would conduct future *E. coli* monitoring.

Exhibits 7.9a and b show annualized costs per system for various compliance activities including implementation, monitoring, and treatment based on the ICR occurrence data set. Each cost has been annualized at 3 percent over 25 years. Costs for individual systems would vary around these averages, depending on the circumstances of the particular system. For example, *E. coli* monitoring costs would be lower for those systems that could do the analysis onsite, as opposed to shipping samples to a commercial laboratory, and only a fraction of small systems would be required to monitor for *Cryptosporidium*.

Many systems would incur no additional treatment costs, while a fraction would be required to provide additional treatment as a result of their bin assignment.

EPA estimates that total mean annualized costs per system range from $1,956 to $3,521 for CWSs, $1,947 to $2,390 for NTNCWSs, and $1,944 to $7,068 for TNCWSs. These costs result in an estimated total annualized cost to Indian Tribes, including Primacy Agency costs, of $227,365 for the LT2ESWTR, as shown in Exhibit 7.9a. (All costs in this paragraph are based on a 3-percent discount rate.)

Exhibit 7.8: Number of Tribal Systems and Percent of Systems Nationally That Will Incur Costs Due to the LT2ESWTR

System Size (Population Served)	Number of Tribal Systems	Percent of Systems Nationally Incurring Cost					
		Implemen-tation	Initial *E.coli* Monitoring[1]	Initial *Crypto* Monitoring[2]	Future *E. coli* Monitoring[3]	Future *Crypto* Monitoring	Adding Treatment[4]
≤10,000	92	100.00%	96.69%	34.30%	86.34%	30.05%	34.92%
>10,000	1	100.00%	98.10%	99.64%	66.99%	66.99%	34.90%

[1]All systems would be required to conduct *E. coli* monitoring, unless a system currently provides at least 5.5 log *Cryptosporidium* treatment.

[2]Small systems are required to monitor for *Cryptosporidium* only if source water *E. coli* concentration exceeds the trigger value. Based on the ICR occurrence data set, EPA estimates a maximum of 35 percent of systems that monitor for *E. coli* will be triggered into *Cryptosporidium* monitoring.

[3]Systems would be required to conduct another round of monitoring 6 years after the initial bin assignment. This monitoring would not be required for those systems that provide at least 5.5 log *Cryptosporidium* treatment.

[4]EPA estimates that 5.3 to 30.4 percent of all plants (including plants that purchase water) would incur costs for additional treatment as a result of being assigned to Bins 2-4.

Note: For systems serving more than 10,000 people, the percentages represent the probability that one system/plant will incur costs as a result of rule requirements.

Sources: Percentages derived from Exhibits 6.1 and 4.11. Percentages are assumed to be the same for Tribal plants/systems as for those nationwide.

Exhibit 7.9a: Estimates of the Total Annualized Costs Incurred by Indian Tribal Public Water Systems Due to the LT2ESWTR (Annualized at 3 Percent)

System Size	Number of Tribal Systems	Implementation Cost per System	Monitoring Cost per System	Future Monitoring Cost per System	Mean Cost per System - Treatment	Mean Cost per System - Total	Estimated Total Tribal Costs
(Population Served)	A	B	C	D	E	F = B+C+D+E	G = A*F
Total CWS	**84**						**$183,626**
–100	16	$10	$909	$909	$129	$1,956	$31,297
101-500	40	$11	$911	$911	$196	$2,029	$81,166
501-1,000	11	$14	$916	$916	$363	$2,208	$24,292
1,001-3,300	13	$14	$916	$916	$677	$2,522	$32,785
3,301-10,000 [1]	4	$14	$917	$917	$1,674	$3,521	$14,086
Total NTNCWS	**4**						**$8,300**
–100	2	$10	$909	$909	$120	$1,947	$3,894
101-500	1	$11	$911	$911	$182	$2,015	$2,015
1,001-3,300	1	$14	$916	$916	$545	$2,390	$2,390
Total TNCWS	**5**						**$15,180**
–100	1	$10	$909	$909	$117	$1,944	$1,944
101-500	2	$11	$911	$911	$174	$2,007	$4,014
501-1,000	1	$14	$916	$916	$309	$2,154	$2,154
10,001-50,000	1	$14	$876	$876	$5,303	$7,068	$7,068
Total Annualized Costs for All System Types							**$207,105**
Annualized Costs for One Primacy Agency [1]							**$20,260**
Total Annualized Tribal Costs							**$227,365**

Exhibit 7.9b: Estimates of the Total Annualized Costs Incurred by Indian Tribal Public Water Systems Due to the LT2ESWTR (Annualized at 7 Percent)

System Size (Population Served)	Number of Tribal Systems	Implementation Cost per System	Monitoring Cost per System	Future Monitoring Cost per System	Mean Cost per System - Treatment	Mean Cost per System - Total	Estimated Total Tribal Costs
	A	B	C	D	E	F = B+C+D+E	G = A*F
Total CWS	**84**						**$274,379**
¬100	16	$15	$1,358	$1,358	$192	$2,923	$46,765
100-499	40	$16	$1,362	$1,362	$293	$3,032	$121,280
500-999	11	$21	$1,368	$1,368	$542	$3,300	$36,298
1,000-3,299	13	$21	$1,368	$1,368	$1,011	$3,768	$48,989
3,300-9,999 [1]	4	$21	$1,370	$1,370	$2,502	$5,262	$21,047
Total NTNCWS	**4**						**$12,402**
¬100	2	$15	$1,358	$1,358	$179	$2,910	$5,819
100-499	1	$16	$1,362	$1,362	$272	$3,011	$3,011
1,000-3,299	1	$21	$1,368	$1,368	$814	$3,571	$3,571
Total TNCWS	**5**						**$22,802**
¬100	1	$15	$1,358	$1,358	$174	$2,905	$2,905
100-499	2	$16	$1,362	$1,362	$260	$2,999	$5,998
500-999	1	$21	$1,368	$1,368	$461	$3,218	$3,218
10,000-49,999	1	$21	$1,368	$1,368	$7,923	$10,681	$10,681
Total Annualized Costs for All System Types							**$309,583**
Annualized Costs for One Primacy Agency [1]							**$24,682**
Total Annualized Tribal Costs							**$334,265**

[1] The Primacy Agency cost for the one Tribe that has primacy is based on the average costs to State primacy agencies (total costs for the Preferred Alternative in Exhibits O.16a and O.19a divided by total number of primacy agencies (57)).
Note: Detail may not add to total due to independent rounding.

Sources:
[A] Number and categories of Tribal systems taken from SDWIS Database, September 2004.
[B] Implementation costs taken from Appendix D, Exhibit D.10, annualized, then divided by the total number of systems to calculate costs per system.
[C] Monitoring costs taken from Appendix D, Exhibits D.12, D.14, and D.16, annualized, then divided by the total number of systems to calculate costs per system.
[D] Future monitoring costs taken from Appendix D, Exhibits D.32, D.35, and D.38, annualized, then divided by the total number of systems to calculate costs per system.
[E] System costs taken from Appendix H, Exhibit H.1, annualized, then divided by the total number of systems to calculate costs per system.

7.9 Impacts on Sensitive Subpopulations

EPA's Office of Water has historically considered risks to sensitive subpopulations, including children) in establishing drinking water assessments, advisories or other guidance, and standards. Maximizing health protection for sensitive subpopulations requires balancing risks to achieve the recognized benefits of controlling waterborne pathogens while minimizing risk of potential DBP toxicity. A primary purpose of LT2ESWTR is to improve control of microbial pathogens, specifically the protozoan *Cryptosporidium.* The health effect of cryptosporidiosis on sensitive subpopulations is much more severe and debilitating than on the general population. These sensitive subpopulations include the young, the elderly (especially those weakened by other conditions), the malnourished and disease-impaired (especially those with diabetes), and a broad category of those with compromised immune systems, such as Acquired Immune Deficiency Syndrome (AIDS) patients, people with lupus or cystic fibrosis, transplant recipients, and individuals undergoing chemotherapy (Rose 1997). The Agency has evaluated several regulatory alternatives and selected the alternative that balances cost with providing significant benefits. It should be noted that the Stage 2 DBPR, which is being promulgated concurrently with this rule, reduces DBP concentrations in drinking water and achieves the goal of increasing the protection of children.

Research outlining the potential health benefits of the LT2ESWTR to both sensitive subpopulations and the general public is discussed in greater detail in the *Occurrence and Exposure Assessment for the Long Term 2 Enhanced Surface Water Treatment Rule* (USEPA 2003c) as well as in Chapter 5 of this EA.

7.9.1 Impacts on the Immunocompromised

As stated in Chapter 5, mortality as a result of cryptosporidiosis is a much greater risk for sensitive subpopulations, particularly for immunocompromised individuals, than it is for the general population. The duration and severity of the disease are significant: whereas the disease may hospitalize 1 percent of the immunocompetent population with very little risk of mortality among those hospitalized (<0.001), *Cryptosporidium* infections are associated with a high rate of mortality in the immunocompromised (50 percent) (Rose 1997).

The duration of cryptosporidiosis in those with compromised immune systems is considerably longer than in those with competent immune systems, with more severe symptoms often requiring lengthy hospital stays. For subpopulations that are immunocompromised, the cost of illness (COI) from cryptosporidiosis would be much greater than that for the general population. During a 1993 outbreak in Milwaukee, 33 AIDS patients with cryptosporidiosis accounted for 400 hospital-days at a cost of nearly $760,000 (Rose 1997). COI due to these hospital-days alone is estimated at $23,000 per patient ($760,000/33 patients). In addition, of the 54 deaths in the Milwaukee outbreak, 46 were AIDS patients.

Based on the severity of illness and the high costs of treatment experienced by the immunocompromised as a result of *Cryptosporidium* infection, the Agency expects LT2ESWTR to have a disproportionately positive impact on all sensitive subpopulations mentioned earlier.

7.9.2 Protection of Children from Environmental Health Risks and Safety Risks

Executive Order 13045 (62 FR 19885; April 23, 1997) applies to any rule initiated after April 21, 1998, that (1) is determined to be "economically significant" as defined under Executive Order 12866; and (2) concerns an environmental, health, or safety risk that EPA has reason to believe may have a disproportionate effect on children. If the regulatory action meets both criteria, EPA must evaluate the environmental, health, or safety effects of the planned rule on children, and explain why the planned regulation is preferable to other potentially effective and reasonably feasible alternatives considered by the Agency.

This final rule subject to the Executive Order because it is economically significant as defined in Executive Order 12866. As a matter of policy, EPA has examined the environmental health effects of *Cryptosporidium* on children. The risk of illness and death due to cryptosporidiosis depends on several factors including age, nutrition, exposure, genetic variability, disease, and the immune status of the individual.

Young children are of particular concern since they are more susceptible than adults to cryptosporidiosis, and the risk of mortality resulting from diarrhea is greatest in the very young and elderly (Rose 1997; Gerba et al. 1996; Fayer and Ungar 1986). Based on data presented in the *Occurrence and Exposure Assessment for the Long Term 2 Enhanced Surface Water Treatment Rule*

(USEPA 2003c), children under 5 years of age make up approximately 6.9 percent of the total population served by surface water and GWUDI sources. An infected child can also spread the disease to other children or family members, and evidence of such secondary transmission of cryptosporidiosis has been found in a number of outbreak investigations (Casemore 1990; Cordell et al. 1997; Frost et al. 1997).

During the 1993 Milwaukee drinking water outbreak, associated mortalities in children were reported. Also, children with laboratory-confirmed cryptosporidiosis were more likely to have an underlying disease that altered their immune status (Cicirello et al., 1997). In that study, the observed association between increasing age of children and increased numbers of laboratory-confirmed cryptosporidiosis suggested to the authors that the data are consistent with increased tap water consumption of older children. However, due to data limitations, this observation could not be adequately analyzed.

Chapell et al. (1999) found that prior exposure to *Cryptosporidium* through the ingestion of a low oocyst dose provides limited protection from infection and illness. It is not known, however, whether this immunity is life-long or temporary. Data also indicate that either mothers confer short-term immunity to their children or that babies have reduced exposure to *Cryptosporidium*, resulting in a decreased incidence of infection during the first year of life. For example, in a survey of over 30,000 stool sample analyses from different patients in the United Kingdom, the 1-5 year age group suffered a much higher infection rate than individuals less than 1 year of age. For children under 1 year of age, those older than 6 months showed a higher rate of infection than individuals aged fewer than 6 months (Casemore 1990). Children may be in contact with environmentally contaminated surfaces and may not have established immunity against the disease (DuPont et al. 1995). Although children consume less water than adults and would, therefore, be expected to have less exposure to *Cryptosporidium* oocycsts, studies show that cryptosporidiosis occurrence is greater in children (Casemore 1990).

EPA has not been able to quantify the health effects for children as a result of *Cryptosporidium*-contaminated drinking water. However, the result of the LT2ESWTR will be a reduction in the risk of illness for the entire population, including children. Because available evidence indicates that children may be more vulnerable to cryptosporidiosis than the rest of the population, the LT2ESWTR would, therefore, result in greater risk reduction for children than for the general population.

7.10 Environmental Justice

Executive Order 12898 (59 FR 7629) establishes a Federal policy for incorporating environmental justice into Federal agency missions by directing agencies to identify and address disproportionately high adverse human health or environmental effects of its programs, policies, and activities on minority and low-income populations. The Agency has considered environmental justice-related issues concerning the potential impacts of this action and consulted with minority and low-income stakeholders.

Two aspects of the LT2ESWTR comply with the order that requires the Agency to consider environmental justice issues in the rulemaking and to consult with stakeholders representing a variety of economic and ethnic backgrounds. These are: (1) the overall nature of the rule, and (2) the convening of a stakeholder meeting specifically to address environmental justice issues.

The Agency built on the efforts conducted during the development of the Interim Enhanced Surface Water Treatment Rule (IESWTR) to comply with Executive Order 12898. On March 12, 1998, the Agency held a stakeholder meeting to address various components of pending drinking water regulations and how they might impact sensitive subpopulations, minority populations, and low-income populations. This meeting was a continuation of stakeholder meetings that started in 1995 to obtain input on the Agency's Drinking Water Programs. Topics discussed included treatment techniques, costs and benefits, data quality, health effects, and the regulatory process. Participants were national, State, Tribal, municipal, and individual stakeholders. EPA conducted the meeting by video conference call among 11 cities. The major objectives for the March 12, 1998, meeting were the following:

- To solicit ideas from stakeholders on known issues concerning current drinking water regulatory efforts.
- To identify key areas of concern to stakeholders.
- To receive suggestions from stakeholders concerning ways to increase representation of communities in OGWDW regulatory efforts.

In addition, EPA developed a plain-English guide for this meeting to assist stakeholders in understanding the multiple and sometimes complex issues surrounding drinking water regulations.

The LT2ESWTR and other drinking water regulations promulgated or under development are expected to have a positive effect on human health regardless of the social or economic status of a specific population. The LT2ESWTR serves to provide a similar level of drinking water protection to all groups. Where water systems have high *Cryptosporidium* levels, they must treat their water to achieve a given level of protection. Further, to the extent that levels of *Cryptosporidium* in drinking water might be disproportionately high now among minority or low-income populations (which is unknown), the LT2ESWTR will work to remove those differences. Thus, the LT2ESWTR meets the intent of Federal policy requiring incorporation of environmental justice into Federal agency missions.

The LT2ESWTR applies uniformly to CWSs, NTNCWSs, and TNCWSs that use surface water or GWUDI as their source. Consequently, this rule provides health protection from pathogen exposure equally to all income and minority groups served by surface water and GWUDI systems.

7.11 Federalism

Executive Order 13132, "Federalism" (64 FR 43255; August 10, 1999), requires EPA to develop an accountable process to ensure "meaningful and timely input by State and Local officials in the development of regulatory policies that have Federalism implications." "Policies that have Federalism implications" are defined in the executive order to include regulations that have "substantial direct effects on the States, on the relationship between the national government and the States, or on the distribution of power and responsibilities among the various levels of government."

Under Section 6(b) Executive Order 13132, EPA may not issue a regulation that has Federalism implications, imposes substantial direct compliance costs, and is not required by statute, unless the Federal government provides the funds necessary to pay the direct compliance costs incurred by State and Local governments, or consults with State and Local officials early in the process of developing the regulation.

EPA has concluded that the LT2ESWTR may have Federalism implications because it will impose substantial direct compliance costs on State or Local governments. It contains a significant intergovernmental mandate under UMRA Section 202, i.e., it is likely to result in expenditure by State, Local, and Tribal governments in the aggregate of $100 million or more in any one year. The aggregate cost to these entities ranges from $93 to $133 million on average annually at a 3 percent discount rate.

Accordingly, EPA provides the following Federalism summary impact statement, as required by Section 6(b) of Executive Order 13132.

EPA consulted with State and Local officials early in the process of developing the LT2ESWTR to permit them to have meaningful and timely input into its development. On February 20, 2001, EPA held a dialogue with representatives of State and Local governmental organizations including those that represent elected officials. Representatives from the following organizations attended the consultation meeting: ASDWA, the National League of Cities (NLC), the National Governors' Association (NGA), the National Conference of State Legislatures (NCSL), the International City/County Management Association (ICMA), NLC, the County Executives of America, and health departments. Attendees posed questions ranging from a basic inquiry into how *Cryptosporidium* gets into water to more detailed queries about anticipated implementation guidance, procedures, and schedules. Some of the State and Local organizations that attended this meeting were also participants in the Stage 2 M-DBP Federal Advisory Committee and signed the Agreement in Principle. In addition, EPA consulted with a mayor in the SBREFA consultation. EPA considered all input from these consultations in the development of the LT2ESWTR.

7.12 Actions Concerning Regulations That Significantly Affect Energy Supply, Distribution, or Use

Executive Order 13211, "Actions Concerning Regulations That Significantly Affect Energy Supply, Distribution, or Use" (66 FR 28355; May 22, 2001), provides that agencies shall prepare and submit to the Administrator of the Office of Information and Regulatory Affairs, OMB, a statement of Energy Effects for certain actions identified as "significant energy actions." Section 4(b) of Executive Order 13211 defines "significant energy actions" as "any action by an agency (normally published in the *Federal Register*) that promulgates or is expected to lead to the promulgation of a final rule or regulation, including notices of inquiry, advance notices of proposed rulemaking, and notices of proposed rulemaking: (1)(i) that is a significant regulatory action under Executive Order 12866 or any successor order, and (ii) is likely to have a significant adverse effect on the supply, distribution, or use of energy; or (2) that is designated by the Administrator of the Office of Information and Regulatory Affairs as a significant energy action."

The LT2ESWTR has not been designated by the Administrator of the Office of Information and Regulatory Affairs as a significant energy action because it is not likely to have a significant adverse effect on the supply, distribution, or use of energy. This determination is based on the analysis presented below.

Energy Supply

The first consideration is whether the LT2ESWTR would adversely affect the supply of energy. The LT2ESWTR does not regulate power generation, either directly or indirectly, and the public and private PWSs that the LT2ESWTR regulates do not, as a rule, generate power. Further, the cost increases borne by customers of PWSs as a result of the LT2ESWTR are a low percentage of the total cost of water, except for a very few small systems that will need to spread the cost of installing advanced technologies over a narrow customer base. Therefore, those customers that are power generation utilities are unlikely to face any significant effects as a result of the LT2ESWTR. In summary, the LT2ESWTR does not regulate the supply of energy, does not generally regulate the utilities that supply energy, and is unlikely significantly to affect the customer base of energy suppliers. Thus, the LT2ESWTR would not would not adversely affect the supply of energy.

In response to the LT2ESWTR, some water utilities are expected to increase their energy use, and those impacts are discussed later in this section.

Energy Distribution

The second consideration is whether the LT2ESWTR would adversely affect the distribution of energy. The LT2ESWTR does not regulate any aspect of energy distribution. PWSs that are regulated by the LT2ESWTR already have electrical service. The rule is projected to increase peak electricity demand at PWSs by only 0.024 percent (see below). Therefore, EPA assumes that the existing connections are adequate and that the LT2ESWTR has no discernable adverse effect on energy distribution.

Energy Use

The third consideration is whether the LT2ESWTR would adversely affect the use of energy. Because some PWSs are expected to add treatment technologies that use electrical power, this potential impact of the LT2ESWTR on the use of energy requires further evaluation. The analyses that underlay the estimation of costs in Chapter 6 are national in scope and do not identify specific plants or systems that may install treatment in response to the LT2ESWTR. As a result, no analysis of the effect on specific energy suppliers is possible with the available data. The approach used to estimate the impact of energy use, therefore, also focuses on national-level impacts. It estimates the additional energy use due to the LT2ESWTR and compares that to the national levels of power generation in terms of average and peak loads.

The first step is to estimate the energy used by the technologies expected to be installed as a result of the LT2ESWTR. Energy use is not directly estimated in *Technologies and Costs Document* (USEPA 2003a), but the annual cost of energy for each technology addition or upgrade necessitated by the LT2ESWTR is provided. An estimate of plant-level energy use is derived by dividing the total energy cost per plant for a range of flows by an average national cost of electricity of $0.076 per kilowatt hour per year (kWh/y) (U.S. DOE EIA 2004a[3]). The energy use per plant for each flow range and technology is then multiplied by the number of plants predicted to install each technology in a given flow range. The energy requirements for each flow range are then added to produce a national total. No electricity use is subtracted to account for the technologies that may be replaced by new technologies, resulting in a conservative estimate of the increase in energy use. The results of the analysis are shown in Exhibit 7.10 for the ICR, ICRSSL, and ICRSSM *Cryptosporidium* occurrence data sets. The incremental national annual energy usage is estimated at 165,552 megawatt hours (MWh) for the ICR occurrence data sets.

Exhibit 7.11 provides a sample calculation for UV showing the increase in energy usage as a result of the LT2ESWTR.

To determine if the additional energy required for systems to comply with the rule would have a significant adverse effect on the use of energy, the numbers in Exhibit 7.10 are compared to the national production figures for electricity. According to the U.S. Department of Energy's Information Administration, electricity producers generated 3,848 million MWh of electricity in 2003 (USDOE EIA

[3] EPA is aware that DOE has updated its 2003 average national cost of electricity per kilowatt hour per year from $0.076 to $0.074. However, EPA continues to use the $0.076 value to maintain consistency with the Technologies and Cost Document.

2004b[4]). Therefore, even using the highest assumed energy use for the LT2ESWTR (165,551,898 kWh/y), the rule would result in only a 0.004 percent increase in annual average energy use when fully implemented. This calculation is shown below:

1. 165,551,898 kWh/y * (mWh/1,000 kWh) = 165,552 mWh/y

2. 165,552 MWh/y ÷ 3,848,000,000 MWh/y * 100 = 0.004%

Exhibit 7.10: Total Increased Annual National Energy Usage Attributable to the LT2ESWTR

Technology	Plants Selecting Technology A	Total Annual Energy Required (kWh/yr) B
UV	1,038	100,829,791
O_3 (0.5 log)	27	20,617,993
O_3 (1.0 log)	18	18,827,749
O_3 (2.0 log)	14	16,245,643
ME/UF	37	7,343,320
Bag Filters	1,523	1,605,380
Cartridge Filters	209	82,022
Total	2,867	165,551,898

Sources: [A] Plants selecting technology taken from Appendix G and Appendix I for uncovered finished water reservoirs predicted to disinfect instead of covering.
[B] Energy costs derived from the Technologies and Costs Document (USEPA 2003a). Energy costs were converted to energy usage by dividing the costs by the unit costs for energy listed in Table 4-3 of the Technologies and Costs Document. Energy usage is different for different size categories; the average per plant is the weighted average for all plants selecting the technology.

[4] EPA is aware that DOE has updated its estimate of total electricity produced in 2003 from 3,848 million to 3,883 million. However, EPA continues to use the 3,848 million estimate to maintain consistency with related electricity estimates used in this EA and the Technologies and Cost Document.

Exhibit 7.11: Sample Calculation for Determining Increase in Energy Usage (Plants Predicted to Add UV)

System Size (population served)	Average Daily Flow Flow per Plant (MGD)	Total Number of Plants	Number of Plants Selecting	Annual Energy Cost per Plant ($/plant/yr)	Annual Energy Requirement (kWhr/plant/yr)	Total Energy Usage for Plants Selecting (kWhr/year)
	A	B	C	D	E = D/$0.076 per kWhr	F=C*E
CWSs						
≤ 100	0.01	377	16	$ 82	1,082	16,801
101 - 500	0.03	771	37	$ 207	2,722	100,032
501 - 1,000	0.08	462	23	$ 416	5,478	123,363
1,001 - 3,300	0.24	1,128	111	$ 991	13,046	1,452,608
3,301 - 10,000	0.73	1,143	112	$ 2,304	30,322	3,391,442
10,001 - 50,000	2.81	1,198	361	$ 4,772	62,789	22,644,385
50,001 - 100,000	7.34	330	100	$ 9,521	125,273	12,517,834
100,001 - 1 Million	26.49	388	114	$ 23,618	310,761	35,455,004
> 1 Million	98.62	66	20	$ 82,270	1,082,497	22,004,695
NTNCWSs						
≤ 100	0.01	226	9	$ 81	1,060	9,240
101 - 500	0.03	312	13	$ 191	2,512	33,459
501 - 1,000	0.08	106	5	$ 406	5,348	24,203
1,001 - 3,300	0.20	91	8	$ 861	11,330	89,963
3,301 - 10,000	0.63	25	2	$ 2,054	27,020	58,944
10,001 - 50,000	3.33	5	1	$ 5,317	69,959	102,735
50,001 - 100,000	-	0	0	$ -	0	0
100,001 - 1 Million	22.94	1	0	$ 21,027	276,669	79,596
> 1 Million	-	0	0	$ -	0	0
TNCWSs						
≤ 100	0.00	1,273	60	$ 71	936	56,471
101 - 500	0.02	610	29	$ 169	2,226	64,366
501 - 1,000	0.08	107	5	$ 398	5,236	26,557
1,001 - 3,300	0.22	67	6	$ 907	11,938	73,807
3,301 - 10,000	0.59	19	2	$ 1,948	25,638	44,951
10,001 - 50,000	2.38	12	4	$ 4,325	56,909	204,313
50,001 - 100,000	-	0	0	$ -	0	0
100,001 - 1 Million	19.38	1	0	$ 18,436	242,581	71,091
> 1 Million	871.95	2	1	$ 283,182	3,726,077	2,183,930
TOTALS		**8,720**	**1,038**		**6,099,407**	**100,829,791**

Notes: Detail may not add due to independent rounding.

Sources: [A] The flows are taken from Exhibit 4.4a.
[B] The baseline numbers of filtered plants are taken from Exhibit 4.3, and added to the number of unfiltered plants, taken from Exhibit 4.5.
[C] Numbers of plants selecting UV are taken from Appendix G (Exhibits G.31–G.33).
[D] The electricity cost per plant is taken from the *Technologies and Costs Document* (USEPA 2003a).
[E] Electricity cost is $0.076/KWh, as presented in the *Technologies and Costs Document* (USEPA 2003a).

In addition to average energy use, the impact at times of peak demand is important. To examine whether increased energy usage might significantly affect the capacity margins of energy suppliers, their peak season generating capacity reserve was compared to an estimate of peak incremental power demand by water utilities. Both energy use and water use peak in the summer months, so the most significant effects on supply would be seen then. In the summer of 2003, U.S. generation capacity exceeded consumption by 15 percent, or approximately 160,000 MW (USDOE EIA 2004b[5]). Assuming around-the-clock operation of water treatment plants, the total energy requirement can be divided by 8,760 hours per year to obtain an average power demand of 19 MW for the modeled ICR occurrence distribution. Assuming that power demand is proportional to water flow through the plant and that peak flow can be as high as twice the average daily flow during the summer months, about 38 MW could be needed to operate treatment technologies installed to comply with the LT2ESWTR. This is only 0.024 percent of the capacity margin available at peak use. This calculation is presented below:

1. 165,551,898 kWh/y * (y/8,760 hr) * (MW/1,000 kW)*2 = 38 MW

2. 38 MW ÷ 160,000 MW * 100 = 0.024%

Although EPA recognizes that not all regions have a 15 percent capacity margin and that this margin varies across regions and over time, this analysis reflects the effect of the rule on national energy supply, distribution, and use. While certain areas, notably California, have experienced shortfalls in generating capacity in the recent past, a peak incremental power requirement of 38 MW nationwide is not likely to significantly change the energy supply, distribution, or use in any given area.

Conclusion

The LT2ESWTR is not a “significant energy action” as defined in Executive Order 13211, “Actions Concerning Regulations That Significantly Affect Energy Supply, Distribution, or Use” (66 FR 28355 May 22, 2001) because it is not likely to have a significant adverse effect on the supply, distribution, or use of energy (based on annual average use and conditions of peak power demand). Therefore, a statement of Energy Effects for the LT2ESWTR has not been prepared.

The total increase in energy usage by water systems as a result of the LT2ESWTR is predicted to be approximately 166 million kWh/y, which is less than five one-thousandths of 1 percent of the total energy produced in 2003. While the rule may have some adverse energy effects, EPA does not believe that this constitutes a significant adverse effect on the energy supply.

[5] EPA is aware that DOE has updated its estimate of capacity exceeding consumption in the summer of 2003 from 160,000 to 159,000 MW. However, EPA continues to use the estimate of 160,000 MW to maintain consistency with related electricity estimates used in this EA and the Technologies and Cost Document.

8. Comparison of Benefits and Costs of the LT2ESWTR

8.1 Introduction

This chapter presents several comparisons of the benefits and costs of the LT2ESWTR. Section 8.2 focuses on the benefits and cost comparisons of the Preferred Regulatory Alternative. Section 8.3 presents several analyses comparing the benefits and costs of all four regulatory alternatives, including multiple measures of cost-effectiveness in Section 8.3.2. The effect of uncertainties on these estimates is discussed in section 8.4. Finally, section 8.5 presents a summary of the conclusions from these analyses.

For comparison purposes, this chapter sometimes presents only mean estimates of benefits and costs. These estimates are discussed in Chapters 5 and 6, respectively. To avoid repetition, the following discussion assumes the reader is familiar with those chapters, the data sets used, and the analyses performed. The remaining sections of this chapter are organized as follows.

- 8.2 Summary of National Benefits, Costs, and Net Benefits of the Preferred Regulatory Alternative
  - 8.2.1 National Benefits Summary
  - 8.2.2 National Cost Summary
  - 8.2.3 National Net Benefits
- 8.3 Comparison of Regulatory Alternatives
  - 8.3.1 Comparison of Benefits and Costs
  - 8.3.2 Cost-Effectiveness Measures
- 8.4 Effect of Uncertainties on the Benefit-Cost Comparisons
- 8.5 Summary of Benefit and Cost Comparisons

8.2 Summary of National Benefits, Costs, and Net Benefits of the Preferred Regulatory Alternative

This section summarizes national benefits, costs, and net benefits of the Preferred Regulatory Alternative for the LT2ESWTR.

The rule will be implemented over time, not instantaneously, and therefore, the treatment costs incurred and benefits realized by the affected systems and population they serve will vary by year. Exhibits 8.1a and 8.1b summarize the undiscounted benefit and cost estimates incurred by systems, according to the implementation schedule (presented in Appendix O, Exhibit O.7-O.9), over the 25 year period analyzed in this EA. Exhibit 8.1a shows benefits calculated using the Enhanced cost of illness (COI) and 8.1b shows benefits calculated using the Traditional COI (section 5.3 explains the two COI values).

The analyses in this EA assume that implementation of this rule will begin in 2005. If implementation of the rule began a year or two later, the fundamental conclusions of the analysis would not be significantly changed. In the first several years, before systems have installed treatment, no benefits are realized, but costs are incurred for rule implementation and monitoring. Once systems begin to install treatment, illnesses and deaths are projected to be avoided in the year following installation of treatment and for each year thereafter. By 2015, all treatment is projected to have been installed;

therefore, starting in 2016, the level of illnesses and deaths avoided annually is estimated to be constant for the rest of the period of analysis (through 2029).

Exhibit 8.1a: Summary of Undiscounted Benefit and Cost Estimates by Year Incurred, Preferred Alternative, ICR Data Set, Enhanced COI[1] (Millions$, 2003$)

Year	Systems ≤10,000		Systems > 10,000		All systems	
	Benefits	Cost	Benefits	Cost	Benefits	Cost
	A	B	C	D	E=A+C	F=B+D
2005	$ -	$ 0.2	$ -	$ 44	$ -	$ 44
2006	$ -	$ 0.2	$ -	$ 49	$ -	$ 49
2007	$ -	$ 6	$ -	$ 54	$ -	$ 59
2008	$ -	$ 8	$ -	$ 143	$ -	$ 151
2009	$ -	$ 14	$ 218	$ 292	$ 218	$ 307
2010	$ -	$ 14	$ 677	$ 470	$ 677	$ 484
2011	$ -	$ 16	$ 1,394	$ 391	$ 1,394	$ 407
2012	$ 13	$ 29	$ 1,927	$ 391	$ 1,940	$ 420
2013	$ 39	$ 45	$ 2,464	$ 124	$ 2,503	$ 170
2014	$ 66	$ 47	$ 2,543	$ 80	$ 2,609	$ 127
2015	$ 106	$ 21	$ 2,590	$ 55	$ 2,696	$ 76
2016	$ 121	$ 8	$ 2,618	$ 54	$ 2,739	$ 62
2017	$ 136	$ 21	$ 2,646	$ 51	$ 2,782	$ 71
2018	$ 138	$ 22	$ 2,675	$ 48	$ 2,813	$ 69
2019	$ 139	$ 23	$ 2,705	$ 48	$ 2,844	$ 71
2020	$ 141	$ 9	$ 2,735	$ 48	$ 2,876	$ 57
2021	$ 142	$ 9	$ 2,765	$ 48	$ 2,908	$ 57
2022	$ 144	$ 9	$ 2,796	$ 48	$ 2,940	$ 57
2023	$ 146	$ 9	$ 2,827	$ 48	$ 2,973	$ 57
2024	$ 147	$ 9	$ 2,859	$ 48	$ 3,006	$ 57
2025	$ 149	$ 9	$ 2,891	$ 48	$ 3,040	$ 57
2026	$ 151	$ 9	$ 2,923	$ 48	$ 3,074	$ 57
2027	$ 153	$ 9	$ 2,956	$ 48	$ 3,109	$ 57
2028	$ 154	$ 9	$ 2,989	$ 48	$ 3,144	$ 57
2029	$ 156	$ 9	$ 3,023	$ 48	$ 3,179	$ 57

Note: Benefits increase each year due to the phasing in of installed treatment and the increases in real income growth, which directly affects COI and, though adjustments for income elasticity, also affects the VSL.

Exhibit 8.1b: Summary of Undiscounted Benefit and Cost Estimates by Year Incurred, Preferred Alternative, ICR Data Set, Traditional COI[1] (Millions$, 2003$)

Year	Systems ≤10,000		Systems > 10,000		All systems	
	Benefits	Cost	Benefits	Cost	Benefits	Cost
	A	B	C	D	E=A+C	F=B+D
2005	$ -	$ 0.2	$ -	$ 44	$ -	$ 44
2006	$ -	$ 0.2	$ -	$ 49	$ -	$ 49
2007	$ -	$ 6	$ -	$ 54	$ -	$ 59
2008	$ -	$ 8	$ -	$ 143	$ -	$ 151
2009	$ -	$ 14	$ 162	$ 292	$ 162	$ 307
2010	$ -	$ 14	$ 503	$ 470	$ 503	$ 484
2011	$ -	$ 16	$ 1,032	$ 391	$ 1,032	$ 407
2012	$ 9	$ 29	$ 1,422	$ 391	$ 1,431	$ 420
2013	$ 27	$ 45	$ 1,814	$ 124	$ 1,841	$ 170
2014	$ 46	$ 47	$ 1,867	$ 80	$ 1,913	$ 127
2015	$ 74	$ 21	$ 1,896	$ 55	$ 1,970	$ 76
2016	$ 84	$ 8	$ 1,913	$ 54	$ 1,997	$ 62
2017	$ 94	$ 21	$ 1,930	$ 51	$ 2,024	$ 71
2018	$ 95	$ 22	$ 1,947	$ 48	$ 2,042	$ 69
2019	$ 96	$ 23	$ 1,964	$ 48	$ 2,060	$ 71
2020	$ 97	$ 9	$ 1,981	$ 48	$ 2,078	$ 57
2021	$ 98	$ 9	$ 1,999	$ 48	$ 2,096	$ 57
2022	$ 98	$ 9	$ 2,016	$ 48	$ 2,115	$ 57
2023	$ 99	$ 9	$ 2,034	$ 48	$ 2,134	$ 57
2024	$ 100	$ 9	$ 2,052	$ 48	$ 2,153	$ 57
2025	$ 101	$ 9	$ 2,071	$ 48	$ 2,172	$ 57
2026	$ 102	$ 9	$ 2,089	$ 48	$ 2,191	$ 57
2027	$ 103	$ 9	$ 2,108	$ 48	$ 2,211	$ 57
2028	$ 104	$ 9	$ 2,126	$ 48	$ 2,230	$ 57
2029	$ 105	$ 9	$ 2,145	$ 48	$ 2,250	$ 57

Note: [1] The Traditional COI only includes valuation for medical costs and lost work time (including some portion of unpaid household production). The Enhanced COI also factors in valuations for lost personal time (non-work time) such as childcare and homemaking (to the extent not covered by the traditional COI), time with family, and recreation, and lost productivity at work on days when workers are ill but go to work anyway.

Sources:
[A] and [C] Exhibit C.17a (Enhanced) and C.17b (Traditional)
[B] and [D] Undiscounted State (O.4a), implementation and monitoring (O.5a), and treatment (O.6a) multiplied by Schedules (O.7-O.9)

8.2.1 National Benefits Summary

The quantified benefits of the LT2ESWTR derive from the reduction in the incidence of adverse health effects, specifically the endemic morbidity and mortality from cryptosporidiosis, attributable to consumption of drinking water from the PWSs affected by the rule. However, the value of other additional benefits that cannot be quantified (and therefore cannot be reflected explicitly in quantitative benefit-cost comparisons) are likely to be substantial. Exhibit 8.2 summarizes the nonquantified benefits and Chapter 5 (section 5.6.6) describes them in more detail. In every comparison of benefits and costs, these real, but nonquantified, benefits must be considered in addition to those that are quantified.

Exhibit 8.2: Summary of Nonquantified Benefits and Groups Affected

Type of Benefit	Nonquantified Benefits	Group(s) Affected
Health related	Reduction in risk of illness to sensitive subpopulations (although mortality for those with AIDS and other although sensitive subpopulations has been included)	Immunocompromised individuals served by systems that make changes to or add treatment.
	Reduction in health risk during outbreaks (and in related response costs)	All individuals served by systems that make changes to or add treatment, including those now served by uncovered finished water reservoirs, (between 34 and 55 million people).
	Reduction in co-occurring/emerging pathogen risk	
	Reduction in endemic morbidity and mortality risk associated with uncovered finished water reservoirs	All individuals receiving water from uncovered finished water reservoirs.
	Reduction in health risks from certain DBPs	All individuals served by systems that install physical disinfection technologies like membranes or UV[1]
Nonhealth related	Improved aesthetic water quality	All individuals served by systems that make changes to or add treatment that is likely to reduce taste and odor problems (e.g., ozone).
	Reduced costs of risk-averting behaviors	Consumers in systems that cease using uncovered finished water reservoirs (through covering or taking such reservoirs off-line) my have greater confidence in water quality. This may result in less averting behavior that reduces both out-of-pocket costs (e.g., purchase of bottled water) and opportunity costs (e.g., time to boil water).

[1] Systems that install chemical disinfection technologies like ozone may increase certain DBPs.

Before reviewing benefits, some reminders are necessary to understand the graphs and tables that follow in this chapter. First, quantified benefits have been calculated separately for each of the three occurrence data sets, two COI values, and two discount rates. Second, the underlying results are in the form of distributions of numbers. These values are obtained from a two-dimensional Monte Carlo simulation, the dimensions being variability and uncertainty. To give a sense of the extent of the distributions, data are summarized using central tendency estimates and usually some bounding information. For example, in many exhibits, data are expressed using mean values, which is based on the 5th and 95th percentiles of a distribution of possible values resulting from the Monte Carlo simulation. The mean value represents the best estimate of benefits, and the 5th and 95th percentiles capture the 90 percent confidence interval of the distribution reflecting uncertainty in that best estimate.

Exhibit 8.3 shows two kinds of estimates. One is the average number of cases avoided annually once the rule is fully implemented (i.e., when all treatment changes are operational) and the second is the annual average over the 25 year period. The second set of estimates is lower because the rule is implemented over time, not instantly. This figure is the simple average of the illnesses and deaths avoided over the first 25 years, including years in which no treatment is yet installed, years in which varying percentages of treatment have been installed, and years at full implementation.

Exhibit 8.3: Summary of Annual Avoided Illnesses and Deaths, Preferred Alternative

	Annual Illnesses Avoided			Annual Deaths Avoided		
		90 % Confidence Bound			90% Confidence Bound	
Data Set	Mean	Lower (5th %ile)	Upper (95th %ile)	Mean	Lower (5th %ile)	Upper (95th %ile)
Annual Total after Full Implementation						
ICR	964,360	149,241	2,277,367	207	34	468
ICRSSL	230,730	38,281	521,925	52	9	113
ICRSSM	455,170	72,128	1,112,374	100	17	230
Annual Average over 25 years						
ICR	712,732	109,486	1,685,176	154	25	348
ICRSSL	170,977	28,314	392,979	39	7	85
ICRSSM	336,652	52,763	826,004	74	12	172

Sources: Appendix C, Exhibit C.4 and C.5, Columns A-F. Annual Average derived from Exhibits C.4 (and C.5) and Exhibit O.9 (O&M schedules).

Exhibits 8.4a and 8.4b monetize these avoided illness and death estimates and present their annualized values using 3 and 7 percent discount rates and Enhanced and Traditional COI values. The calculation also includes factors for income growth and income elasticity that vary by year. The COI values are applied to cases of illness avoided, and a distribution of undiscounted estimates for Value of a Statistical Life (VSL) (represent uncertainty in the estimate) is applied to deaths avoided. The initial value for COI is a constant, but its value of lost time in any year is adjusted to reflect growth in real income as described in Chapter 5. The VSL also considers the long-term growth in real income and includes a portion of that growth using an income elasticity analysis, as described in Chapter 5. The data in Exhibit 8.4 represent the monetized values from each year, discounted to the year 2003 (to obtain present values) and then annualized over the 25 year period. These figures represent the annualized value of the estimated annual number of illnesses and deaths avoided according to the rule schedule. (That is, they are the annualized values of the undiscounted benefit data presented in Exhibit 8.1.)

Exhibit 8.4a: Summary of Quantified Benefits, Preferred Alternative—Enhanced Cost of Illness[1]

Data Set	Value of Benefits—Enhanced COI[1] ($ Millions, 2003$) Mean	90% Confidence Bound Lower (5th %ile)	90% Confidence Bound Upper (95th %ile)
Annualized Value (at 3%, 25 Years)			
ICR	$ 1,853	$ 224	$ 4,941
ICRSSL	$ 458	$ 55	$ 1,242
ICRSSM	$ 886	$ 103	$ 2,420
Annualized Value (at 7%, 25 Years)			
ICR	$ 1,501	$ 181	$ 3,998
ICRSSL	$ 371	$ 45	$ 1,005
ICRSSM	$ 718	$ 84	$ 1,961

Exhibit 8.4b: Summary of Quantified Benefits, Preferred Alternative—Traditional Cost of Illness[1]

Data Set	Value of Benefits—Traditional COI[1] ($ Millions, 2003$) Mean	90% Confidence Bound Lower (5th %ile)	90% Confidence Bound Upper (95th %ile)
Annualized Value (at 3%, 25 Years)			
ICR	$ 1,341	$ 128	$ 3,929
ICRSSL	$ 335	$ 31	$ 989
ICRSSM	$ 644	$ 58	$ 1,919
Annualized Value (at 7%, 25 Years)			
ICR	$ 1,089	$ 104	$ 3,195
ICRSSL	$ 272	$ 25	$ 802
ICRSSM	$ 523	$ 47	$ 1,559

Notes: [1] The Traditional COI includes values for medical costs and lost work time (including a portion of unpaid household production). The Enhanced COI also includes values for lost personal time (non-work time) such as child care and homemaking (to the extent not covered by the Traditional COI), time with family, and recreation, and lost productivity on days when workers are ill but go to work anyway.
Sources: Exhibit C.4 (3%) and C.5 (7%), Columns M-O.

8.2.2 National Cost Summary

Exhibit 8.5 presents a national cost summary that reflects all costs estimated for promulgating the LT2ESWTR. The costs shown are based on detailed information presented in Chapter 6 for the Preferred Regulatory Alternative. The total national costs of the LT2ESWTR include those associated with implementation, monitoring for bin classification, covering reservoirs, and additional treatment.

As with the benefit estimates, the estimates of the national annualized costs of the LT2ESWTR are not point estimates, but are best characterized as distributions. Uncertainty in the occurrence estimates, together with uncertainty in the estimates of capital and operation and maintenance (O&M) unit costs, contributed to the uncertainty estimated for the national costs. (See section 6.11 for further explanation of the distribution of cost estimates.)

Exhibit 8.5 summarizes cost information in four ways. The first block of estimates is the total undiscounted capital and one-time costs in 2003 dollars. The second block is for total annual O&M costs once all treatment has been installed (again in 2003 dollars). Because both capital/one-time costs and O&M costs occur over time, these figures are also discounted to present values (Year 2003 dollars), and then annualized over 25 years. The annualized costs (at both 3- and 7-percent discount rates) are shown in the last two blocks of information.

Exhibit 8.5: Summary of the Costs for the LT2ESWTR Preferred Regulatory Alternative ($Millions, 2003$)

Data Set	Total Capital and One-Time Costs (At Full Implementation)			Annual Operations and Maintenance Costs (At Full Implementation)			Annualized Cost					
							3 percent, 25 Years			7 Percent, 25 Years		
		90 Percent Confidence Bound			90 Percent Confidence Bound			90 Percent Confidence Bound			90 Percent Confidence Bound	
	Mean	Lower (5th %ile)	Upper (95th %ile)	Mean	Lower (5th %ile)	Upper (95th %ile)	Mean	Lower (5th %ile)	Upper (95th %ile)	Mean	Lower (5th %ile)	Upper (95th %ile)
ICR	$ 2,104	$ 1,715	$ 2,425	$ 55	$ 48	$ 64	$ 133	$ 111	$ 160	$ 150	$ 125	$ 181
ICRSSL	$ 1,526	$ 1,164	$ 1,743	$ 33	$ 26	$ 39	$ 93	$ 72	$ 112	$ 107	$ 83	$ 129
ICRSSM	$ 1,719	$ 1,372	$ 1,941	$ 39	$ 33	$ 45	$ 106	$ 86	$ 126	$ 121	$ 99	$ 144

Sources: Exhibit 8.11 (A3-Preferred).

8.2.3 National Net Benefits

Net benefits are the difference between the estimated value of human health benefits from the LT2ESWTR and the estimated costs of complying with the rule. The net benefit calculations use the estimate of quantified benefits only and do not include nonquantified benefits. All of the comparisons that follow, therefore, should be considered in the light of the additional benefits that are likely attributable to this rule but were not quantified.

The overall conclusion from the analyses of net national benefits is that the LT2ESWTR meets a basic economic threshold condition: benefits are very likely to exceed costs. The first set of tables shows the net benefits for the Preferred Alternative based on the mean estimate of annualized benefits, less the mean estimate of annualized costs (Exhibits 8.6a and 8.6b).

Benefits and costs were not computed within the same model, and the confidence bounds characterizing the uncertainty in the mean benefits and cost estimates cannot be compared directly in a meaningful way. Consequently, uncertainty in net benefits based on their bounding estimates has not been explicitly quantified. The uncertainty assessments in the benefits and costs do indicate that the uncertainty in the value of the benefits is greater than the uncertainty in the costs.

Exhibit 8.6a: Mean Net Benefits, Preferred Alternative—Enhanced Cost of Illness[1] ($Millions, 2003$)

Data Set	Mean Benefits	Mean Costs	Mean Net Benefits
3 Percent, 25 Years			
ICR	$ 1,853	$ 133	$ 1,720
ICRSSL	$ 458	$ 93	$ 365
ICRSSM	$ 886	$ 106	$ 780
7 Percent, 25 Years			
ICR	$ 1,501	$ 150	$ 1,351
ICRSSL	$ 371	$ 107	$ 264
ICRSSM	$ 718	$ 121	$ 597

Exhibit 8.6b: Mean Net Benefits, Preferred Alternative—Traditional Cost of Illness [1] ($Millions, 2003$)

Data Set	Mean Benefits	Mean Costs	Mean Net Benefits
3 Percent, 25 Years			
ICR	$ 1,341	$ 133	$ 1,208
ICRSSL	$ 335	$ 93	$ 242
ICRSSM	$ 644	$ 106	$ 538
7 Percent, 25 Years			
ICR	$ 1,089	$ 150	$ 939
ICRSSL	$ 272	$ 107	$ 166
ICRSSM	$ 523	$ 121	$ 402

Note: [1] The Traditional COI includes values for medical costs and lost work time (including a portion of unpaid household production). The Enhanced COI also includes values for lost personal time (non-work time) such as child care and homemaking (to the extent not covered by the Traditional COI), time with family, and recreation, and lost productivity on days when workers are ill but go to work anyway.
Sources: Exhibit 8.10, 8.11, 8.12, Preferred Alternative.

One approach to evaluating net benefits when there is a significant discrepancy between the magnitudes of the uncertainties for costs and benefits is a "Breakeven Analysis." Using the estimate with less uncertainty (in this case, costs), a calculation is made of the minimum levels of benefits which, if achieved, would cause the rule to break even. Comparing this breakeven level of benefits with the actual benefit estimate provides a measure of the likelihood that the Preferred Regulatory Alternative will have positive net benefits.

In this analysis, monetized values of the two health endpoints—illnesses and deaths—are compared against the mean cost estimate. This method of comparison does not take into account the timing of illnesses and deaths avoided, nor does it incorporate income elasticities into the value of cases avoided. The cost estimates are based on a stream of costs, discounted into year 2003, and annualized over 25 years. Thus, this analysis compares the annualized compliance costs to the costs of illness and deaths in the same year (both expressed in year 2003 dollars). The breakeven point is where the benefits value, calculated from avoided illnesses and deaths, equals the cost estimate.

Exhibits 8.7a and 8.7b present the number of illnesses avoided at the breakeven point using Enhanced COI and Traditional COI. The number of deaths avoided are not included in the exhibit because deaths are assumed to result from a fixed percentage of illnesses. Deaths increase or decrease proportionally with illnesses but at a much lower rate, and are included proportionally in these estimates. The exhibits also present the mean estimates of illnesses avoided to show that the estimated benefits are well above the breakeven point for all occurrence estimates and discount rates using the mean number of avoided illness. This is true for all conditions except when using the ICRSSL data set and using the 5th percentile of estimated avoided illness.

Exhibit 8.7a: Breakeven Points, Enhanced COI[1,2]
(Number of Avoided Illnesses Needed to Break Even with Cost Estimates)

Data Set	Annual Avoided Illnesses			Breakeven Cases (at 3 Percent, 25 Years)			Breakeven Cases (at 7 Percent, 25 Years)		
	Mean	90 Percent Confidence Bound		Mean	90 Percent Confidence Bound		Mean	90 Percent Confidence Bound	
		Lower (5th %ile)	Upper (95th %ile)		Lower (5th %ile)	Upper (95th %ile)		Lower (5th %ile)	Upper (95th %ile)
ICR	964,360	149,241	2,277,367	56,616	47,122	67,891	63,853	53,091	76,639
ICRSSL	230,730	38,281	521,925	38,166	29,632	46,095	43,878	34,193	52,941
ICRSSM	455,170	72,128	1,112,374	44,365	36,153	52,677	50,660	41,300	60,163

Exhibit 8.7b: Breakeven Points, Traditional COI[1,2]
(Number of Avoided Illnesses Needed to Break Even with Cost Estimates)

Data Set	Annual Avoided Illnesses			Breakeven Cases (at 3 Percent, 25 Years)			Breakeven Cases (at 7 Percent, 25 Years)		
	Mean	90 Percent Confidence Bound		Mean	90 Percent Confidence Bound		Mean	90 Percent Confidence Bound	
		(5th %ile)	(95th %ile)		(5th %ile)	(95th %ile)		(5th %ile)	(95th %ile)
ICR	964,360	149,241	2,277,367	74,674	62,153	89,546	84,220	70,025	101,083
ICRSSL	230,730	38,281	521,925	49,838	38,694	60,191	57,296	44,650	69,131
ICRSSM	455,170	72,128	1,112,374	58,279	47,491	69,198	66,549	54,252	79,032

Notes: [1] Breakeven points include benefits from both avoided illness and deaths. The number of illnesses avoided implies a proportioned number of avoided deaths. The 90 percent confidence bounds for breakeven cases results from the 90 percent confidence bounds of the cost estimates.
[2] The Traditional COI includes values for medical costs and lost work time (including a portion of unpaid household production). The Enhanced COI also includes values for lost personal time (non-work time) such as child care and homemaking (to the extent not covered by the Traditional COI), time with family, and recreation, and lost productivity on days when workers are ill but go to work anyway.
Sources: Annual Avoided Illnesses from Exhibit 8.3.
Breakeven Cases derived from Exhibit 8.6, Annualized Cost and Appendix C, Exhibits C.6-C.9, Columns A-C.

If the value of nonquantified benefits could be included in the breakeven analysis, the number of cases that would need to be avoided in order to break even would be even lower. This is additional confirmation that benefits are very likely to exceed costs.

8.3 Comparison of Regulatory Alternatives

As discussed in Chapter 3, EPA and the Stage 2 Microbial and Disinfection Byproduct (M-DBP) Federal Advisory Committee considered numerous regulatory alternatives for the LT2ESWTR. Through this process, the potential regulatory alternatives were narrowed to four major ones for further evaluation, one of which was agreed upon by the Advisory Committee as the preferred approach. As previously mentioned, the rule provisions for the filtered systems were the only ones with alternatives (that is, there were no alternatives identified for the promises of the rule governing unfiltered systems and uncovered finished–water reservoirs). Detailed benefit and cost analyses for each of the alternatives are presented in Chapters 5 and 6, respectively, and are summarized in this chapter. The following sections present several analyses that compare the Preferred Regulatory Alternative to the other three.

Exhibit 8.8: Summary of Binning and Treatment Scenarios for Filtered Systems for All Regulatory Alternatives

Source Water *Cryptosporidium* Monitoring Results (oocysts/L)	Additional *Cryptosporidium* Treatment Requirements
Alternative A1	
2.0 log inactivation required for all systems	
Alternative A2	
< 0.03	No action
≥ 0.03 and < 0.1	0.5-log
≥ 0.1 and < 1.0	1.5-log
≥ 1.0	2.5-log
Alternative A3 - Preferred Alternative	
< 0.075	No action
≥ 0.075 and < 1.0	1-log
≥ 1.0 and < 3.0	2-log
≥ 3.0	2.5-log
Alternative A4	
< 0.10	No action
≥ 0.1 and < 1.0	0.5-log
≥ 1.0	1-log

Note: Additional treatment requirements are in addition to levels already required under existing rules (Interim Enhanced Surface Water Treatment Rule and Long Term 1 Enhanced Surface Water Treatment Rule).

8.3.1 Comparison of Benefits and Costs

Exhibit 8.9 presents a summary of quantified benefits in terms of illnesses and deaths avoided. Two sets of numbers are shown—annual after full implementation and annual average over 25 years. The first set represents the number of cases avoided once all systems have the required treatment installed (year 2015). The second set takes the number of cases avoided each year over a 25 year period (using the implementation schedule in Exhibit O.9) and calculates an annual average of those 25 values. Exhibits 8.10a and 8.10b present the annualized value of the benefits for each regulatory alternative using Enhanced and Traditional COI values. The benefits derive only from treatment improvements made as a result of being in an Action Bin (for filtered systems) or from the 2 and 3 log treatment improvements made at unfiltered plants. No benefits are included for improvements made by systems with uncovered finished water reservoirs. Further, only reductions in endemic illness and mortality associated with cryptosporidiosis (as opposed to those that occur as outbreaks) are included. As stated previously, unquantified benefits are likely significant.

Exhibit 8.11 follows with a presentation of the quantified costs. The annualized total costs of the rule include costs for filtered systems, unfiltered systems, uncovered reservoirs, and implementation costs for systems and for States/Primacy Agencies.

Exhibit 8.9: Comparison of Number of Illnesses and Deaths Avoided for All Regulatory Alternatives

Data Set	Rule Alternative	Annual Illnesses Avoided: Mean	Annual Illnesses Avoided: 90 Percent Confidence Bound Lower (5th %ile)	Annual Illnesses Avoided: 90 Percent Confidence Bound Upper (95th %ile)	Annual Deaths Avoided: Mean	Annual Deaths Avoided: 90 Percent Confidence Bound Lower (5th %ile)	Annual Deaths Avoided: 90 Percent Confidence Bound Upper (95th %ile)
Annual Average after Full implementation [1]							
ICR	A1	989,954	151,965	2,347,055	211	35	480
	A2	975,326	150,295	2,307,247	209	35	474
	A3-Preferred	964,360	149,241	2,277,367	207	34	468
	A4	902,500	143,231	2,088,993	197	33	437
ICRSSL	A1	292,992	45,926	702,369	62	10	143
	A2	250,153	40,612	578,528	55	10	123
	A3-Preferred	230,730	38,281	521,925	52	9	113
	A4	197,892	34,572	431,263	47	9	98
ICRSSM	A1	514,150	78,383	1,285,283	109	18	259
	A2	476,008	74,499	1,173,586	103	17	241
	A3-Preferred	455,170	72,128	1,112,374	100	17	230
	A4	399,799	66,646	949,132	91	16	204
Annual Average over 25 years							
ICR	A1	731,304	111,442	1,737,522	157	26	357
	A2	720,635	110,288	1,707,991	155	25	352
	A3-Preferred	712,732	109,486	1,685,176	154	25	348
	A4	667,732	104,766	1,549,243	146	25	325
ICRSSL	A1	216,232	33,661	521,823	46	8	107
	A2	185,009	29,918	433,840	41	7	92
	A3-Preferred	170,977	28,314	392,979	39	7	85
	A4	146,951	25,629	325,686	35	6	74
ICRSSM	A1	379,491	57,314	950,498	81	13	193
	A2	351,691	54,474	871,678	76	13	179
	A3-Preferred	336,652	52,763	826,004	74	12	172
	A4	296,138	48,695	706,762	67	12	152

Note: [1] Full implementation occurs 7 years after rule promulgation.
Source: Appendix C, Exhibit C.4, Columns A-F. Annual Average derived from Exhibits C.4 and Exhibit O.9.

Exhibit 8.10a: Comparison of Annualized Value of Illnesses and Deaths Avoided for All Regulatory Alternatives, Enhanced COI[1]

Data Set	Rule Alternative	Value of Benefits ($ Millions, 2003$) Mean	90% Confidence Bound Lower (5th %ile)	90% Confidence Bound Upper (95th %ile)
Annualized Value (at 3%, 25 Years)				
ICR	A1	$ 1,895	$ 227	$ 5,079
	A2	$ 1,871	$ 225	$ 4,992
	A3 - Preferred	$ 1,853	$ 224	$ 4,941
	A4	$ 1,753	$ 216	$ 4,642
ICRSSL	A1	$ 558	$ 63	$ 1,553
	A2	$ 489	$ 58	$ 1,341
	A3 - Preferred	$ 458	$ 55	$ 1,242
	A4	$ 405	$ 51	$ 1,070
ICRSSM	A1	$ 981	$ 110	$ 2,713
	A2	$ 919	$ 106	$ 2,533
	A3 - Preferred	$ 886	$ 103	$ 2,420
	A4	$ 796	$ 96	$ 2,134
Annualized Value (at 7%, 25 Years)				
ICR	A1	$ 1,534	$ 184	$ 4,115
	A2	$ 1,515	$ 182	$ 4,042
	A3 - Preferred	$ 1,501	$ 181	$ 3,998
	A4	$ 1,421	$ 175	$ 3,766
ICRSSL	A1	$ 452	$ 51	$ 1,258
	A2	$ 396	$ 47	$ 1,086
	A3 - Preferred	$ 371	$ 45	$ 1,005
	A4	$ 328	$ 41	$ 867
ICRSSM	A1	$ 794	$ 89	$ 2,199
	A2	$ 744	$ 86	$ 2,051
	A3 - Preferred	$ 718	$ 84	$ 1,961
	A4	$ 645	$ 78	$ 1,730

Exhibit 8.10b: Comparison of Annualized Value of Illnesses and Deaths Avoided for All Regulatory Alternatives, Traditional COI[1]

Data Set	Rule Alternative	Value of Benefits ($ Millions, 2003$) Mean	90% Confidence Bound Lower (5th %ile)	90% Confidence Bound Upper (95th %ile)
Annualized Value (at 3%, 25 Years)				
ICR	A1	$ 1,369	$ 130	$ 4,017
	A2	$ 1,353	$ 129	$ 3,969
	A3 - Preferred	$ 1,341	$ 128	$ 3,929
	A4	$ 1,273	$ 124	$ 3,692
ICRSSL	A1	$ 403	$ 35	$ 1,219
	A2	$ 356	$ 32	$ 1,065
	A3 - Preferred	$ 335	$ 31	$ 989
	A4	$ 299	$ 29	$ 861
ICRSSM	A1	$ 708	$ 62	$ 2,140
	A2	$ 666	$ 59	$ 1,995
	A3 - Preferred	$ 644	$ 58	$ 1,919
	A4	$ 583	$ 54	$ 1,706
Annualized Value (at 7%, 25 Years)				
ICR	A1	$ 1,112	$ 105	$ 3,257
	A2	$ 1,099	$ 104	$ 3,220
	A3 - Preferred	$ 1,089	$ 104	$ 3,195
	A4	$ 1,034	$ 100	$ 3,001
ICRSSL	A1	$ 327	$ 29	$ 990
	A2	$ 289	$ 26	$ 864
	A3 - Preferred	$ 272	$ 25	$ 802
	A4	$ 243	$ 23	$ 700
ICRSSM	A1	$ 575	$ 50	$ 1,739
	A2	$ 541	$ 48	$ 1,623
	A3 - Preferred	$ 523	$ 47	$ 1,559
	A4	$ 474	$ 44	$ 1,386

Note: [1] The Traditional COI includes values for medical costs and lost work time (including a portion of unpaid household production). The Enhanced COI also includes values for lost personal time (non-work time) such as child care and homemaking (to the extent not covered by the Traditional COI), time with family, and recreation, and lost productivity on days when workers are ill but go to work anyway.
Sources: Appendix C, Exhibits C.4 (Enhanced COI) and C.5 (Traditional COI), Columns M-O

Exhibit 8.11: Comparison of Costs for All Regulatory Alternatives ($ Millions, 2003$)[1]

Data Set	Rule Alternative	Capital and One-Time (Undiscounted, at Full Implementation)			Operations and Maintenance (Undiscounted, at Full Implementation)			Annualized Value (Discounted at 3%, 25 Years)*			Annualized Value (Discounted at 7%, 25 Years)*		
			90% Confidence Bound			90% Confidence Bound			90% Confidence Bound			90% Confidence Bound	
		Mean	Lower (5th %ile)	Upper (95th %ile)	Mean	Lower (5th %ile)	Upper (95th %ile)	Mean	Lower (5th %ile)	Upper (95th %ile)	Mean	Lower (5th %ile)	Upper (95th %ile)
ICR	A1	$ 5,631	$ 4,879	$ 6,364	$ 226	$ 213	$ 240	$ 403	$ 361	$ 444	$ 436	$ 389	$ 484
	A2	$ 2,511	$ 2,104	$ 2,840	$ 74	$ 65	$ 87	$ 163	$ 140	$ 197	$ 182	$ 155	$ 219
	A3-Preferred	$ 2,104	$ 1,715	$ 2,425	$ 55	$ 48	$ 64	$ 133	$ 111	$ 160	$ 150	$ 125	$ 181
	A4	$ 1,328	$ 1,085	$ 1,454	$ 28	$ 24	$ 32	$ 81	$ 67	$ 95	$ 93	$ 78	$ 110
ICRSSL	A1	$ 5,631	$ 4,879	$ 6,364	$ 226	$ 213	$ 240	$ 403	$ 361	$ 444	$ 437	$ 389	$ 484
	A2	$ 1,959	$ 1,538	$ 2,147	$ 50	$ 40	$ 59	$ 123	$ 98	$ 148	$ 139	$ 110	$ 167
	A3-Preferred	$ 1,526	$ 1,164	$ 1,743	$ 33	$ 26	$ 39	$ 93	$ 72	$ 112	$ 107	$ 83	$ 129
	A4	$ 973	$ 786	$ 1,049	$ 16	$ 13	$ 19	$ 57	$ 47	$ 68	$ 68	$ 56	$ 80
ICRSSM	A1	$ 5,631	$ 4,879	$ 6,364	$ 226	$ 213	$ 240	$ 403	$ 361	$ 444	$ 437	$ 389	$ 484
	A2	$ 2,155	$ 1,757	$ 2,342	$ 58	$ 49	$ 66	$ 137	$ 114	$ 161	$ 154	$ 128	$ 181
	A3-Preferred	$ 1,719	$ 1,372	$ 1,941	$ 39	$ 33	$ 45	$ 106	$ 86	$ 126	$ 121	$ 99	$ 144
	A4	$ 1,082	$ 886	$ 1,156	$ 20	$ 17	$ 23	$ 65	$ 54	$ 76	$ 76	$ 63	$ 88

Note: [1] Operation and maintenance costs are annual costs incurred by all systems upon full implementation of the rule.

Sources: Appendix O.

Capital and One-time: Undiscounted–Exhibit O.4 (State total), Exhibit O.5 (system implementation and monitoring total), and O.6 (sum of filtered and unfiltered treatment costs)

Annual Operations and Maintenance Cost: Undiscounted–Exhibit O.6 (sum of filtered and unfiltered O&M costs)

Annualized Cost at 3 Percent: Exhibits O.16 + O.17 + O.18.

Annualized Cost at 7 Percent: Exhibits O.19 + O.20 + O.21.

Net Benefits

As described previously, net benefits are calculated as the difference between the monetized benefits and cost estimates. Exhibit 8.12a and 8.12b present net benefits based on the annualized present value of quantified benefits at 3 and 7 percent discount rates for both enhanced and traditional cost of illness. Adding nonquantified benefits would raise the overall net benefits. The data are based on the mean benefits less the mean values for costs. Using net benefits as a threshold measure shows that almost all alternatives provide benefits that exceed their costs, based on their average values.

Maximum Net Benefits

Identifying the maximum net benefits among the regulatory alternatives is a first step in a comparative analysis of regulatory alternatives. The bold numbers in heavily outlined boxes in Exhibits 8.12a and 8.12b indicate the maximum net benefit of the four rule alternatives. For most combinations of occurrence data sets, COI values, and discount rates, the Preferred Regulatory Alternative (A3) had the maximum net benefits among the alternatives (8 of 12 scenarios). However, the differences are often slight among three of the regulatory alternatives (A2, A3, and A4). The range from the high to the low of A2, A3, and A4 is 1 to 10 percent for all but one of the combinations.

Exhibit 8.12a: Comparison of Mean Net Benefits for All Regulatory Alternatives—Enhanced COI [1] (Million $/Year)

Data Set	Rule Alternative	Annualized Value 3%, 25 Years	Annualized Value 7%, 25 Years
ICR	A1	$ 1,492	$ 1,098
	A2	$ 1,708	$ 1,333
	A3 - Preferred	$ 1,720	$ 1,351
	A4	$ 1,673	$ 1,328
ICRSSL	A1	$ 156	$ 15
	A2	$ 366	$ 257
	A3 - Preferred	$ 365	$ 264
	A4	$ 347	$ 261
ICRSSM	A1	$ 578	$ 358
	A2	$ 782	$ 591
	A3 - Preferred	$ 780	$ 597
	A4	$ 731	$ 569

Exhibit 8.12b: Comparison of Mean Net Benefits for All Regulatory Alternatives—Traditional COI [1] (Million $/Year)

Data Set	Rule Alternative	Annualized Value	
		3%, 25 Years	7%, 25 Years
ICR	A1	$ 967	$ 675
	A2	$ 1,190	$ 917
	A3 - Preferred	$ 1,208	$ 939
	A4	$ 1,193	$ 941
ICRSSL	A1	$	$ -109
	A2	$ 233	$ 150
	A3 - Preferred	$ 242	$ 166
	A4	$ 242	$ 175
ICRSSM	A1	$ 306	$ 138
	A2	$ 529	$ 387
	A3 - Preferred	$ 538	$ 402
	A4	$ 518	$ 398

Note: [1] The Traditional COI includes values for medical costs and lost work time (including a portion of unpaid household production). The Enhanced COI also includes values for lost personal time (non-work time) such as child care and homemaking (to the extent not covered by the Traditional COI), time with family, and recreation, and lost productivity on days when workers are ill but go to work anyway.

Sources: 3 percent data: Exhibit 8.10, "Mean" column - Exhibit 8.11, Annualized Value at 3 percent, "Mean" column.

7 percent data: Exhibit 8.10, "Mean" column - Exhibit 8.11, Annualized Value at 7 percent, "Mean" column.

Incremental Net Benefits

Rule alternatives can also be compared on the basis of their incremental net benefits. Generally, the goal of an incremental analysis is to identify the last regulatory option with positive net incremental benefits. Each additional regulatory alternative costs more per unit of protection than its predecessor. The result is a declining net benefit as more stringent alternatives are considered. When the next more stringent alternative costs more than it returns in absolute benefits, net benefit becomes negative and the alternative is not worth pursuing. However, the usefulness of this analysis is limited because many benefits from the rule are nonquantified and not monetized.

Exhibits 8.13a and 8.13b present the incremental net benefits calculated from Enhanced and Traditional COI values. Usually an incremental analysis implies increasingly stringent control along a single parameter, with each alternative providing all the protection of the previous alternative, plus additional protection. However, the regulatory alternatives for this rule base their treatment requirements on a system's source water quality (except for A1). As a result, the number of systems requiring additional treatment, and thus the population affected by the rule, differ among the alternatives. With net benefits calculated using different occurrence estimates, COI values, and discount rates, the last alternative with positive net benefit is not always the same. The sensitivity of the mean net benefit estimates to various input assumptions in this analysis is illustrated by the ranking analysis presented in section 8.4.

Exhibit 8.13a: Incremental Net Benefits [1] for All Alternatives, By Data Set, Enhanced COI [2] ($Millions, 2003$)

Data Set	Rule Alternative	Annual Costs A	Annual Benefits B	Incremental Costs [1] C	Incremental Benefits D	Incremental Net Benefits E=D-C
3 Percent Discount Rate						
ICR	A4	$ 81	$ 1,753	$ 81	$ 1,753	$ 1,673
	A3 - Preferred	$ 133	$ 1,853	$ 53	$ 100	$ 47
	A2	$ 163	$ 1,871	$ 30	$ 18	$ -12
	A1	$ 403	$ 1,895	$ 239	$ 24	$ -216
ICRSSL	A4	$ 57	$ 405	$ 57	$ 405	$ 347
	A3 - Preferred	$ 93	$ 458	$ 35	$ 53	$ 18
	A2	$ 123	$ 489	$ 30	$ 31	$ 1
	A1	$ 403	$ 558	$ 280	$ 69	$ -210
ICRSSM	A4	$ 65	$ 796	$ 65	$ 796	$ 731
	A3 - Preferred	$ 106	$ 886	$ 41	$ 90	$ 49
	A2	$ 137	$ 919	$ 31	$ 33	$ 2
	A1	$ 403	$ 981	$ 266	$ 62	$ -204
7 Percent Discount Rate						
ICR	A4	$ 93	$ 1,421	$ 93	$ 1,421	$ 1,328
	A3 - Preferred	$ 150	$ 1,501	$ 57	$ 80	$ 23
	A2	$ 182	$ 1,515	$ 31	$ 14	$ -17
	A1	$ 436	$ 1,534	$ 255	$ 19	$ -236
ICRSSL	A4	$ 68	$ 328	$ 68	$ 328	$ 261
	A3 - Preferred	$ 107	$ 371	$ 39	$ 43	$ 4
	A2	$ 139	$ 396	$ 32	$ 25	$ -7
	A1	$ 437	$ 452	$ 298	$ 56	$ -242
ICRSSM	A4	$ 76	$ 645	$ 76	$ 645	$ 569
	A3 - Preferred	$ 121	$ 718	$ 45	$ 73	$ 27
	A2	$ 154	$ 744	$ 33	$ 27	$ -6
	A1	$ 437	$ 794	$ 283	$ 50	$ -233

Exhibit 8.13b: Incremental Net Benefits[1] for All Alternatives, By Data Set, Traditional COI [2] ($Millions, 2003$)

Data Set	Rule Alternative	Annual Costs A	Annual Benefits B	Incremental Costs [1] C	Incremental Benefits D	Incremental Net Benefits E=D-C
3 Percent Discount Rate						
ICR	A4	$ 81	$ 1,273	$ 81	$ 1,273	$ 1,193
	A3 - Preferred	$ 133	$ 1,341	$ 53	$ 68	$ 15
	A2	$ 163	$ 1,353	$ 30	$ 12	$ -18
	A1	$ 403	$ 1,369	$ 239	$ 16	$ -223
ICRSSL	A4	$ 57	$ 299	$ 57	$ 299	$ 242
	A3 - Preferred	$ 93	$ 335	$ 35	$ 36	$ 1
	A2	$ 123	$ 356	$ 30	$ 21	$ -9
	A1	$ 403	$ 403	$ 280	$ 47	$ -233
ICRSSM	A4	$ 65	$ 583	$ 65	$ 583	$ 518
	A3 - Preferred	$ 106	$ 644	$ 41	$ 61	$ 20
	A2	$ 137	$ 666	$ 31	$ 23	$ -9
	A1	$ 403	$ 708	$ 266	$ 42	$ -224
7 Percent Discount Rate						
ICR	A4	$ 93	$ 1,034	$ 93	$ 1,034	$ 941
	A3 - Preferred	$ 150	$ 1,089	$ 57	$ 55	$ -3
	A2	$ 182	$ 1,099	$ 31	$ 10	$ -22
	A1	$ 436	$ 1,112	$ 255	$ 13	$ -242
ICRSSL	A4	$ 68	$ 243	$ 68	$ 243	$ 175
	A3 - Preferred	$ 107	$ 272	$ 39	$ 29	$ -10
	A2	$ 139	$ 289	$ 32	$ 17	$ -15
	A1	$ 437	$ 327	$ 298	$ 38	$ -260
ICRSSM	A4	$ 76	$ 474	$ 76	$ 474	$ 398
	A3 - Preferred	$ 121	$ 523	$ 45	$ 49	$ 4
	A2	$ 154	$ 541	$ 33	$ 18	$ -15
	A1	$ 437	$ 575	$ 283	$ 34	$ -249

Notes: [1]

Derivation: Incremental costs are the cost of each regulatory alternative minus the cost of the next least expensive alternative (which is zero for Alternative A4, the least expensive alternative). The derivation for incremental benefits is analogous to the derivation for incremental costs.

[2] The Traditional COI includes values for medical costs and lost work time (including a portion of unpaid household production). The Enhanced COI also includes values for lost personal time (non-work time) such as child care and homemaking (to the extent not covered by the Traditional COI), time with family, and recreation, and lost productivity on days when workers are ill but go to work anyway.

Sources: [A] Exhibit 8.11, Annualized Value at 3 percent, “Mean” column and Annualized Value at 7 percent, “Mean” column.

[B] Exhibit 8.10, “Mean” column.

Consideration of Uncertainty in the Ranking of Alternatives by Net Benefits

Cost estimates for a given occurrence level contain less uncertainty than the corresponding estimates of benefits. Benefit estimates have significant uncertainty due to inputs such as infectivity, morbidity, income elasticity, and even the value of a statistical life. In addition, quantified benefits constitute only a portion of the likely total benefits from this rule. Under these conditions, it is important to assess how the ranking of alternatives will change as estimates of benefits vary. Using two COI values, as has been done so far, gives a snapshot of how the ranking may change. This analysis goes further by analyzing how the ranking changes on a continuum of changing benefits.

As estimates of possible benefits proportionately increase while cost estimates are held constant, the alternative with the highest net benefits shifts from Alternative A4 to Alternative A3 (the Preferred Alternative), then to A2, and finally to A1 (A4 being the least protective through to A1 being the most protective). Because the level of benefits dictates which alternative performs best and how well each performs relative to the other alternatives, the selection of the Preferred Alternative requires examining where these transition points are, and how the relative closeness of the alternatives to each other varies. The selection of an occurrence data set and a discount rate affects this pattern of relationships between alternatives. Graphs, therefore, were constructed for all combinations of occurrence and discount rates using Enhanced and Traditional COI values.

Exhibits 8.14a and 8.14b show the value of the upper 90 percent confidence bound benefit estimates for each alternative and how much greater these values are than the mean benefit estimates (as a percent of the mean). Exhibits 8.15 and 8.16 show these rankings and transition points graphically. Each graph has four lines representing the four alternatives. On the horizontal axis, the graphs show a range of benefits, expressed as multiples of the calculated benefits shown in Exhibit 8.10. The entire scale shows a range of benefits from zero to as much as five times the calculated benefits. The graphs display this large range because (1) the range of quantified benefits at the 90^{th} percentile is about 247 to 291 percent of the mean benefits (Exhibit 8.14), and (2) the consideration of unquantified benefits dictates that the analysis consider a range of benefits beyond the range of calculated quantified benefits. Consequently, a five-fold range is reasonable to display. The vertical axis of the graphs shows the relative ranking of the four alternatives. Specifically, for any given level of benefits, one alternative will yield the highest net benefits (shown as 100 percent), and one will give the lowest (shown as zero percent). The relative benefits of the remaining two alternatives fall somewhere in between. Thus, a vertical reading of the graphs shows the ranking of the alternatives at that level of benefits, and the closeness of the relative rankings.

Exhibit 8.14a: Upper End of 90 Percent Confidence Bound as a Percent of Mean Estimate of Benefits, By Data Set, Annualized at 3 Percent, Enhanced COI ($Millions, 2003$)

Data Set	Rule Alternative	Benefits ($Millions, 2000$) Mean	Benefits ($Millions, 2000$) Upper End of 90% Confidence	Upper End of 90% Confidence Bound as a %
ICR	A1	$ 1,895	$ 5,079	268%
	A2	$ 1,871	$ 4,992	267%
	A3-Preferred	$ 1,853	$ 4,941	267%
	A4	$ 1,753	$ 4,642	265%
ICRSSL	A1	$ 558	$ 1,553	278%
	A2	$ 489	$ 1,341	274%
	A3-Preferred	$ 458	$ 1,242	271%
	A4	$ 405	$ 1,070	264%
ICRSSM	A1	$ 981	$ 2,713	277%
	A2	$ 919	$ 2,533	276%
	A3-Preferred	$ 886	$ 2,420	273%
	A4	$ 796	$ 2,134	268%

Exhibit 8.14b: Upper End of 90 Percent Confidence Bound as a Percent of Mean Estimate of Benefits, By Data Set, Annualized at 3 Percent, Traditional COI ($Millions, 2003$)

Data Set	Rule Alternative	Benefits ($Millions, 2000$) Mean	Benefits ($Millions, 2000$) Upper End of 90% Confidence Bound	Upper End of 90% Confidence Bound as a % of Mean
ICR	A1	$ 1,369	$ 4,017	293%
	A2	$ 1,353	$ 3,969	293%
	A3-Preferred	$ 1,341	$ 3,929	293%
	A4	$ 1,273	$ 3,692	290%
ICRSSL	A1	$ 403	$ 1,219	302%
	A2	$ 356	$ 1,065	299%
	A3-Preferred	$ 335	$ 989	295%
	A4	$ 299	$ 861	288%
ICRSSM	A1	$ 708	$ 2,140	302%
	A2	$ 666	$ 1,995	299%
	A3-Preferred	$ 644	$ 1,919	298%
	A4	$ 583	$ 1,706	293%

Notes:
The Traditional COI includes values for medical costs and lost work time (including a portion of unpaid household production). The Enhanced COI also includes values for lost personal time (non-work time) such as child care and homemaking (to the extent not covered by the Traditional COI), time with family, and recreation, and lost productivity on days when workers are ill but go to work anyway.
Upper end of 90 percent confidence bound is the 95th percentile.
Source: Exhibit 8.10.

What conclusions can be derived from the graphs of the actual data? Consider the first graph in Exhibit 8.15a, based on occurrence distributions modeled from the ICR data set. The expected pattern is depicted: at low levels of benefits, Alternative A4 ranks highest, but as estimates of benefits increase, Alternative A3 and then A2 have the highest net benefits. Alternative A1 will eventually become the alternative with highest net benefits, but at a level of benefits beyond the scale of the graph. More important, the graph shows that A4 has the highest net benefits only for low estimates of benefits: from zero benefits to about 50 percent of quantified benefits. Alternative A3, the Preferred Alternative, has the highest net benefits throughout the range that lies nearest to the mean quantified benefits: from about 50 percent to 150 percent of quantified benefits (ICR data set).

Under most combinations of occurrence data sets, discount rates, and COI values, the Preferred Alternative ranks highest near the mean estimate of quantified benefits. The relative strength of this alternative across all scenarios is also shown by the fact that over a wide range, from zero benefits to approximately 350 percent of quantified benefits, the Preferred Alternative has either the highest or second highest level of net benefits. So even under a range of uncertainty, the absolute value of the projected benefits does not affect the relative ranking of the Preferred Alterative.

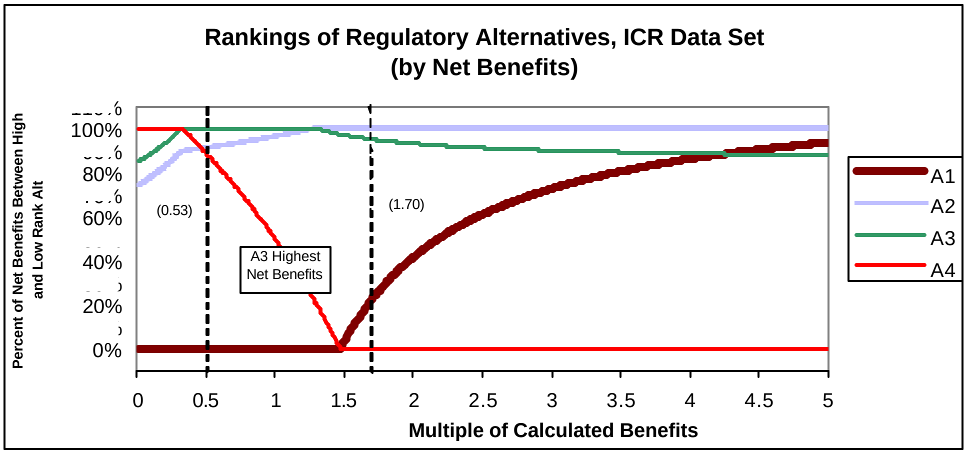
Alternative A4 appears to be the best alternative only when benefits are less than the mean estimated values of the various data sets, and for a few of the data sets using Traditional COI values in the range of best estimates. However, Alternative A4's relative ranking falls rapidly as benefits increase and taking into account the nonquantified benefits, A4 would likely not be the best alternative for any of the estimates.

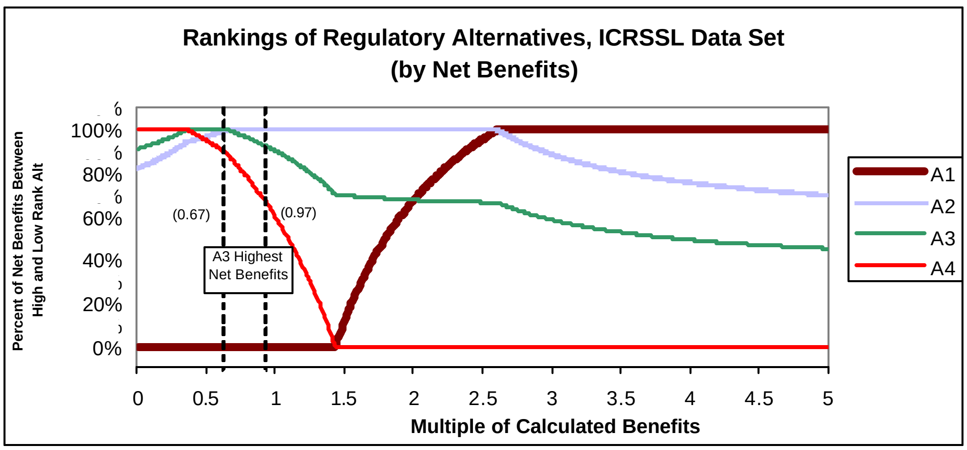
Alternative A2 is also a strong alternative over a wide range of benefits above those discussed for the Preferred Alternative. If total benefits are substantially greater than the value of mean quantified benefits, then Alternative A2 would be a consistently strong choice.

Alternative A1, the most stringent alternative, is not a strong contender unless true benefits are many multiples of the mean quantified benefits. The lowest level of benefits at which Alternative A1 has the highest net benefits is at about 450 percent of mean quantified benefits (ICRSSL, Enhanced COI, 3 percent).

Overall, the Preferred Alternative and Alternative A2 are strong alternatives considering both the range of quantified benefits (with an upper 90 percent confidence bound of 267 to 302 percent of mean benefits) and the significant benefits that have not been quantified. The M-DBP Federal Advisory Committee and EPA selected the Preferred Alternative after also considering other factors such as technical, managerial, and financial capacities of water systems.

Exhibit 8.15a
Comparison of Regulatory Alternatives Ranked by Net Benefits, 3 Percent Cost Enhanced COI





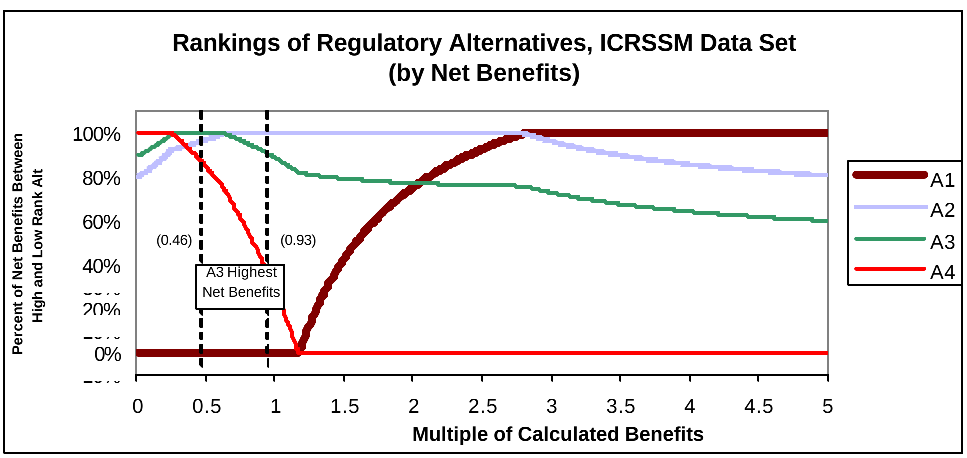
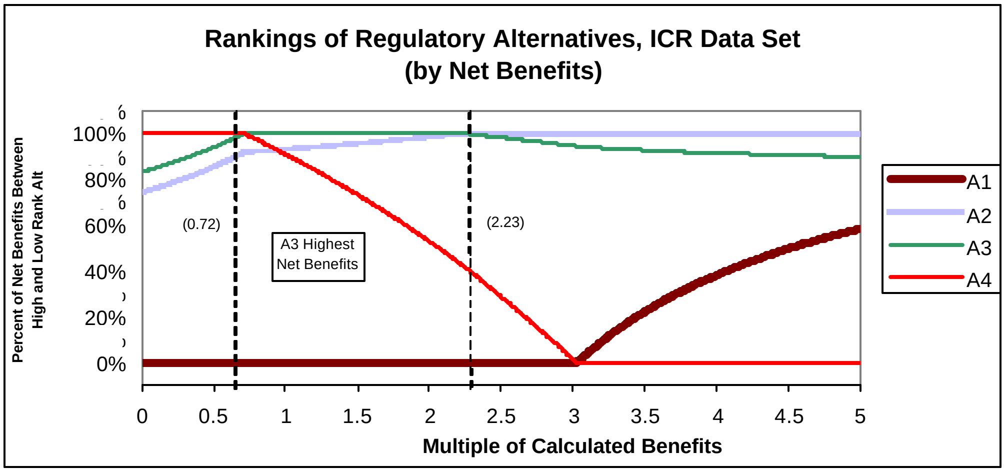
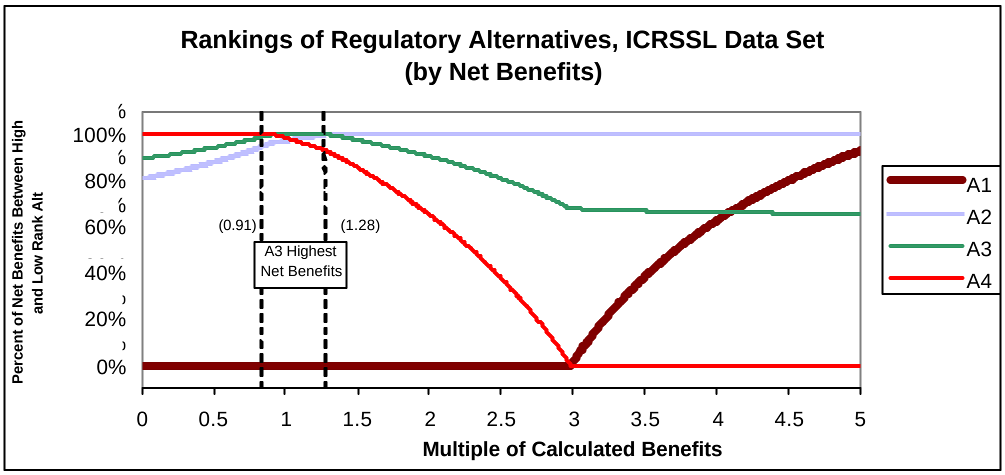


Exhibit 8.15b
Comparison of Regulatory Alternatives Ranked by Net Benefits, 7 Percent Cost Enhanced COI





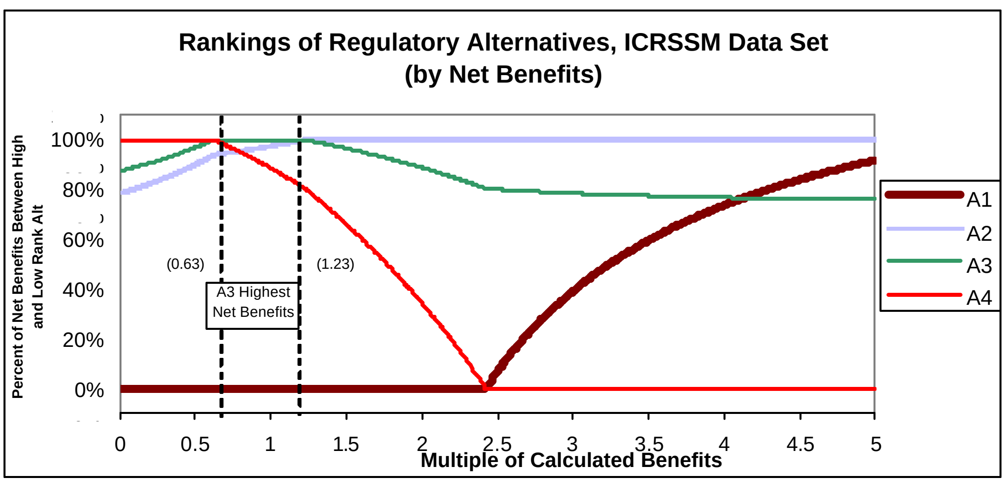
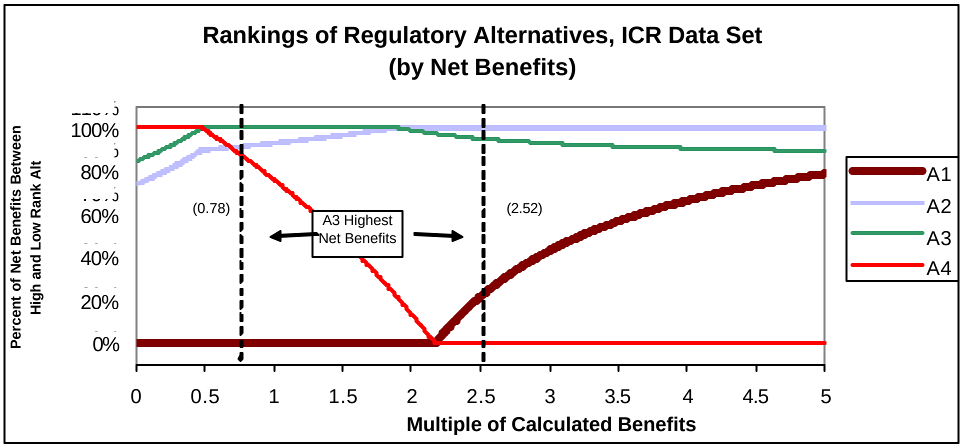
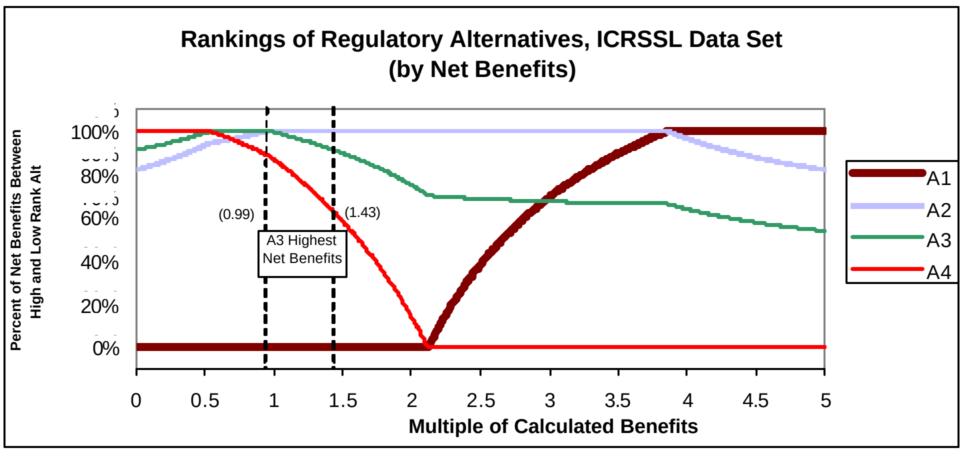


Exhibit 8.16a
Comparison of Regulatory Alternatives Ranked by Net Benefits, 3 Percent Cost Traditional COI





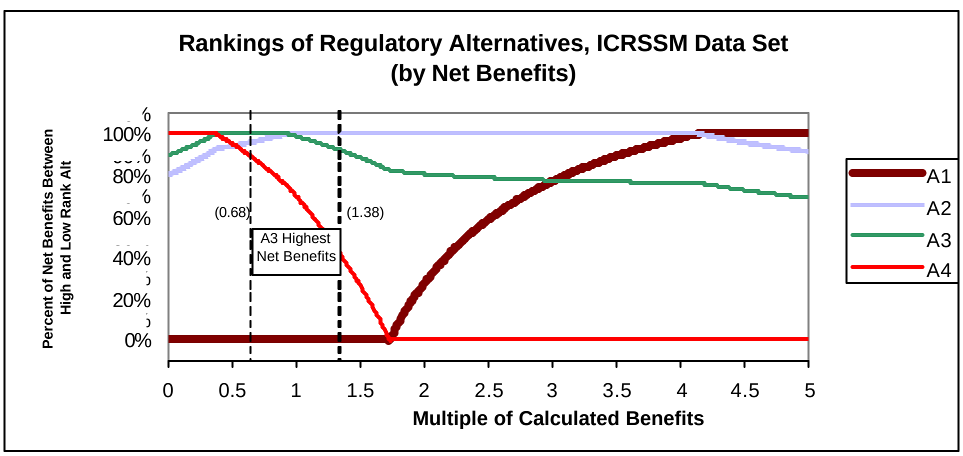
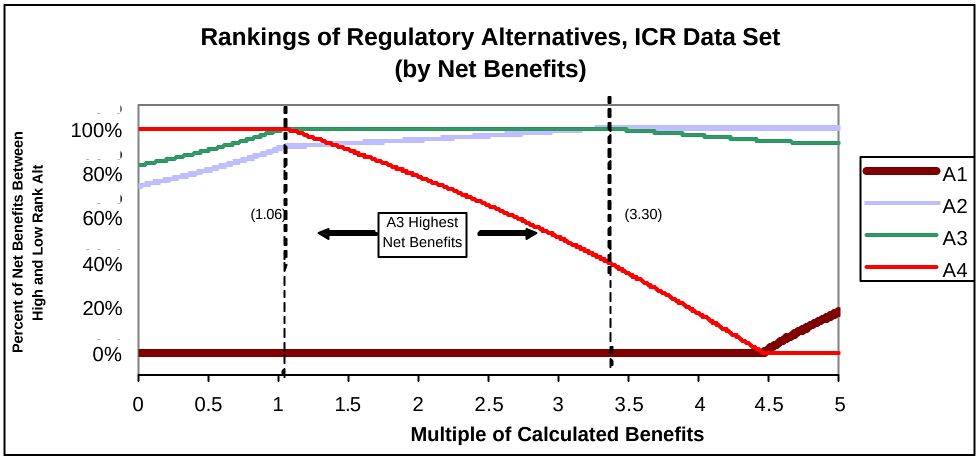
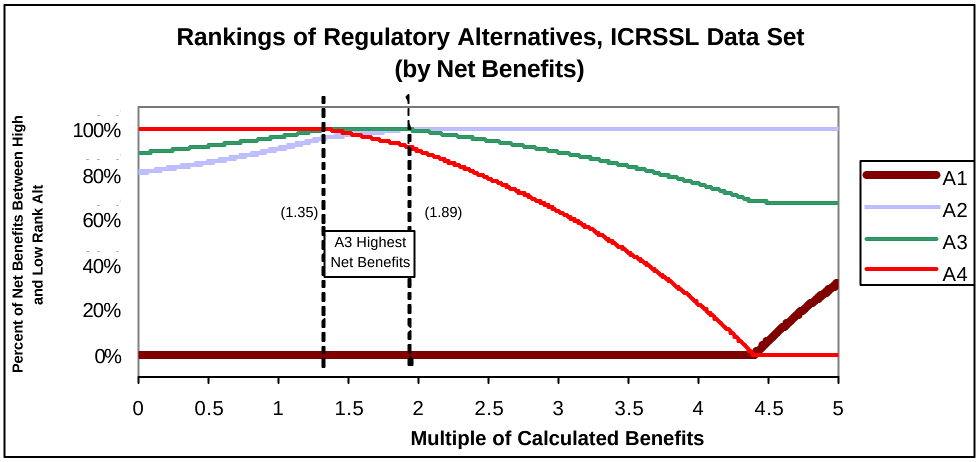
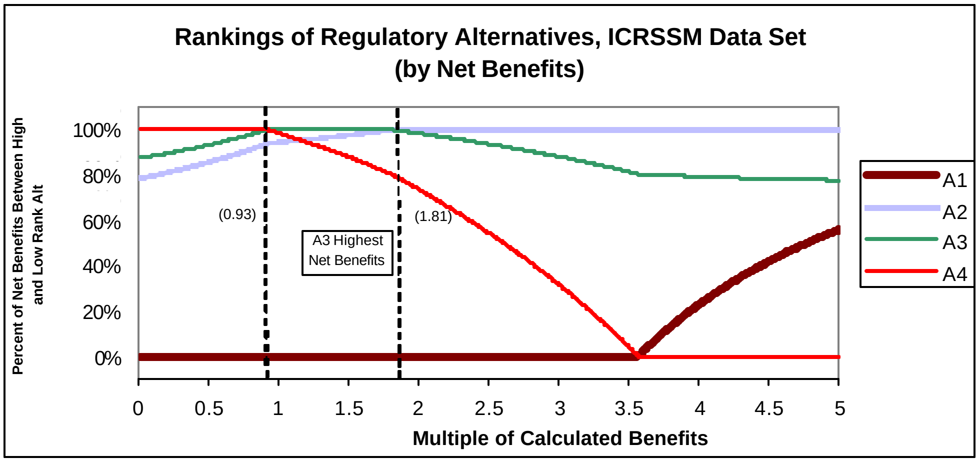


Exhibit 8.16b
Comparison of Regulatory Alternatives Ranked by Net Benefits, 7 Percent Cost
Traditional COI







8.3.2 Cost-Effectiveness Measures

Cost-effectiveness analysis is a policy evaluation tool that allows comparisons of regulatory alternatives. Evaluating cost-effectiveness for actions that reduce both illness and deaths is difficult and there is no universally accepted approach. In this EA, EPA presents several approaches to assess cost effectiveness: a "traditional approach" in which benefits and costs are graphically compared across alternatives, and comparisons of cost per illness avoided, cost per death avoided, incremental cost per illness and death avoided, and benefit-cost ratios. Additionally, a Quality-Adjusted Life Years approach, historically used in policy decisions regarding medical interventions, is applied to this analysis in Appendix U as an experimental approach to evaluating environmental policy costs and benefits.

Cost-effectiveness–Traditional Approach

The concept of cost-effectiveness can be defined simply as getting the greatest level of benefits for a given expenditure or imposing the least cost for a given level of benefits. Exhibits 8.17a and 8.17b show the annualized value of benefits and costs for the four alternatives, calculated using the various combinations of occurrence data sets, COI values, and discount rates. For each alternative, the graph plots the mean benefit versus its corresponding range of cost estimates (a 90 percent confidence bound shown as a vertical bar). A trend line connects the mean estimate of costs for each alternative. These graphs help to visually show the concept of cost-effectiveness and to compare the alternatives. In Exhibit 8.17, the test would be to see if any alternative was to the right and completely below any other alternative. If so, the alternative to the right and below would be more cost-effective and would "dominate" the alternative that provided fewer benefits at higher costs.

In Exhibit 8.17, some graphs show the lower range of the cost estimate for Alternative A2 extending below the top of the cost range for Alternative A3. Does this mean that Alternative A2 in some cases "dominates" A3? The answer is no, because the modeling approach that generates the higher portion of the cost range for Alternative A3 also generates the higher portions of the range for Alternative A2. Thus, it is most appropriate to compare corresponding values from each range to determine the possibility or extent of overlap. In the cases shown, therefore, Alternative A2 cannot be said to be more cost effective than Alternative A3.

In the strict sense, each of the regulatory alternatives is cost effective—no regulatory alternative provides more benefits at the same or a lower cost than another, and no alternative can achieve lower costs for the same or a greater level of benefits than another. Thus, no alternative dominates any other or is more cost effective. Instead, the alternatives offer increasing levels of benefits at increasing levels of cost, as seen in Exhibit 8.17.

The alternatives shown in Exhibit 8.17 map boundaries of cost-effective alternatives. In addition to allowing a visual comparison of cost-effectiveness, the exhibit shows information graphically about the incremental benefits of each alternative. Compared to Alternative A4, the Preferred Alternative achieves significant incremental benefits at a relatively low increase in costs. The step to Alternative A2 achieves more benefits, but at higher incremental rate. The step to Alternative A1 achieves a similar increase in benefits, but at a significantly higher cost. The Preferred Alternative, and perhaps Alternative A2, appear to be good values; other alternatives have either significantly fewer benefits for similar costs or greater benefits, but at dramatically higher costs.

Exhibit 8.17a: Range of Annualized Costs at Mean Benefit Level, All Regulatory Alternatives—Enhanced Cost of Illness[1]

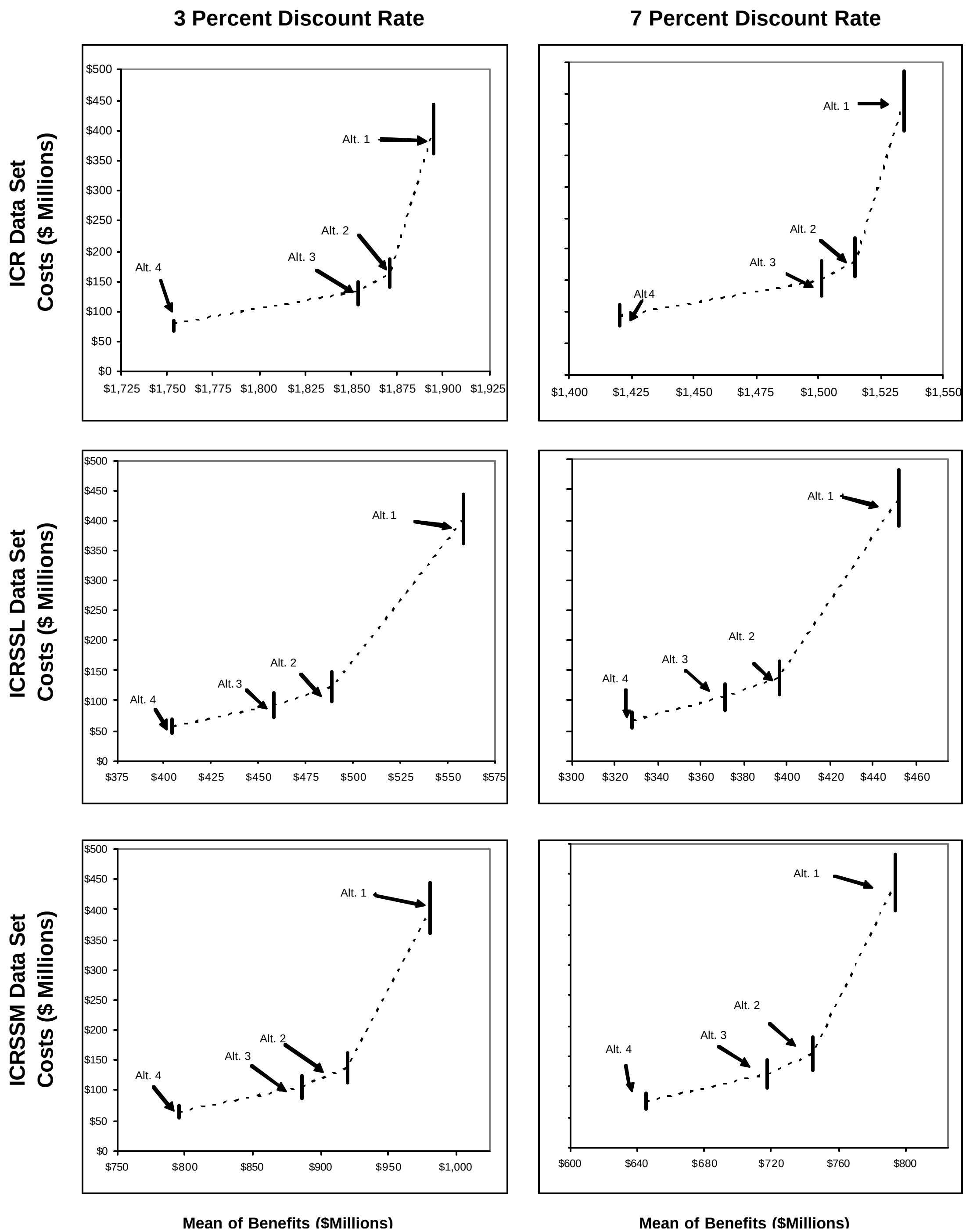
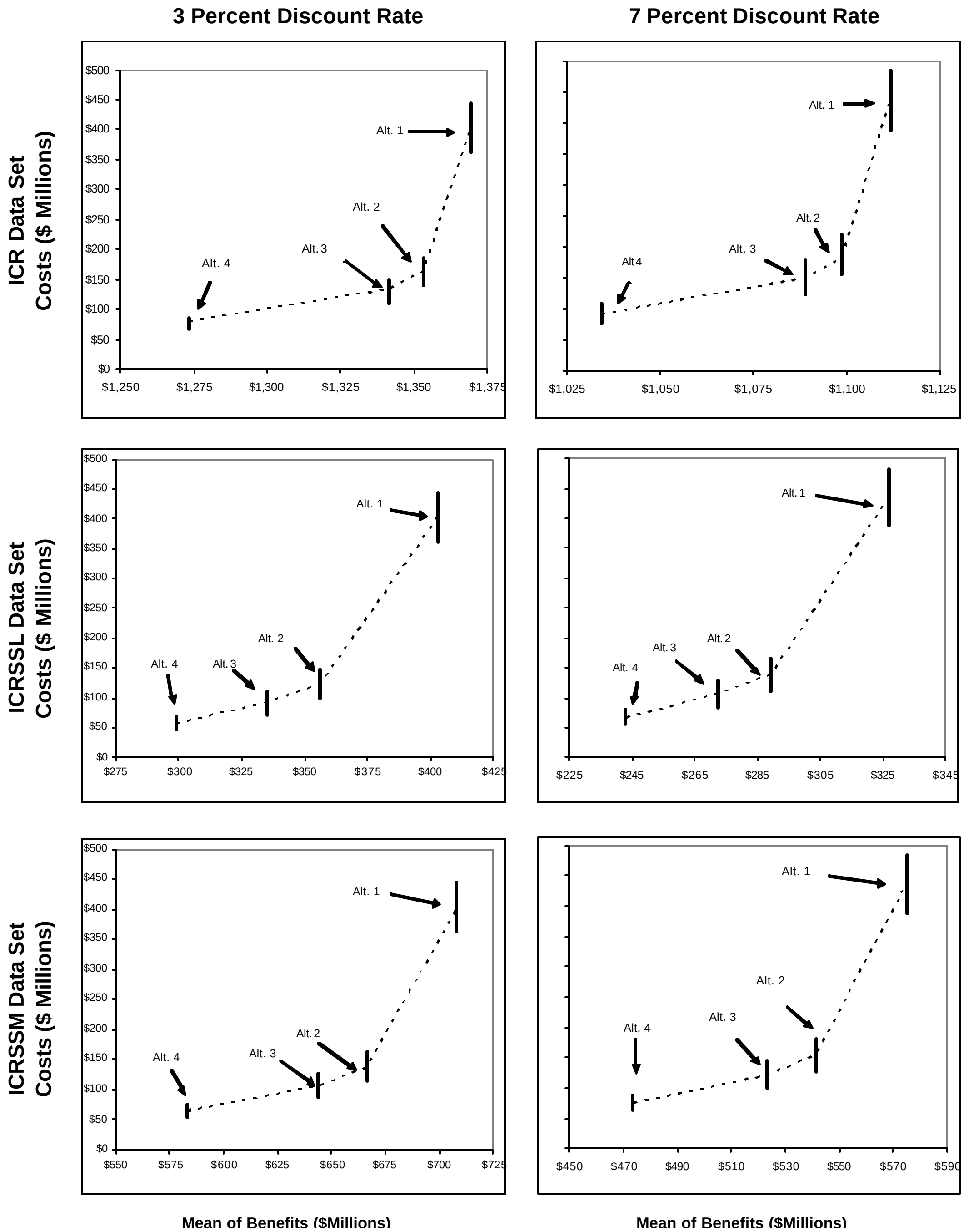


Exhibit 8.17b: Range of Annualized Costs at Mean Benefit Level, All Regulatory Alternatives—Traditional Cost of Illness[1]



Note (from 8.17a and 8.17b):

[1]The Traditional COI includes values for medical costs and lost work time (including a portion of unpaid household production). The Enhanced COI also includes values for lost personal time (non-work time) such as child care and homemaking (to the extent not covered by the Traditional COI), time with family, and recreation, and lost productivity on days when workers are ill but go to work anyway.

Sources: Exhibits 8.10 and 8.11.

Other Measures–Cost Per Illness Avoided and Cost Per Death Avoided

Other measures related to cost-effectiveness not only analyze the performance of the regulatory alternatives, but also allow for comparisons across rules. The cost-effectiveness measures presented in Exhibits 8.18 and 8.19 include the cost, net cost, and incremental net cost for each illness and death avoided. All regulatory alternatives for the LT2ESWTR reduce the risk of both illness and deaths.

Cost per illness or death avoided assigns the total cost of a regulatory alternative entirely to avoided illness or entirely to avoided deaths. *Net cost* adjusts the cost of regulation for avoided illnesses and deaths, so that cost of illnesses is considered alone (by removing the benefits of deaths) and vice versa. *Incremental net cost* considers only the increase in cost and in avoided illnesses or deaths from one regulatory alternative to the next (in the direction of the least to the most costly alternative).

In addition to the net cost concept, this cost-effectiveness analysis provides a different comparison for cost to cases of illnesses and deaths by discounting the *number* of cases avoided. Because estimates of future costs are discounted, the *number* of illnesses and deaths avoided are discounted to make the cost and benefit data comparable. The practice of discounting outcomes (such as illnesses and deaths) is less common than discounting the *valuation* of illnesses and deaths, which is carried out in Chapter 5 and used in the all other analyses of this chapter.

The numbers of avoided illnesses and deaths are discounted by incorporating the schedule of benefits incurred, discount rates, value of a statistical life yearly values (for deaths), and cost of illness yearly values (for illness). Exhibit 8.18 shows the cost per illness avoided, net cost per discounted illness, and incremental net cost per discounted illness. Exhibit 8.19 follows with cost per death avoided analyses. Both exhibits show these data by regulatory alternative, *Cryptosporidium* occurrence data set, cost of illness method (Enhanced COI (ECOI) or Traditional COI (TCOI)), and discount rate.

To compare against the cost per illness avoided values in Exhibits 8.18, EPA estimated the average cost of illness over the 20-year evaluation period for both ECOI and TCOI (presented below Exhibit 8.18). These weighted average values adjust for changes in income growth and the four implementation schedules used for systems of different sizes. The cost of illness grows due to income growth because the value of time increases with real income. The four implementation schedules (for different system size categories) produce four weighted average costs of illness; thus, the results are expressed here as a range between the highest and lowest COIs (the large and small systems bracket the range). All costs are expressed in 2003$.

The results of the comparison for net cost per illness show that all regulatory alternatives, except A1, have costs per avoided illness below the ECOI and TCOI under every discount and occurrence data set combination. When considering incremental net costs per illness avoided, the Preferred Alternative is below the ECOI in four of the six combinations, and below the TCOI in two of the combinations. Only Alternative A4 consistently is below both measures.

Exhibit 8.18: Incremental Net Cost per Discounted Illness Avoided, By Discount Rate, Data Set, and Alternative

Data Set	Rule Alternative	Cost Per Discounted Illness Avoided ($)		Net Cost Per Discounted Illness Avoided ($)		Incremental Net Cost Per Discounted Illness Avoided ($)	
		3%	7%	3%	7%	3%	7%
ICR	A4	$ 147	$ 309	$ (1,708.3)	$ (1,548.4)	$ 147	$ 309
	A3 - Preferred	$ 227	$ 468	$ (1,599.2)	$ (1,360.9)	$ 1,408	$ 2,816
	A2	$ 275	$ 559	$ (1,546.8)	$ (1,264.8)	$ 4,506	$ 8,745
	A1	$ 668	$1,322	$ (1,147.8)	$ (495.6)	$ 26,961	$ 52,665
ICRSSL	A4	$ 476	$1,022	$ (1,527.3)	$ (983.3)	$ 476	$ 1,022
	A3 - Preferred	$ 661	$1,385	$ (1,257.9)	$ (535.8)	$ 1,780	$ 3,597
	A2	$ 808	$1,663	$ (1,071.0)	$ (218.8)	$ 2,574	$ 5,022
	A1	$ 2,258	$4,472	$ 447.2	$ 2,658.8	$ 10,758	$ 21,045
ICRSSM	A4	$ 265	$ 565	$ (1,660.5)	$ (1,362.7)	$ 265	$ 565
	A3 - Preferred	$ 382	$ 796	$ (1,480.9)	$ (1,069.1)	$ 1,228	$ 2,477
	A2	$ 473	$ 969	$ (1,370.2)	$ (876.4)	$ 2,473	$ 4,813
	A1	$ 1,287	$2,548	$ (524.4)	$ 734.7	$ 11,480	$ 22,442

Comparison Data:

	Range of Weighted Average, 2003$	
Enchanced COI	$ 1,150.74	$ 1,177.37
Traditional COI	$ 343.94	$ 349.99

Notes: Cost per Discounted Illness Avoided: cost represents full cost of the rule (i.e., no subtraction for deaths avoided). Net Cost per Discounted Illness Avoided: cost represents only illnesses avoided (i.e., cost attributed to avoiding deaths subtracted to produce net cost).
Comparison data: The Traditional COI includes values for medical costs and lost work time (including a portion of unpaid household production). The Enhanced COI also includes values for lost personal time (non-work time) such as child care and homemaking (to the extent not covered by the Traditional COI), time with family, and recreation, and lost productivity on days when workers are ill but go to work anyway.
Sources: Derived from Exhibits C.4 and C.5 (number of illnesses and deaths avoided); Exhibit O.9 (schedule); and Exhibit 8.11 (total cost of the rule).

To compare against the net incremental cost per death avoided values presented in Exhibits 8.19, EPA has estimated the quantified benefits of preventing a fatality from cryptosporidiosis as $5.0-$5.2 million. When considering the values of deaths avoided, EPA uses a distribution to represent the value of a statistical life. For this analysis, a weighted average is calculated that incorporates the four implementation schedules used for systems of different sizes and adjusts for changes in income growth and income elasticity.

Similar to the cost per illness analyses, Alternatives A3 and A4 consistently have net cost per death avoided values below the range of VSL estimates under all combinations of discount rates and occurrence datasets. The incremental net cost analysis shows, as expected, that incremental costs increase with rule stringency.

Exhibit 8.19: Incremental Net Cost per Discounted Death Avoided, By Discount Rate, Data Set, and Alternative

Data Set	Rule Alternative	Cost Per Discounted Death Avoided ($Millions)		Net Cost Per Discounted Death Avoided ($Millions)				Incremental Net Cost Per Discounted Death Avoided ($Millions)			
				ECOI		TCOI		ECOI		TCOI	
		3%	7%	3%	7%	3%	7%	3%	7%	3%	7%
ICR	A4	$ 0.7	$ 1.4	$ (2.5)	$ (0.3)	$ (0.3)	$ 0.9	$ (2.5)	$ (0.3)	$ (0.3)	$ 0.9
	A3 - Preferred	$ 1.1	$ 2.2	$ (2.2)	$ 0.4	$ 0.1	$ 1.6	$ 4.3	$ 14.7	$ 7.2	$ 16.3
	A2	$ 1.3	$ 2.6	$ (2.0)	$ 0.8	$ 0.3	$ 2.1	$ 23.0	$ 50.5	$ 26.0	$ 52.2
	A1	$ 3.1	$ 6.2	$ (0.2)	$ 4.4	$ 2.1	$ 5.6	$ 158.7	$ 315.9	$ 161.6	$ 317.5
ICRSSL	A4	$ 2.0	$ 4.3	$ (1.0)	$ 2.7	$ 1.1	$ 3.8	$ (1.0)	$ 2.7	$ 1.1	$ 3.8
	A3 - Preferred	$ 2.9	$ 6.1	$ (0.2)	$ 4.4	$ 2.0	$ 5.6	$ 6.5	$ 19.4	$ 9.5	$ 21.0
	A2	$ 3.7	$ 7.5	$ 0.5	$ 5.8	$ 2.7	$ 7.0	$ 11.3	$ 28.0	$ 14.3	$ 29.7
	A1	$ 10.6	$ 21.0	$ 7.3	$ 19.2	$ 9.6	$ 20.4	$ 60.8	$ 124.9	$ 63.7	$ 126.5
ICRSSM	A4	$ 1.2	$ 2.5	$ (1.9)	$ 0.8	$ 0.2	$ 2.0	$ (1.9)	$ 0.8	$ 0.2	$ 2.0
	A3 - Preferred	$ 1.7	$ 3.6	$ (1.5)	$ 1.9	$ 0.8	$ 3.1	$ 3.2	$ 12.7	$ 6.2	$ 14.3
	A2	$ 2.2	$ 4.5	$ (1.1)	$ 2.7	$ 1.2	$ 3.9	$ 10.7	$ 26.8	$ 13.7	$ 28.4
	A1	$ 6.0	$ 11.9	$ 2.7	$ 10.1	$ 5.1	$ 11.4	$ 65.1	$ 133.3	$ 68.1	$ 134.9

Comparison Data:

Range of VSL Weighted Average, $Millions, 2003$	
$ 4.98	$ 5.16

Notes: Cost per Discounted Death Avoided: cost represents full cost of the rule (i.e., no subtraction for illnesses avoided). Net Cost per Discounted Death Avoided: cost represents only illnesses avoided (i.e., cost attributed to avoiding illnesses subtracted to produce net cost).

The Traditional COI includes values for medical costs and lost work time (including a portion of unpaid household production). The Enhanced COI also includes values for lost personal time (non-work time) such as child care and homemaking (to the extent not covered by the Traditional COI), time with family, and recreation, and lost productivity on days when workers are ill but go to work anyway.

Sources: Derived from Exhibits C.4 and C.5 (number of illnesses and deaths avoided); Exhibit O.9 (schedule); and Exhibit 8.11 (total cost of the rule).

Benefit-Cost Ratios

In addition to an evaluation of cost per illness avoided, EPA has evaluated the benefit/cost ratio for each alternative. This measure compares the ratio of the overall value of benefits to the overall costs (including costs to the States). The benefit-cost ratio is used as a threshold measure of cost-effectiveness. Benefit/cost ratios should exceed 1, that is, benefits should exceed costs. All but one of the ratios shown in Exhibit 8.20 are above this cost-effectiveness threshold based on mean values of benefit and cost estimates. This is not surprising given that this proportion is simply another way of expressing the results of section 8.2.3, National Net Benefits. If the nonquantified benefits were included, the ratios would all be larger.

Exhibit 8.20: Benefit-Cost Ratios for Each Regulatory Alternative

Data Set	Rule Alternative	Benefit/Cost Ratio (Enhanced COI)		Benefit/Cost Ratio (Traditional COI)	
		3%	7%	3%	7%
ICR	A1	4.7	3.5	3.4	2.5
	A2	11.5	8.3	8.3	6.0
	A3 - Preferred	13.9	10.0	10.1	7.2
	A4	21.7	15.3	15.8	11.1
ICRSSL	A1	1.4	1.0	1.0	0.7
	A2	4.0	2.9	2.9	2.1
	A3 - Preferred	4.9	3.5	3.6	2.6
	A4	7.1	4.9	5.2	3.6
ICRSSM	A1	2.4	1.8	1.8	1.3
	A2	6.7	4.8	4.9	4.3
	A3 - Preferred	8.4	5.9	6.1	4.3
	A4	12.3	8.5	9.0	6.3

8.4 Effect of Uncertainties on the Benefit-Cost Comparisons

Detailed discussions of the uncertainties and assumptions associated with the national benefits and costs are contained in Chapters 5 and 6, respectively. Exhibit 8.21 is a summary of the most important assumptions and their effects on the estimates. It is EPA's judgment that the overall uncertainties regarding the occurrence of *Cryptosporidium* in drinking water have been greatly reduced over the past several years through many data collection efforts, the most significant being the Information Collection Rule and the ICR Supplemental Surveys. The result is that many uncertainties have been identified, researched, and where possible, resolved. As can be seen in Exhibit 8.20, the remaining uncertainties are inherent in the data and represent assumptions where the direction of the biases is unknown. It is EPA's judgment that the largest uncertainty that affects the conclusions in this EA is that surrounding the infectivity of *C. parvum*.

Exhibit 8.21: Effects of Uncertainties on the National Estimates of Benefits and Costs

Assumptions for Which There Is Uncertainty	Section with Full Discussion of Uncertainty	Effect on Estimates		
		Under-estimate	Over-estimate	Under- or Over-estimate
Benefits				
Not all benefits are quantified	8.2.1, 5.2.3	X		
Infectivity for *C. parvum* estimated from only three known isolates	5.2.3			X
Source water concentrations estimated using three data sets, calculation of central tendencies, and bounds	5.2.4.1			X
Fraction of oocysts that are infectious (represented by triangular distribution)	5.2.4.1			X
Pre-LT2 removal/inactivation using triangular distributions (with uncertain modes)	5.2.4.1			X
Value of illnesses avoided based on COI data rather than WTP data	5.3.1.1	X		
Costs				
Using ICR, ICRSSL, and ICRSSM occurrence distribution data to predict plant bin assignments	4.5.3			X
Single flow rate used to evaluate unit costs within each of 9 size categories	6.5.1			X
Potentially lower-cost treatment options not considered	6.5.1		X	
Typical water quality and operating parameters used to estimate unit costs	6.5.1			X

8.5 Summary of Benefit and Cost Comparisons

The following is a summary of the important points regarding the potential net benefits of the LT2ESWTR.

The Preferred Alternative passes key threshold economic criteria:

- The Preferred Alternative (A3) has positive net benefits (Exhibit 8.12). (In fact, this is also true for Alternatives A2 and A4, and true for Alternative A1 under 11 of the 12 possible scenarios of occurrence, COI value, and discount rate.) In other words, for these alternatives, benefits are very likely to exceed costs (Exhibit 8.6) and have a benefit-cost ratio greater than 1.0 (Exhibit 8.19). This conclusion is especially strong because the benefit estimates do not include the value of the unquantified benefits and are therefore artificially low.

- The number of illnesses that would have to be prevented in order to break even relative to costs is well below the mean estimated number of avoided illnesses and deaths (Exhibits 8.3, 8.7a and 8.7b).

- The Preferred Alternative is cost-effective: no other alternative achieves greater benefits at the same cost or the same benefits at lower cost (Exhibit 8.17).

- The Preferred Alternative is cost-effective based on the cost of the rule and the number of illnesses and deaths avoided (net cost per discounted death or illness), but only Alternative A4 is below the comparison threshold when considering incremental net cost per illness or death (Exhibits 8.18 and 8.19).

The Preferred Alternative is the superior alternative across a wide variety of measures when considering all combinations of occurrence data sets, discount rates, and COI values:

- The Preferred Alternative shows the highest mean net benefits under more conditions than any other one alternative (Exhibits 8.12, 8.15, and 8.16).

- In the analysis of incremental benefits, the Preferred Alternative is the last alternative having positive net benefits in 8 of the 12 combinations of cost of illness, discount rate, and data set (Exhibit 8.13).

The Preferred Alternative is the superior alternative when benefits are near the average values estimated. At substantially higher levels of estimated benefits, Alternative A2 becomes economically superior:

- The net benefits of the Preferred Alternative are most often highest near the mean value of benefits and over much of the range that describes uncertainty in benefits estimates (Exhibits 8.15 and 8.16). If unquantified benefits are determined to be substantially higher, Alternative A2 would become an increasingly better choice from an economic perspective.

Alternative A3 was recommended by the Stage 2 Microbial Disinfectants and Disinfection Byproducts (Stage 2 M-DBP) Advisory Committee. Based on this recommendation, and supported by the evaluations presented above, EPA selected Alternative A3 as the Preferred Alternative.

9. References

Abdalla, C.W. 1990. Measuring economic losses from ground water contamination: an investigation of household avoidance costs. *Water Resources Bulletin* 26:451-463.

Abdalla, C.W., B.A. Roach, and D.J. Epp. 1992. Valuing environmental quality changes using averting expenditures: application to groundwater contamination. *Land Economics* 68:163-69.

Aboytes, Ramon, G. Di Giovanni, F. Abrams, C. Rheinecker, W. McElroy, N. Shaw, and M.W. LeChevallier. 2004. Detection of Infectious *Cryptosporidium* in Filtered Drinking Water . *Journal of AWWA* 96(9):88-97.

Akiyoshi, D.E., S. Mor, S. Tzipori. 2003. Rapid Displacement of *Cryptosporidium parvum* Type 1 by Type 2 in Mixed Infections in Piglets. *Infection and Immunity.* 71(10):5765-5771.

AWWA (American Water Works Association) Committee Report. 1983. Deterioration of water quality in large distribution reservoirs (open reservoirs). AWWA Committee on Control of Water Quality in Transmission and Distribution Systems. *Journal of AWWA* 75(4):191-195.

AWWA. 2000. *WATER:\STATS.* Database containing 1996 AWWA survey of water systems. Denver: American Water Works Association. June, 2000.

Amvrosieva, T.V., L.P. Titov, M. Mulders, T. Hovi, O.V. Dyakonova, V.I. Votyakov, Z.B. Kvacheva, V.F. Eremin, R.M. Sharko, S.V. Orlova, O.N. Kazinets, and Z.F. Bogush. 2001. Viral water contamination as the cause of aseptic meningitis outbreak in Belarus. *Central European J Public Health* 9(3): 154-157.

Barwick, R.S., D.A. Levy, G.F. Craun, M.J. Beach, and R.L. Calderon. 2000. Surveillance for waterborne-disease outbreaks - United States, 1997-1998. *Morbidity and Mortality Weekly Report* 49(SS04):1-35.

Beesley, M. 1965. The value of time spent traveling: some new evidence. *Economica* 32(2):174-185.

Berger, Mark C., Glenn C. Blomquist, Don Kenkel, and George S. Tolley. 1987. Valuing changes in health risks: a comparison of alternative measures. *The Southern Economics Journal* 53:977-984.

Blackburn, B.G., G.F. Craun, J.S. Yoder, V. Hill, R.L. Calderon, N. Chen, S. H. Lee, D.A. Levy, and M. J. Beach. 2004. Surveillance for waterborne-disease outbreaks associated with drinking water --- United States, 2001--2002. *Morbidity and Mortality Weekly Report* 53(SS08):23-45.

Boardman, Anthony E., David H. Greenberg, Aidan R. Vining and David L. Weimer, Cost-Benefit Analysis Concepts and Practice, 1996, p. 405.

Boutin, B., M. B. Brown, R. Clark, J. C. Lipscomb, R. Miltner, P. Murphy, L. R. Papa, D. Reasoner, and R. Rheingans. Comparative Risk Framework Methodology and Case Study. U.S. Environmental Protection Agency, Office of Research and Development, National Center for Environmental Assessment, Washington, DC, 1998.

Boyle, Brian. 2002. HAART has significantly causes of death in HIV-infected persons. http://www.hivandhepatitis.com/2002conf/9thcroi/37.html

Bridgman S.A., Robertson R.M., Syed Q., Speed N., Andrews N., Hunter P.R. 1995. Outbreak of cryptosporidiosis associated with a disinfected groundwater supply. *Epidemiol. Infect.* 115:555-566.

Brock, D.W. 2002. "Chapter 14.3: Fairness and Health." In Summary Measures of Population Health: Concepts, Ethics, Measurement and Applications, C.J.L. Murray, J.A. Salomon, C.D. Mathers, and A.D. Lopez (eds.). Geneva: World Health Organization.

Brown, D. 2001. Study Finds Drug-Resistant HIV in Half of Infected Patients. Washington Post, December 19, Page A02.

Brown, E.A.E., Casemore D.P., Gerken A., Greatorex I.F. 1989. Cryptosporidiosis in Great Yarmouth, the investigation of an outbreak. *Public Health* 103:3-9.

Bruzelius, Nils. 1979. *The value of travel time.* London: Croon Helm.

Buzby, J.C., T. Roberts, C.T. Jordan Lin, and J.M. MacDonald. 1996. Bacterial foodborne illness: medical costs and productivity losses. Economic Research Service, U.S. Department of Agriculture, Agricultural Economic Report No. 741. August 1996.

Carollo. 1999. Report on water quality issues at Sheffield Reservoir for the City of Santa Barbara.

Casemore, D.P. 1990. Epidemiological aspects of human cryptosporidiosis. *Epidemiol. Infect.* 104:1-28.

CDC (Centers for Disease Control and Prevention). 2002. *HIV/AIDS Surveillance Report* vol. 14. http://www.cdc.gov/hiv

CDC. 2001a. Wonder Database. http://wonder.cdc.gov

CDC. 2001b. *HIV/AIDS Surveillance Supplemental Report* 7(1):7. http://www.cdc.gov/hiv

CDC. 2000. *HIV/AIDS Surveillance Report* 12(2):7,30. http://www.cdc.gov/hiv

CDC. 1999. *HIV/AIDS Surveillance Report* 11(2):7,31,37. http://www.cdc.gov/hiv

CDC. 1995. *Vital and Health Statistics: Detailed Diagnoses and Procedures, National Hospital Discharge Survey, 1993.* October, 13(122). http://www.cdc.gov/nchs/

CDC. 1993. *HIV/AIDS Surveillance Report* 5(4):26. http://www.cdc.gov/hiv

CDC. 2004 Fact Sheet on Cryptosporidiosis (accessed January 18, 2005): www.cdc.gov/ncidod/dpd/parasites/cryptosporidiosis/2004_PDF_ _Cryptosporidiosis.pdf

Cesario, F.J. 1976. Value of time in recreation benefit studies. *Land Economics* 52:32-41.

Chappell, C.L..et al. 2004. Experimental Challenge of Healthy Adults with the Human Genotype (Type 1) of *Cryptosporidium.*

Chappell C.L., P.C. Okhuysen, C.R. Sterling, C. Wang, W. Jakubowski, and H.L. DuPont. 1999. Infectivity of Cryptosporidium parvum in healthy adults with pre-existing anti-*C. parvum* serum immunoglobulin G. *Am J Trop Med Hyg*. 60:157-64.

Chappell, C.L., H.L. DuPont, and P.C. Okhuysen. 1997. *Virulence factors in Cryptosporidium and infective dose in humans*. Progress Report for Grant R82-4759, U.S. EPA, to the University of Texas-Houston School of Public Health, Center for Infectious Diseases.

Cicirello, H., K. Kehl, D. Addiss, M. Chusid, R. Glass, J. Davis, and P. Havens. 1997. Cryptosporidiosis in children during a massive waterborne outbreak in Milwaukee, Wisconsin: Clinical, laboratory and epidemiologic findings. *Epidemiol. Infect.* 119(1):53-60.

Clancy, J.L., Bukhari, Z., Hargy, T.M., Bolton, J.R., Dussert, B.W., Marshall, M.M.. 2000. Using UV to inactivate *Cryptosporidium*. *Journal AWWA* 92(9):97-104.

Connell, K., C.C. Rodgers, H.L. Shank-Givens, J. Scheller, M.L. Pope, and K. Miller. 2000. Building a better protozoa data set. *Journal of AWWA* 92:10:30.

Cooke, G.D. and R.E. Carlson. 1989. Reservoir Management for Water Quality and THM Precursor Control. AWWARF. Denver, CO.

Cooper, B.S. and D.P. Rice. 1976. The economic cost of illness revisited. *Social Security Bulletin* 39(2):21-36.

Cordell, R.L., P.M. Thor, D.G. Addiss, J. Theurer, R. Lichterman, S.R. Ziliak, D.D. Juranek, and J.P. Davis. 1997. Impact of a massive waterborne cryptosporidiosis outbreak on child care facilities in metropolitan Milwaukee, Wisconsin. *Pediatr. Infect. Dis. J.* 16(7):639-644.

Corso, P.S., M.H. Kramer, K.A. Blair, D.G. Addiss, J.P. Davis, and A.C. Haddix 2003. Cost of illness in the 1993 waterborne *Cryptosporidium* outbreak, Milwaukee, Wisconsin. *Emerging Infectious Diseases* 9(4):426-431.

Craik, S.A., D. Weldon, G.R. Finch, J.R. Bolton, and M Belosevic. 2001. Inactivation of *Cryptosporidium parvum* oocysts using medium- and low-pressure ultraviolet radiation. *Water Research* 35(6):1387-1398.

Craun, G.F. 1996. Task 1. Cases of illness required to initiate a waterborne outbreak investigation. September 18. Task 2. Epidemiological and water supply information from waterborne outbreaks of giardiasis and levels of cysts detected in water during outbreaks. September 23. Task 3. Epidemiological and water supply information from waterborne outbreaks of cryptosporidiosis and levels of oocysts detected in water during outbreak investigations. September 20. Task 4. Waterborne disease in the USA: reported waterborne outbreaks, 1993-94. September 27. 68-C3-0368. Wade Miller Associates, Inc.

Craun, G.F. and R. Calderon. 1996. Microbial risks in groundwater systems: epidemiology of waterborne outbreaks. In: *Under the Microscope: Examining Microbes in Groundwater.* Boston: Proceedings of the Groundwater Foundation's 12th Annual Fall Symposium.

Craun, G.F., S. Hubbs, F.J. Frost, R. Calderon, and S. Via. 1998. Waterborne outbreaks of cryptosporidiosis. *Journal of AWWA* 90(9):81-91.

Crystal-Peters, J., W.H. Crown, R.Z. Goetzel, D.C. Schutt. 2000. The cost of productivity losses associated with allergic rhinitis. *The American Journal of Managed Care* 6(3):373-378.

CWC (Culp/Wesner/Culp Engineering). 1994. *W/W Costs and design criteria guidelines 2.0, computer software for estimating water and wastewater technology costs.* San Clemente, CA: CWC Engineering Software.

de Melker, H.E., F.G.A. Versteegh, M.A.E. Conyn-van Spaendonck, L.H. Elvers, G.A.M. Berbers, A. van der Zee. 2000. Specificity and sensitivity of high levels of IgG antibodies against pertussis toxin in a single serum for diagnosis of infection with *Bordetella pertussis*. *J. Clin. Microbiol.* 38:800-806.

Douglas, J., G. Kenny, and T.R. Miller. 1990. Which estimates of household production are best? *Journal of Forensic Economics* 4:25-45.

Dugan, N.R., K.R. Fox, R.J. Miltner, D.A. Lytle, D.J. Williams, C.J. Parrett, C.M. Feld, and J.H. Owens. 1999. *Control of Cryptosporidium oocysts by steady-state conventional treatment*. Cincinnati: EPA Water Supply and Water Resources Division. Annual Conference Proceedings of the American Water Works Association. #ACE99567.

DuPont, H.L., C. Chappell, C. Sterling, P. Okhuysen, J. Rose, and W. Jakubowski. 1995. The infectivity of *Cryptosporidium parvum* in healthy volunteers. *New England J. Med.* 332:855-859.

DynCorp. 2002. E-mail dated May 22 from Kevin Connell to Curtis Haymore at The Cadmus Group, Inc., Alexandria, Virginia.

DynCorp I&ET. 2000. E-mail to EPA. July 6, 2000.

D'Antonio, R.G., R.E. Winn, J.P. Taylor, T.L. Gustafson, W.L. Current, M.M. Rhodes, G.W. Gary, and R.A. Zajac. 1985. A waterborne outbreak of cryptosporidiosis in normal hosts. *Ann. Intern. Med.* 103:888.

Edzwald, J.K. and M.B. Kelley. 1998. Control of *Cryptosporidium* from reservoirs to clarifiers to filters. *Water Si. Technol.* 37(2):1-8.

Egerov, A., F. Frost, T. Muller, E. Naumova, A. Tereschenko, T. Ford. 2003. Serological Evidence of *Cryptosporidium* Infections in a Russian City and Evaluation of Risk Factors for Infections. *AEP*. 14(2): 129-136.

Fayer, R. and B.L.P. Ungar. 1986. *Cryptosporidium spp.* and cryptosporidiosis. *Microbiol. Rev.* 50(4):458-483.

Framm, S.R. and R. Soave. 1997. Agents of diarrhea. *Med. Clin. N. Amer.* 81(2):427-447.

Freeman, A.M. 1979. The Benefits of Environmental Improvement: Theory and Practice. Baltimore: Johns Hopkins University Press.

Freeman, A.M. III. 1993. *The measurement of environmental and resource values: theory and methods.* p.6. Washington, DC: Resources for the Future.

Frisby H.R., D.G. Addiss, W.J. Reiser, B. Hancock, J.M. Vergeront, N.J. Hoxie, J.P. Davis. 1997. Clinical and epidemiologic features of a massive waterborne outbreak of cryptosporidioisis in persons with HIV infection. *J. Acq. Immun. Def. Synd.* 16(5):367-373.

Frost, F.J., R.L. Calderon, T.B. Muller, M. Curry, J.S. Rodman, D.M. Moss, A.A. de la Cruz. 1998. A two-year follow-up survey of antibody to *Cryptosporidium* in Jackson County, Oregon following an outbreak of waterborne disease. *Epidemiological Infection*. 121: 213-217.

Frost, F., G.F. Craun, R. Calderon, and S.A. Hubbs. 1997. So many oocysts, so few outbreaks. *Journal of AWWA* 89(12):8-10.

Furomoto, W.A. and Mickey, R. 1967a. A mathematical model for the infectivity-dilution curve of tobacco mosaic virus: theoretical considerations. *Virology* 32: 216.

Furomoto, W.A. and Mickey, R. 1967b. A mathematical model for the infectivity-dilution curve of tobacco mosaic virus: experimental tests. *Virology* 32: 224.

Gerba, C.P, J.B. Rose, and C.N. Haas. 1996. Sensitive populations: who is at the greatest risk? *Int. J. Food Microbiol.* 30(1-2):113-123.

Gold, M. R., J.E. Siegel, L.B. Russell, and M.C. Weinstein (eds.). 1996. *Cost-effectiveness in health and medicine*. New York: Oxford University Press.

Gold, M.R., D. Stevenson, and D.G. Fryback. 2002. "HALYS and QALYS and DALYS, Oh My: Similarities and Differences in Summary Measures of Population Health." Annual Review of Public Health 23:115-34

Goldschmidt-Clermont, L. 1982. *Unpaid work in the household.* p. 4. Prepared for the International Labor Office, United Nations.

Goodrich, J.A., S.Y. Li, and B.W. Lykins Jr. 1995. Cost and Performance of Alternative Filtration Technologies for Small Communities. *Proceedings of the 1995 AWWA Annual Conference*.

Griffith, C. 1988. Floating Reservoir Cover Controls Algae Growth, Allows Lowered THM's. *Journal of AWWA* 80(10):66,68-69.

Griffiths, J.K. 2002. Personal Communication. October 23, 2002.

Gronau, R. 1986. Home production - a survey. *Handbook of Labor Economics Volume 1*. Orley Ashenfelter and Richard Layard, eds. New York: North-Holland.

Grunberg, S.M., Boutin, N., Ireland, A., Miner, S., Silvera, J., and Ashikaga, T., "Impact of Nausea/Vomiting on Quality of Life as a Visual Analogue Scale-Derived Utility Score," Support Care Cancer, November 1996, 4(6): 435-439.

Grunberg, S.M., Srivastava, A., Grunberg, K.J., Weeks, J., "Intensity of Chemotherapy-Induced Emesis and Overall Survival as Determinants of a Global Utility Score," Support Care Cancer, November 2002, 10(8): 624-629.

Guerrant, R.L. 1997. Cryptosporidiosis: An emerging, highly infectious threat. *Emerg. Infect. Dis.* 3(1):1-9. January-March. www.cdc.gov/ncidod/EID/vol3no1/guerrant.htm

Haas, C.N., Rose, J.B. and Gerba C.P. 1999. *Quantitative Microbial Risk Assessment*. John Wiley and Sons.

Haas, C.N., C.S. Crockett, J.B. Rose, C.P. Gerba and A.M. Fazil. 1996. Assessing the Risk Posed by Oocysts in Drinking Water. *Journal of AWWA* 88(9):131-136.

Haas, C.N., and J.B. Rose. 1994. Reconciliation of Microbial Risk Models and Outbreak Epidemiology: The Case of the Milwaukee Outbreak. *Proceedings of the AWWA Annual Conference*, New York: 517-521.

Holcomb, DL, Smith, MA, Ware, GO, Hung, Y-C, Brackett, RE and Doyle, MP. 1999. Comparison of six dose-response models for use with food-borne pathogens. *Risk Analysis*. 19(6): 1091-1100.

Harrington, W., A.J. Krupnick, and W.O. Spofford. 1991. *Economics and Episodic Disease: The Benefits of Preventing a Giardiasis Outbreak.* Washington, DC: Resources for the Future.

Hartunian, N.S., C.N. Smart, and M.S. Thompson. 1981. *The incidence and economic costs of major health impairments: a comparative analysis of cancer, motor vehicle injuries, coronary heart disease, and stroke.* An Institute for Highway Safety Book. p. 45. Lexington, MA: Lexington Books.

Havelaar, A.H., de Hollander, A.E.M., Teunis, P.F.M., Evers, E.G., van Kranen, H.J., Versteegh, F.M., van Koten, J.E.M., and Slob, W., "Balancing the Risks and Benefits of Drinking Water Disinfection: Disability Adjusted Life-Years on the Scale," Environmental Health Perspectives, 108(4): 315-321, April 2000.

Heijbel H, K. Slaine, B. Seigel, P. Wall, S.J.N McNabb, W. Gibbons, G.R. Istre. 1987. Outbreak of diarrhea in a day care center with spread to household members: the role of Cryptosporidium. *Pediatr Infect Dis J.* 6(6):532-535.

Highleyman, L. 2000. Adverse Effects Associated with Antiretroviral Therapy. Bulletin of Experimental Treatments for AIDS. April. http://www.aegis.com/pubs/beta/2000/BE000405.html

Hoxie, N.J., J.P. Davis, J.M. Vergeront, R.D. Nashold, and K.A. Blair. 1997. Cryptosporidiosis-associated mortality following a massive waterborne outbreak in Milwaukee, Wisconsin. *Amer. J. Publ. Health* 87(12):2032-2035.

Hunter, P.R., S. Hughes, S. Woodhouse, N. Raj, Q. Syed, R. Chalmers, N. Verlander, J. Goodacre. 2004. Health Sequelae of Human Cryptosporidiosis in Immunocompetent Patients. *CID.* 15:504-510.

Hunter, P.R. and Q. Syed. 2001. Community Surveys of self-reported diarrhoea can dramatically overestimate the size of outbreaks of waterborne cryptosporidiosis. *Water Science and Technology* 43(12):27-30

Industrial Economics, Incorporated. 2001. *Assessing the Benefits of Drinking Water Regulations (Draft Final Report)*. Prepared for the U.S. Environmental Protection Agency. June 2001.

Industrial Economics, Incorporated. 2002. *Valuing Time Losses Due to Illness under the 1996 Amendments to the Safe Drinking Water Act (Draft Final)*. Prepared for the Office of Ground Water and Drinking Water, U.S. Environmental Protection Agency. October 2002.

Inungu, J.N., A.A. Morse, and C. Gordon. 2000. Risk factors, seasonality, and trends of cryptosporidisois among patients infected with human immunodeficiency virus. *Am. J. Trop. Med. Hyg.* 62(3):384-387.

Juranek, D. 1995. Cryptosporidiosis: Sources of infection and guidelines for prevention. *Clin. Infect. Dis.* 21(Suppl. 1):S57-S61.

Karon, J.M., P.L. Fleming, R.W. Steketee, and K.M. De Cock. 2001. HIV in the United States at the Turn of the Century: An Epidemic in Transition. *Am. J. Pub. Health* 91(7):1060-68.

Keech, M., A.J. Scott, and P.J.J. Ryan. 1998. The impact of influenza and influenza-like illness on productivity and healthcare resource utilization in a working population. *Occupational Medicine* 48(2):85-90.

Kessler, R.C., C. Barber, H.G. Birnbaum, R.G. Frank, P.E. Greenberg, R.M. Rose, G.E. Simon, and P. Wang. 1999. Depression in the workplace: effects on short-term disability. *Health Affairs* 18(5):163-171.

Kim, K.S., G. Hufnagel, N.M. Chapman, and S. Tracy. 2001. The group B coxsackieviruses and myocarditis. *Rev. Med. Virol.* 11(6):355-68.

Kleckner, N. and J. Neumann. 2000. Memorandum: Update to Recommended Approach to Adjusting WTP Estimates to Reflect Changes in Real Income. September 30, 2000.

Kocagil P., N. Demarteau, A. Fisher, and J.S. Shortle. 1998. The Value of Preventing *Cryptosporidium* Contamination Risk. *Health, Safety, & Environment* 175(Spring 1998).

Kramer, M.H., B.L. Herwaldt, R.L. Calderon, and D.D. Juranek. 1996a. Surveillance for Waterborne-Disease Outbreaks—United States, 1993-1994. *MMWR* 45(SS-1):1-33.

Kramer, M.H., B.L. Herwaldt, G.F. Craun, R.L. Calderon, and D.D. Juranek. 1996b. Waterborne Disease: 1993 and 1994. *Journal of AWWA* 88(3):66-80.

Larson, D.M. 1993. Joint Recreation choices and implied values of time. *Land Economics* 69(3):270-286.

LeChevallier, M.W., G.D. Di Giovanni, J.L. Clancy, Z. Bukhari, S. Bukhari, J.S. Rosen, J. Sobrinho, and M.M. Frey. 2003. Comparison of method 1623 and cell culture-PCR for detection of *Cryptosporidium* spp. in source waters. *Appl. Environ. Microbiol.* 69(2):971-979.

LeChevallier, M.W., J.L. Clancy, Z. Bukhari, S. Bukhari, T. Hargy, J.S. Rosen, J. Sobrinho, and M.M. Frey. 2000. Source Water Assessment: Variability of Pathogen Concentrations (Paper presented at 2000 WQTC).

LeChevallier, M.W., W. North, M. Abbaszadegan, T. Atherhold, and J. Rosen. 1997a. Variations in *Giardia* and *Cryptosporidium* in Source water: Statistical Approaches to Analyzing ICR Data. (Paper presented at 1997 WQTC).

LeChevallier, M.W., W.D. Norton, and T.B. Atherholt. 1997b. Protozoa in open reservoirs. *Journal of AWWA.* 89(9):84-96.

Labutiuk, C.W., F.W. Schaefer, III, G.R. Finch, and M. Belosevic. 1991. Comparison of animal infectivity, excystation and fluorogenic dye as measure of *Giardia muris* cyst inactivation by ozone. *Appl. Environ. Microbiol.* 57:3187-3192.

Lee, S.H. and S.J. Kim. 2002. Detection of infectious enteroviruses and adenoviruses in tap water in urban areas in Korea. *Water Research* 36(1):248-256.

Lee, S.H., D.A. Levy, G.F. Craun, M.J. Beach, and R.L. Calderon. 2002. Surveillance for waterborne disease outbreaks, United States, 1999–2000. *Morbidity and Mortality Weekly Report, Surveillance Summaries* 51(SS08):1-28.

Levy, D.A., M.S. Bens, G.F. Craun, R.L. Calderon, and B.L. Herwaldt. 1998. Surveillance for Waterborne Disease Outbreaks - United States, 1995-1996. *MMWR* 47(55-5):1-34.

Lindeburg, M.R. 1997. *Civil engineering reference manual for the PE exam*. 6th ed. p. 7-17. Belmont, CA: Professional Publications, Inc.

Louie, J., L.C. Hsu, D.H. Osmond, M.H. Katz, S.K. Schwarcz. 2002. Trends in causes of death in persons with AIDS in the era of High Active Antiretrovial Therapy, San Francisco: The importance of risk factor reduction. UCSF AIDS Research Institute. http://ari.ucsf.edu/pdf/Posters/barcelona/louie.pdf (10/30/02).

MacKenzie, W.R., W.L. Schell, KA. Blair, D.G. Addiss, D.E. Peterson, N.J. Hoxie, J.J. Kazmierczak, J.P. Davis. 1995a. Massive outbreak of waterborne *Cryptosporidium* infection in Milwaukee, Wisconsin: Recurrence of illness and risk of secondary transmission. *Clinical Infect. Diseases* 21:57-62.

MacKenzie, W.R., J.J. Kazmierczak, J.P. Davis. 1995b. An outbreak of cryptosporidiosis associated with a resort swimming pool. *Epidemiol. Infect.* 115:545-553.

MacKenzie, W.R., N.J. Hoxie, M.E. Proctor, M.S. Gradus, K.A. Blair, D.E. Peterson, J.J. Kazmierczak, D.G. Addiss, K.R. Fox, J.B. Rose, and J.P. Davis. 1994. A massive outbreak in Milwaukee of *Cryptosporidium* infection transmitted through the public water supply. *New England Jour. Med.* 331(3):161-167.

Makri, A, Modarres, R, Parkin, R. 2004. Cryptosporidiosis susceptibility and risk: a case study. *Risk Analysis*. 24(1): 209-220.

Marble, M. 2000. AIDS Therapies: Relapse is Rapid after Cessation of Therapy. AIDSWeekly Plus, January 24th. http://www.aegis.com/pubs/aidswkly/2000/AW000109.html (10/30/02).

Mauskopf, J.A. and French, M.T., "Estimating the Value of Avoiding Morbidity and Mortality from Foodborne Illnesses," Risk Analysis,11(4):619-631, December 1991.

McConnell, K.E., and I. Strand. 1981. Measuring the cost of time in recreation demand analysis: an application to sportfishing. *American Journal of Agricultural Economics* 63:153-156.

McDonald, A., W. MacKenzie, D. Addiss, M. Gradus, G. Linke, E. Zembrowski, M. Hurd, M. Arroweed, P. Lammie, and J. Priest. 2001. Cryptosporidium parvum-specific antibody responses among children residing in Milwaukee during the 1993 waterborne outbreak. Jour. Infectious Diseases 183:1373-1379.

McDowell, I. and Newell, C., Measuring Health: A Guide to Rating Scales and Questionnaires, Oxford University Press: New York, 1996.

McMenamin, P. 1994. Costs of hay fever in the United States in 1990. *Annals of Allergy* 73:35-39.

Mead, P.S., Slutsker, L., Dietz, V., McCaig, L.F., Bresee, J.S., Shapiro, C., Griffin, P.M., and Tauxe, R.V. 1999. Food-Related Illness and Death in the United States. *Center for Disease Control and Prevention* 5(5):607-625.

Medscape. 2002. Studies Involving Complete Treatment Withdrawal or Interruption. http://www.medscape.com/viewarticle/408261_3 (10/30/02).

Millard, P.S., K.F. Gensheimer, D.G. Addiss, D.M. Sosin, G.A. Beckett, A. Houckjankoski, A. Hudson. 1994. An outbreak of cryptosporidiosis from fresh-pressed apple cider. *JAMA* 272:1592-1596.

Ministry of Women's Affairs, Statistics New Zealand. 1999. *New Zealand Time Use Survey*. p. 22-23. December 1999.

Moore, A.C., B.L. Herwaldt, G.F. Craun, R.L. Calderon, A.K. Highsmith, and D.D. Juranek. 1993. Surveillance for waterborne disease outbreaks - United States, 1991-1992. *MMWR.* 42(SS-5):1-22 (November 19).

Morgan, D., M. Allaby, S. Crook, D. Casemore, T.D. Healing, N. Soltanpoor, S. Hill, and W. Hooper. 1995. Waterborne cryptosporidiosis associated with a borehole supply. *Communicable Disease Report/CDR Review* 5(7):R93-R97.

Morgan-Ryan, U., A. Fall, L. Ward, N. Hijjawi, I. Sulaiman, R. Fayer, R. Thompson, M. Olson, A. Lal, and L. Xiao. 2002. Cryptosporidium hominis n. sp. (Apicomplexa: Cryptosporidiidae) from Homo sapiens. Jounal of Eukaryotic Microbiology. 49:6:443-440.

Morra, J.J. 1979. *A review of water quality problems caused by various open distribution storage reservoirs*. p. 316-21.

Muller, T.B., F.J. Frost, G.F. Craun, and R.L. Calderon. 2001. Serological Responses to Cryptosporidium Infection. Letters to the Editor. Infection and Immunity. 69:3.

National Drinking Water Advisory Council. 2001. *Report of the Arsenic Cost Working Group to the National Drinking Water Council.* August 14, 2001.

National Research Council, and Commission on Behavioral and Social Sciences and Education. 2000. *Time use measurement and research: report of a workshop*. Committee on National Statistics, Michele Ver Ploeg, Joseph Altonji, Norman Bradburn, Julie DaVanzo, William Nordhaus, and Francisco Samaniego (eds.). Washington, D.C: National Academy Press.

National Research Council. 1997. *Safe water from every tap.* National Academy Press, Washington, DC.

Naumova, E.N, A.I. Egorov, R.D. Morris, and J.K. Griffiths. 2003. The elderly and waterborne *Cryptosporidium* infection: gastroenteritis hospitalizations before and during the 1993 Milwaukee outbreak. *Emerging Infectious Diseases* 9(4):418-425.

NJMS (New Jersey Medical School), NJMS National Tuberculosis Center. 1996. Brief History of TB. http://www.umdnj.edu/~ntbcweb/history.htm (July 23).

NYSDHAI (New York State Department of Health AIDS Institute). 2002. Criteria for the Medical Care of Adults with HIV Infection: Antiretroviral Therapy for Adults. http://www.hivguidelines.org/public_html/CENTER/clinical-guidelines/adult_hiv_guidelines/supplemental_pages/adult_arv/adults_arv_page3.htm. February 2002.

Nord, Erik, "Cost-Value Analysis in Health Care: Making Sense of QALYS," Cambridge University Press, 1999, p. 50.

Office of Management and Budget. 2003. Circular A-4, (September).

Okhuysen, P.C., C.L. Chappell, J.H. Crabb, C.R. Sterling, H.L. DuPont. 1999. Virulence of Three Distinct *Cryptosporidium parvum* Isolates for Healthy Adults. *The Journal of Infectious Diseases*. 180:1275-81.

Okhuysen, P.C., C.L. Chappell, C.R. Sterling, W. Jakubowski, and H. L. DuPont. 1998. Susceptibility and serologic response of health adults to reinfection with *Cryptosporidium parvum*. *Infect. Immun*. 66(2):441-443.

Okun, D., G. Craun, J. Edzwald, J. Gilbert, and J. Rose. 1997. New York City: To filter or not to filter? *Journal of AWWA* 89(3):62-74.

Osewe P., D.G. Addiss, K.A. Blair, A. Hightower, M.L. Kamb, J.P. Davis. 1996. Cryptosporidiosis in Wisconsin: a case-control study of post-outbreak transmission. *Epidemiol Infec.* 117(2):297-304.

Park, S.R., W.G. Mackay, and D.C. Reid. 2001. Helicobacter sp. recovered from drinking water biofilm sampled from a water distribution system. *Water Research* 35(6):1624-1626.

Partnership for Safe Water. 2002. *Partnership for safe water annual data summary report.* January 2002.

Patania, N.L., Jacangelo, J.G., Cummings, L., and Wilczak, A. 1995. Removal of *Cryptosporidium, Giardia*, and Particles by Granular Media Filtration in Pilot Studies. *Proceedings from 1995 AWWA Annual Conference*.

Pauley, M.V., S. Nicholson, J. Xu, D. Polsky, P.M. Danzon, J.F. Murray, M.L. Berger. 2002. A general model of the impact of absenteeism on employers and employees. *Health Economics* 11(3):221-231.

Payment, P., J. Siemiatycki, L. Richardson, R. Gilles, E. Franco, and M. Prevost. 1997. A Prospective epidemiological Study of Gastrointestinal Health Effects Due to the Consumption of Drinking Water. *International J. Environmental Health Research.* 7:5-31.

Perz J., F. Ennever, and S. Le Blanq. 1998. Cryptosporidium in tap water; Comparison of predicted risks with observed levels of disease. *Amer. J. Epidem.* 147:289-301.

Pluntze, J.D. 1974. Health Aspects of Uncovered Reservoirs. *Journal of AWWA.* 66(8):432-37.

Posnett, J and S. Jan. 1996. Indirect cost in economic evaluation: the opportunity cost of unpaid inputs. *Health Economics* 5:13-23.

Pouillot, R, Beaudeau, P, Denis, J-B, and Drouin, F. 2004. A quantitative risk assessment of waterborne Cryptosporidiosis in France using second-order Monte Carlo simulation. *Risk Analysis*. 24(1): 1-17.

Pozio, E., G. Rezza, A. Boschini, P. Pezzotti, A. Tamburrini, P. Rossi, M. Di Fine, C. Smacchia, A. Schiesari, E. Gattei, R. Zucconi, and P. Ballarini. 1997. Clinical cryptosporidiosis and human immunodeficiency virus (HIV)-induced immunosuppression findings from a longitudinal study of HIV-positive and HIV-negative former injection drug users. *J. Infect. Dis.* 176:969-975.

Ray, N.F., M. Thamer, E. Gardner, J.K. Chan, R. Kahn. 1998. Economic consequences of Diabetes Mellitus in the U.S. in 1997. *Diabetes Care* 21(2):296-309.

Regli, S, Rose, JB, Haas, CN and Gerba CP. 1991. Modeling the risk from Giardia and Viruses in Drinking Water. *Journal AWWA.* November. 76-84.

Reid, M. 1934. *Economics of Household Production.* New York: John and Wiley Sons, Inc.

Rice, D.P. 1966. Estimating the cost of illness. *Health Economic Series No. 6.* PHS Publication No. 947-6. Washington, DC: U.S. Government Printing Office. May 1966.

Rice, D.P. and W. Max. 1992. *The cost of smoking in California, 1989*. Sacramento, California: California State Department of Health Services.

Rochelle, P.A., M.M. Marshall, J.R. Mead, A.M. Johnson, D.G. Korich, J.S. Rosen, R. De Leon. 2002. Comparison of In Vitro Cell Culture and a Mouse Assay for Measuring Infectivity of *Cryptosporidium parvum. Applied and Environmental Microbiology*. 68(8):3809-3817.

Rose, J.B. 1997. Environmental ecology of *Cryptosporidium* and public health implications. *Annual Rev. Public Health* 18:135-161.

Rowe, R.D. and L.G. Chestnut. 1986. *Valuing changes in morbidity: WTP vs. COI measures.* Presented at the American Economics Association annual meeting. December 1986.

SAB. 2003. SAB Executive Committee Review Draft (Jan 14-15, 2003 Meeting).

SAB and USEPA. 1990. *Reducing risk: setting priorities and strategies for environmental protection.* Washington, DC: U.S. EPA Science Advisory Board. SAB-EC-90-021.

Sepulveda, A.R. and D.Y. Graham. 2002. Role of *Helicobacter pylori* in gastric carcinogenesis. *Gastroenterol. Clin. North America* 31(2):517-535.

Shaw, W.D. and P. Feather. 1999. Possibilities for including the opportunity cost of time in recreation demand systems. *Land Economics* 75(4):592-602.

Silverman, G.S., L.A. Nagy, and B.H. Olson. 1983. Variations in Particulate Matter, Algae, and Bacteria in Uncovered Finished Drinking Water Reservoirs. *Journal of AWWA* 75(4):191-195.

Small, K.A. 1992. *Urban transportation economics.* Chur, Switzerland: Harwood Academic Publishers.

Statistics Canada. 1999. "Average time spent on activities, total population and participants, by sex," *General Social Survey, 1998.* http://www.statcan.ca/english/Pgdb/People/Families /famil36a.htm as viewed August 2002.

Statistics New Zealand. 1999. "Table 19: Average minutes per day spent on each individual activity counting only primary activities, with subtotals giving the four major types of time, by sex, cross-classified by family type, for all people aged 12 and over living in private households." *New Zealand Time Use Survey*, Ministry of Women's Affairs.

Sun, H., J.C. Bergstrom, and J.H. Dorfman. 1992. Estimating the Benefits of Groundwater Contamination Control. *Southern Journal of Agricultural Economics* 63-71.

Tangerman, R.H., S. Gordon, P. Wiesner, and L. Kreckman. 1991. An outbreak of cryptosporidiosis in a day-care center in Georgia. *American Jour. of Epidemiology* 133:471-476.

Teunis P.F.M., C.L. Chappell, and P.C. Okhuysen. 2002. *Cryptosporidium* dose response studies: variation between isolates. *Risk Analysis* 22(1):175-183.

Teunis, PFM and Havelaar, AH. 2002. The Beta Poisson dose-response model is not a single hit model. *Risk Analysis*. 20(4): 513-520.

Tolley, G., D.Kenkel, and R. Fabian (eds.). 1994. *Valuing health for policy: an economic approach*. University of Chicago Press.

Tolley, G.S. and L. Babcock. 1986. *Valuation of reductions in human health symptoms and risks.* University of Chicago. Final report for the U.S. Environmental Protection Agency. January.

Torrance, G.W., Zhang, Y., Feeny, D., Furlong, W., Barr, R.. 1992. Multi-attribute preference functions for a comprehensive health status classification system. CHEPA Working Paper Series No. 92-18, McMaster University.

Trewin, D. 2000. *Unpaid work and the Australian economy: 1997*. Australian Bureau of Statistics. October 2000.

Ungar W.J. and P.C. Coyte. 2000. Measuring productivity loss days in asthma patients. *Health Economics* 9:37-46.

U.S. Bureau of Labor Statistics. Undated. *American Time Use Survey: frequently asked questions.* http://www.bls.gov/tus/atusfaqs.htm#QA4 (August 2002).

U.S. Bureau of Labor Statistics. Undated. "Table 2: Income before taxes: Average annual expenditures and characteristics." *Consumer Expenditure Survey, 2000.*

U.S. Bureau of Labor Statistics. Undated. "Table 39: Median weekly earnings of full-time wage and salary workers by detailed occupation and sex." *Current Population Survey*.

U.S. Bureau of Labor Statistics. 2001. 2000 National Occupational Employment and Wage Estimates. "17-2051 Civil Engineers" and "51-8031 Water and Liquid Waste Treatment Plant and System Operators." http://stats.bls.gov/oes/2000/oes_nat.htm.

U.S. Bureau of Labor Statistics. 2002. "Table 626: Employer costs for employee compensation per hour worked: 2001." *Statistical Abstract of the United States: 2001*.

U.S. Bureau of Labor Statistics. 2001. Employment cost index. http://www.bls.gov.

U.S. Bureau of Labor Statistics. 2004. Consumer Price Index for All Urban Consumers, Not Seasonally Adjusted. http://www.bls.gov.

U.S. Census Bureau. 2004. No. 11. Resident population by age and sex: 1930 to 2002; No. 12. Resident population projections by sex and age: 2005 to 2050. Statistical Abstract of the United States: 2003. pp. 13-14. http://www.census.gov/prod/2004pubs/03statab/pop.pdf.

U.S. Census Bureau. 2002. Table RDI-1. "Household income before and after taxes: 1979 to 2000." March 2002. http://www.census.gov/hhes/income/histinc/rdi01x1.html.

U.S. Census Bureau. 2001a. Households and Families: 2000. Census 2000 Brief. C2KBR/01-8.

U.S. Census Bureau. 2001. *Statistical Abstract of the United States: 2001*. Washington, DC: U.S. Department of Commerce. "Table No. 567. Employment Status of the Civilian Population: 1960 to 2000;" "Table No. 582. Persons at Work by Hours Worked: 2000;" "Table No. 621. Full-Time Wage and Salary Workers—Number and Earnings: 1985 to 2000." November 2001.

U.S. Census Bureau. 2000. *Statistical Abstract of the United States: 2000*. Washington, DC: U.S. Department of Commerce. "Table 701. Employer Costs for Employee Compensation Per Hour Worked: 2000." December 2000.

U.S. Council of Economic Advisors. 2002. *Economic Report of the President: 2002*. Washington, DC "Table B-31 Total and per capita disposable personal income and personal consumption expenditures, and per capital gross domestic product, in current and real dollars, 1959-2001."

U.S. Department of Agriculture. 1994-96 Continuing Survey of Food Intakes by Individuals (CSFII). http://www.usda.gov

U.S. Department of Commerce, Bureau of Economic Analysis. 2004a. Table 1.1.6. Real Gross Domestic Product, Chained Dollars (Billions of chained (2000) dollars). http://www.bea.gov

U.S. Department of Commerce, Bureau of Economic Analysis. 2004b. Table 3.9.4 Price Indexes for Government Consumption Expenditures and Gross Investment. http://www.bea.doc.gov

U.S. Department of Commerce. 1992. *1992 Census of Governments*, GC92(4)-4: Finances of Municipal and Township Governments. U.S. Dept. of Commerce, Bureau of the Census.

U.S. Department of Energy, Energy Information Administration. 2004a. Table ES1.A. Total Electric Power Industry Summary Statistics, 2004 and 2003. http://www.eia.doe.gov/cneaf/electricity/epm/tablees1a.html

U.S. Department of Energy, Energy Information Administration. 2004b. Table 7.1. Electricity Overview (Billion Kilowatthours). http://www.eia.doe.gov/emeu/mer/txt/mer7-1

U.S. Department of Labor. Undated. "Fact sheet #23: Overtime pay requirements of the FLSA." http://www.dol.gov/esa /regs/compliance/whd/whdfs23.htm as viewed August 2002.

USEPA. 2005. *Regulatory Impact Analysis for the Final Clean Air Interstate Rule*, EPA-452/R-05-002, Appendix G, pp. 369 - 420 (March).

USEPA. 2004a. *Information Collection Request for the Long Term 2 Enhanced Surface Water Treatment Rule.* Prepared by The Cadmus Group, Inc. U.S. EPA Contract 68-C-02-026. October 2004.

USEPA. 2004b. *Cost and Technology Document for the Ground Water Rule.* Prepared by The Cadmus Group, Inc., Arlington, VA. U.S. EPA Contract 68-C-99-206. 2004.

USEPA 2003a. *Technologies and Costs for Control of Microbial Contaminants and Disinfection By-products.* Office of Ground Water and Drinking Water. Standards and Risk Reduction Branch. Standards and Risk Management Division. U.S. EPA Contract 68-C-02-026. May 2003.

USEPA. 2003b. *Labor Costs for National Drinking Water Rules*.

USEPA. 2003c. *Draft Occurrence and Exposure Assessment for the Long Term 2 Enhanced Surface Water Treatment Rule*. Prepared by The Cadmus Group, Inc. Arlington, VA. U.S. EPA Contract 68-C-02-026. June 2003.

USEPA. 2003d. *Draft Economic Analysis for the Stage 2 Disinfectants and Disinfection Byproducts Rule*. Prepared by The Cadmus Group, Inc. Arlington, VA. U.S. EPA Contract 68-C-02-026 July 2003.

USEPA. 2003e. *SDWIS Database*. September 2003 SDWIS freeze data, adjusted for population errors.

USEPA. 2002. *Community Water System Survey 2000*. December 2002.

USEPA. 2001a. *Assessing the Benefits of Drinking Water Regulations*. June 2001.

USEPA. 2001b. National Rural Water Association Survey User Database. Prepared by The Cadmus Group, Inc. U.S. EPA Contract 68-C-99-206.

USEPA. 2001c. *Drinking Water Baseline Handbook*, *Third Edition*. Draft. Prepared by International Consultants, Inc. Contract 68-C6-0039. May, 2001.

USEPA. 2001d. *Arsenic Rule Benefits Analysis: An SAB Review*. Science Advisory Board. EPA-SAB-RSAC-01-005. May 2001.

USEPA. 2000a. *Geometries and characterization of public water systems*. Office of Ground and Drinking Water. U.S. EPA Contract 815-R-00-024. December 2000.

USEPA. 2000b. *Surface Water Analytical Tool (SWAT) Version 1.1 - program design and assumptions*. Prepared by Malcolm Pirnie, Inc.

USEPA. 2000c. *Data Reliability Analysis of the EPA Safe Drinking Water Information System/Federal Version (SDWIS/FED)*. Office of Water. U.S. EPA Contract 816-R-00-020. October, 2000.

USEPA. 2000d. *Guidelines for Preparing Economic Analyses*. U.S. EPA Office of the Administrator. U.S. EPA Contract 240-R-00-003. September 2000.

USEPA. 2000e. *Stage 2 M-DBP Agreement in Principle*. (65 FR 83015, December 29, 2000).

USEPA. 2000f. *Handbook for Non-cancer Health Effects Valuation*. Prepared by the Non-Cancer Health Effects Valuation Subcommittee of the EPA Social Science Discussion Group, with assistance from Industrial Economics, Incorporated. The literature review in this *Handbook* was updated and extended to include cancers in: Industrial Economics, Incorporated. Unpublished. *Appendix B: Monetary values for health effects.* Prepared for the U.S. Environmental Protection Agency.

USEPA. 2000g. *Final Heavy Duty Engine/Diesel Fuel Rule: Air Quality Estimation, Selected Health and Welfare Effects Methods, and Benefits Results*. December 2000.

USEPA. 2000h. *AUX1 Database CD version 5.0*. EPA Office of Water. Data extracted from ICRFED database.

USEPA. 2000i. *ICR Supplemental Survey Database*. Prepared by DynCorp, Inc.

USEPA. 2000j. *Regulatory Impact Analysis for the LT1ESWTR.* U.S. EPA Contract 815-R-00-005. February 2000.

USEPA. 2000k. *Estimated Per Capital Water Ingestion in the United States.* U.S. EPA Office of Water. Washington, DC. EPA-822-R-00-008. April 2000.

USEPA. 1999a. *Method 1622: Cryptosporidium in Water by Filtration/IMS/FA.* Office of Water, Washington, DC. U.S. EPA Contract 821-R-99-001. January 1999.

USEPA. 1999b. *Method 1623: Cryptosporidium and Giardia in Water by Filtration/IMS/FA.* Office of Water, Washington, DC. U.S. EPA Contract 821-R-99-006. April 1999.

USEPA. 1999c. *Uncovered finished water reservoirs guidance manual.* Washington, DC: U.S. EPA Office of Research and Development. U.S. EPA Contract 815-R-99-011. April 1999.

USEPA. 1998. *Consumer Confidence Reports: Final Rule*. *Fed. Reg*. 63:44511-44536.

USEPA. 1998a. *Demographic distribution of sensitive population groups*. Final Report. Prepared by SRA Technologies, Inc., Falls Church, VA. Work Assignment No. B-11/22 (SRA 557-05/14). February 24, 1998.

USEPA. 1998b. *Regulatory impact analysis for the Interim Enhanced Surface Water Treatment Rule (IESWTR)*. Prepared by The Cadmus Group and by SAIC. U.S. EPA Contract 68-C6-0059. November 12, 1998.

USEPA. 1998c. *Guidance on implementing the capacity development provisions of the Safe Drinking Water Act Amendments of 1996.* Office of Water. U.S. EPA Contract 816-R-98-006. July 1998.

USEPA. 1997a. *Policy for use of probabilistic analysis in risk assessment*. Office of Research and Development. May 15, 1997.

USEPA. 1997b. *The Benefits and Costs of the Clean Air Act, 1970-1990.* Prepared for U.S. Congress.

USEPA. 1997c. *1995 Community Water Systems Survey*. U.S. EPA Contract 815-R-97-001b.

USEPA. 1997d. *Exposure Factors Handbook (Final Report).* Washington, D.C.: Office of Research and Development. “Chapter 15 - Activity Factors and Table 15A-2".

USEPA. 1996a. *ICR Microbial Laboratory Manual*. U.S. EPA Office of Research and Development. Washington, DC. EPA/600/R-95/178. April 1996.

USEPA. 1996b. *Economic analysis of Federal regulations under Executive Order 12866.* Office of Management and Budget. January 11, 1996.

USEPA. 1995a. *Policy for risk characterization at the U.S. Environmental Protection Agency*. Memorandum. March 21, 1995.

USEPA. 1995b. *Guidance for Risk Characterization.* Science Policy Council. February 1995.

USEPA. 1991. *Guidance Manual for Compliance with the Filtration and Disinfection Requirements for Public Water Systems Using Surface Water Sources*. AWWA. Prepared for USEPA.

USEPA. 1984. *Estimation of Small System Water Treatment Costs* (Water Model). USEPA Contract No. 68-03-3093. Drinking Water Research Division, Cincinnati, OH.

US FDA. 2001. 21 CFR Part 120. Hazard Analysis and Critical Control Point (HAACP); Procedures for the Safe and Sanitary Processing and Importing of Juice; Final Rule, 66(13), 6137-6202, January 19, 2001.

US FDA. 2004. 21 CFR Parts 1 and 11. Establishment and Maintenance of Records Under the Public Health and Security and Bioterrorism Preparedness and Response Act of 2002; Establishment and Maintenance of Records for Foods; Notice of Public Meeting; Availability of Draft Guidance for Records Access Authority; Final Rules and Notice. 69(236), 71561-71655, December 9, 2004.

US FDA. 1998. 21 CFR Parts 101 and 120. Preliminary Regulatory Impact Analysis and Initial Regulatory Flexibility Analysis of the Proposed Rules to Ensure the Safety of Juice and Juice Products; Proposed Rule, 63(84), 24253-24302, May 1, 1998.

U.S. House of Representatives. 1996. House Report No. 104-632 (Commerce Committee). June 24, 1996 in *U.S. Code Congressional and Administrative News* (USCCAAN), 1996, 4, pp. 1373, 1401 and 1409, discussing §§132(b) and 1418(a) of the House bill.

Van Houtven, G.L., J.C. Whitehead, T.H. Bingham and B. Depro. 1997. *Valuing Drinking Water Benefits: Theory, Methods, and Research Needs*. Draft Report.

Waitzman, N.J., R.M. Scheffler, and P.S. Romano. 1996. *The Cost of Birth Defects: Estimates of the Value of Prevention*. Lanham: University Press of America, Incorporated.

Waters, II, W.G. 1992. *Values of travel time savings and the link with income*. Paper presented at the Annual Meeting of the Canadian Transportation Research Forum. Banff, Alberta.

Weinstein, M.C., Siegel, J.E., Garber, A.M., Lipscomb, J., Luce, B.R., Manning, Jr., W.G., and Torrance, G.W. 1997. *Productivity Costs, Time Costs and Health-related Quality of Life: A Response to the Erasmus Group.* Health Economics, 6:505-510.

Whynes, D.K. and Neilson, A.R. 1993. *Convergent Validity of Two Measures of the Quality of Life.* Health Economics, 2: 229-235.

The White House. 1993. Executive Order 12866. *Regulatory Planning and Review*. Signed September 30, 1993. *Fed. Reg.* 58:190:51735-51744. October 4, 1993.

Willocks, L., A. Crampin, L. Milne, C. Seng, M. Susman, R. Gair, M. Moulsdale, S. Shafi, R. Wall, R. Wiggins, N. Lightfoot. 1998. A large outbreak of cryptosporidiosis associated with a public water supply from a deep chalk borehole. *Communicable Disease and Public Health* 1(4):239-243.