REGULATORY IMPACT ANALYSIS FOR THE PROPOSED GROUND WATER RULE

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1. Executive Summary

1.1 Introduction

This document presents the analysis of the impacts of the proposed Ground Water Rule (GWR). The proposed GWR has been developed by the Environmental Protection Agency (EPA) working with States and other interested stakeholders. The primary goal of the proposed GWR is to improve public health by identifying public ground water systems that are now, or are likely to become, fecally contaminated, and to insure adequate measures are taken to remove or inactivate pathogens in drinking water provided to the public by these systems. This document provides: a description of the need for the rule, a description of the regulatory options, baseline information on ground water systems, estimates of the monetized benefits and costs of the proposed rule, a description of additional unquantified and nonmonetized benefits, analysis of the economic impact of the rule, and a comparison of the overall benefits and costs of the rule alternatives.

1.2 Need for the Rule

EPA has developed the proposed GWR in fulfillment of its responsibility established under Section 1412(b)(8) that EPA develop regulations specifying the use of disinfectants for ground water systems as necessary.

EPA believes that there is a substantial likelihood that fecal contamination of ground water supplies is occurring at frequencies and levels that present a public health concern. Fecal contamination refers to the contaminants, particularly the microorganisms, contained in human or animal feces. These microorganisms may include bacterial and viral pathogens that can cause illnesses, and in some cases death, in the individuals that consume them.

Fecal contamination is introduced to ground water from a number of sources including, septic systems, leaking sewer pipes, landfills, sewage lagoons, cesspools, and storm water runoff. Microorganisms can be transported with the ground water as it moves through an aquifer. The distance that the microorganisms can be transported through a ground water aquifer depends on a number of factors including, the nature of the microorganism, temperature, and soil properties. For example, protozoan organisms are much larger in size than bacteria and viruses and are therefore much less likely to be able to move through the soil matrix. The transport of microorganisms to wells or other ground water system sources can also be affected by poor well construction (e.g., improper well seals) that can result in large, open conduits for fecal contamination to pass unimpeded into the water supply.

Recent studies of public water system supply wells show that there are a number of ground water supplies that contain fecal contamination. The American Water Works Association Research Foundation (AWWARF) Study (Abbaszadegan, et. al, 1999) collected data from more than 400 public water supply wells located in 35 States, and is perhaps the most representative study of public ground water supplies to date. This study found that almost 5 percent of the wells contained infectious enteroviruses, almost 10 percent of the wells contained bacteria and almost 15 percent of the wells contained rotavirus fragments that may or may not be capable of causing infections.

Waterborne pathogens contained in fecally contaminated water can result in a variety of illnesses that range in the severity of their outcomes from mild diarrhea to kidney failure or heart disease. Exhibit 1–1 presents a list of the illnesses that are caused by pathogenic viruses and bacteria in fecally contaminated ground water. The populations that are particularly sensitive to waterborne and other pathogens include, infants, young children, pregnant and lactating women, the elderly and the chronically ill. These individuals may be more likely to become ill as a result of exposure to the pathogens, and are likely to have a more severe illness.

Exhibit 1–1. Illnesses Caused by Waterborne Pathogens

Viral Waterborne Illnesses	Bacterial Waterborne Illnesses
Gastroenteritis (diarrhea, stomach cramps etc.) Myocarditis (heart disease) Meningitis Diabetes Hepatitis Paralysis	Gastroenteritis (diarrhea, stomach cramps etc.) Hemolytic uremic syndrome(kidney failure) Cholera Legionnaires Disease

Many ground water systems currently practice disinfection to inactivate or remove the pathogens in ground water prior to distributing the water to their customers. However, data collected by the Centers for Disease Control and Prevention (CDC) and EPA indicate that almost as many waterborne disease outbreaks were reported between 1971 and 1996 in systems with disinfection treatment that was inadequate or interrupted (134 outbreaks) as were reported in the same period among ground systems that did not disinfect (163 outbreaks). The CDC outbreak data also indicate that fecal contamination may be introduced into a public water system by the distribution system itself. Between 1971 and 1996, 49 reported outbreaks of the waterborne disease occurred as a result of distribution system contamination. The reported outbreaks probably represent a small fraction of the total number of waterborne disease outbreaks because reporting of outbreaks is voluntary, and not all States have outbreak surveillance systems.

Currently the Total Coliform Rule is the only federal drinking water regulation that directly governs the presence of microbes in public ground water systems. The rule applies to all public water systems, and requires systems to collect samples from their distribution systems and test for the presence of coliform bacteria. Total coliform monitoring is used to screen for fecal contamination, determine the effectiveness of treatment, and determine the integrity of the distribution system. The frequency of total coliform sampling depends upon the number of people served by the system and the system type.

1.3 Regulatory Options Considered

EPA has been working with a regulatory workgroup, stakeholders and other interested parties to develop regulatory options to address fecal contamination of ground water systems. Four options have been developed through this process. The first three regulatory options— Sanitary Survey, Sanitary Survey and Triggered Monitoring, and the Multi-Barrier options— build successively upon one another adding mechanisms to detect and address ground water systems at risk of fecal contamination. The fourth option, Across-the-Board Disinfection, does not include a component to target the systems that are at risk, but requires all systems to install treatment to remove or inactivate microbial contamination. Exhibit 1–2 lists the regulatory options and their components.

Exhibit 1–2. Regulatory Options and Basic Provisions

	Regulatory Options			
Provisions	**1 Sanitary Survey**	**2 Sanitary Survey and Triggered Monitoring**	**3 Multi-Barrier**	**4 Across-the-Board Disinfection**
Sanitary Survey	o	o	o	o
Triggered source water (microbial) monitoring[1]		o	o	
Hydrogeologic sensitivity assessment and routine source water monitoring[2]			o	
All systems install/upgrade and maintain treatment				o

[1] Triggered by a total coliform-positive sample in the distribution system
[2] For those systems determined to be hydrogeologically sensitive

The first regulatory option would require States and other primacy agencies to conduct a sanitary survey of community ground water systems once every three years and, noncommunity water systems, once every five years. Most States already perform sanitary surveys, but with wide variation in frequency and stringency. This requirement would increase their frequency for most CWSs, specify minimum sanitary survey elements, and ensure that systems correct significant deficiencies. The sanitary survey reviews all aspects of the ground water system including the source, treatment, storage, pumps, distribution system, monitoring records, operator certification, and management. States would require systems to correct any significant deficiencies identified in the survey or to install disinfection treatment.

The second regulatory option would incorporate triggered monitoring of ground water systems source water with the sanitary survey required under the first option. Source water monitoring would be triggered by the detection of total coliform in the samples that systems collect for compliance with the Total Coliform Rule. When a TCR sample in the distribution system is positive for total coliform, the ground water system would be required to sample its sources within 24 hours and analyze the sample for the presence of one of three fecal indicator organisms. Systems that find fecal indicators in their source water would be required to eliminate the contamination from the well, obtain a new source water, or provide 4-log inactivation or removal of viruses in the source water.

The third regulatory option combines the components of the first two options with routine monitoring of sources that are sensitive to fecal contamination. The sensitivity of a well or other ground water source to contamination would be determined by the State or other primacy agency based upon hydrogeologic information which the State may have already compiled in its source water assessment or from its well construction approval process. States would determine if the well is drawing water from aquifers that are sensitive. At a minimum, States would consider wells in karst, fractured bedrock or gravel cobble aquifers to be sensitive unless there was a hydrogeologic barrier present which prevents the movement of microbial contamination. Systems determined to be sensitive would collect monthly samples of their source water, and test these samples for the presence of one of three fecal indicator organisms. If any of these tests are positive for the fecal indicator organism, the system would be required to eliminate the contamination, obtain a new source of water, or provide disinfection treatment that can achieve 4-log inactivation or removal of viruses in the source water.

The fourth regulatory option requires all ground water systems to disinfect their source waters regardless of the potential risk of fecal contamination. The systems would be required to achieve 4-log inactivation or removal of viruses. States would be required to conduct sanitary surveys as required under the first three options. However, additional emphasis in the survey would be placed on ensuring that the disinfection treatment is properly operated and maintained.

1.4 Baseline Analysis

There are approximately 156,000 public ground water systems in the United States that include community water systems (systems serving year-round residents), nontransient noncommunity water systems (e.g., systems serving factories, schools, office buildings, etc.) and transient noncommunity water systems (e.g., systems serving restaurants, rest stops, etc.). Exhibit 1–3 lists the total number of ground water systems and populations served by each system type. Ninety-nine percent of the ground water systems are considered to be small, because they each serve fewer than 10,000 people.

Exhibit 1–3. Ground Water Systems and Population Served

	Community	Nontransient Noncommunity	Transient Noncommunity	Total
Number of Systems	43,906	19,322	93,618	156,846
Population Served	88.7 million	5.3 million	14.9 million	108.9 million

EPA has prepared a risk assessment to estimate the number of viral illnesses and deaths resulting from fecal contamination of ground water systems. The risk assessment estimates the number of illnesses and deaths from rotavirus and enterovirus viruses (Type A and Type B viruses, respectively). Type A viruses are highly infective but produce mild health effects, while Type B viruses are moderately infective but with moderate to severe health effects. Exhibit 1–4 presents the estimated number of illnesses and deaths attributable to the presence of these viruses in public ground water systems with current levels of treatment. There are uncertainties associated with the key assumptions made to prepare the estimates including the number of systems with viral contamination of their source water or distribution system, and the concentration of the viral pathogens in the contaminated water. The uncertainty in these estimates is indicated by the 10^{th} and 90^{th} percentile values shown in parentheses (indicating a 10 percent chance the estimate falls below the 10^{th} percentile and a 10 percent chance it falls above the 90^{th} percentile).

Exhibit 1–4. Baseline Viral Illness/Deaths in Ground Water Systems

	Type A Viruses	Type B Viruses
Mean annual illnesses [10^{th} and 90^{th} percentile estimates]	133,498 (132,879 - 134,133)	34,157 (33,062 - 35,227)
Mean annual number of deaths [10^{th} and 90^{th} percentile estimates]	1 (1 - 1)	14 (14 - 15)

These estimates also do not include the deaths and illnesses associated with bacterial contamination of ground water systems. Data reported to CDC for waterborne disease outbreaks indicate that for every five outbreak illnesses caused by virus (or of unknown etiology thought to be viruses) there is one bacterial outbreak illness. Thus the number of baseline illnesses shown in Exhibit 1–4 are increased by 20 percent to account for bacterial pathogens in ground water systems.

1.5 Benefits of the Regulatory Options

The regulatory options under consideration for the GWR are expected to reduce viral illness and deaths by reducing the public's exposure to the pathogens. Exhibit 1–5 presents the estimated reductions expected for each rule alternative considered.

Exhibit 1–5. Viral Illnesses/Deaths Avoided

	Sanitary Survey	Sanitary Survey & Triggered Monitoring	Multi-Barrier	Across-the-Board Disinfection
Viral Illnesses Avoided	13,596	83,502	96,305	132,129
Viral Deaths Avoided	1	8	9	12

The monetized benefit of the avoided illnesses is estimated using cost-of-illness estimates for rotavirus (Type A) and enterovirus (Type B) of $158 per illness to $19,711 per illness, depending upon the age of the patient, immune status, and severity of illness. The monetized benefit from viral deaths avoided is estimated using a "value of a statistical life" estimate of $6.3 million (1999 dollars). The monetized benefits of reduced bacterial illnesses and deaths are estimated by employing a simple ratio assumption in which the benefits estimated for reduced viral infections were increased by an additional

20 percent to account for bacterial infection reduction benefits. This ratio is based on CDC data that suggest that the ratio between waterborne bacterial illness and viral illness in ground water systems is 0.2. Exhibit 1–6 presents the estimated benefits associated with reduced viral and bacterial illnesses and deaths in each regulatory option.

Exhibit 1–6. Annual Monetized Benefit of Avoided Illness and Deaths (Millions of Dollars, 1999)

	Sanitary Survey	Sanitary Survey and Triggered Monitoring	Multi-Barrier	Across-the-Board Disinfection
Illness Avoided—Mean [10th and 90th percentile estimates]	\$22 [\$7 to \$38]	\$120 [\$101 to \$140]	\$139 [\$115 to \$163}	\$192 [174 to \$210]
Deaths Avoided—Mean [10th and 90th percentile estimates]	\$11 [\$2 to \$20]	\$58 [\$47 to \$68]	\$66 [\$54 to \$79]	\$91 [\$81 to \$101]
Total Quantified Benefit — Mean [10th and 90th percentile estimates]	**\$33 [\$9 to \$58]**	**\$178 [\$147 to \$209]**	**\$205 [\$169 to \$242]**	**\$283 [\$255 to \$311]**

EPA recognizes that, in addition to the benefits associated with reductions in acute illness and death from viral and bacterial infection, the proposed GWR would provide chronic heath benefits as well as non-health benefits. For example, medical and epidemiological literature identifies several potential chronic diseases resulting from illnesses caused by enteroviruses (e.g., heart disease, diabetes, post-viral fatigue syndrome, and pancreatitis). The strongest evidence for an association between enteroviral infection and chronic decease appears to exist for the development of diabetes and myocarditis (inflammation of the muscular walls of the heart). In addition, non-health benefits may result from overall system improvements (e.g., upgrades to distribution systems, increased efficiencies, increased frequency/intensity of process surveillance), from improved risk perception of drinking water quality, or from avoided outbreak response costs. EPA was able to quantify neither the chronic health benefits nor the non-health benefits in dollar terms. The benefits gained, however, are not inconsequential, merely unquantifiable.

1.6 Cost of the Regulatory Options

To estimate the cost of the four regulatory options, the impact on both public water systems and on States was considered. With all rule options, a greater proportion of the regulatory burden is placed on those systems that do not currently disinfect to a 4-log virus inactivation. Other system costs vary with the rule option and may include costs for monitoring, correcting significant deficiencies, or installing treatment. Depending on the option, States will incur costs for an increase in sanitary survey requirements and frequency, for conducting sensitivity assessments, and for follow-up inspections. Both systems and States will incur implementation costs.

The annual cost of the four rule options range from $76 million to $866 million using a 7 percent discount rate (Exhibit 1–7). Using a 3 percent discount rate, the costs range from $73 million to $777 million. For the first three options, the costs increase as more methods are added for identifying fecally contaminated wells and wells sensitive to fecal contamination. However, the costs of these methods (e.g., hydrogeologic assessment, triggered and routine monitoring) are minor compared to the costs of correcting fecally contaminated wells. The fourth option of Across-the-Board Disinfection is the most costly because it requires all systems to install treatment regardless of actual or potential fecal contamination.

Exhibit 1–7. Comparison of Annual Compliance Costs Across Regulatory Options

	Mean Compliance Costs ($Millions) [10th and 90th percentile estimates]	
Option/Regulatory Scenario	**At 3%**	**At 7%**
Option 1: Sanitary Survey Only	**$72.7** ($71.1 to $74.4)	**$76** ($74.3 to $77.7)
Option 2: Sanitary Survey and Triggered Monitoring	**$157.6** ($152.8 to $162.4)	**$168.5** ($163.0 to $174.0)
Option3: Multi-Barrier Approach	**$182.7** ($177.0 to $188.4)	**$198.6** ($191.7 to $205.5)
Option 4: Across-the-Board Disinfection Option	**$777.1** ($743.9 to $810.3)	**$866.0** ($822.7 to $909.4)

In addition to the corrective action costs and the costs to address significant deficiencies, EPA estimated system monitoring costs and start-up costs. All options have additional monitoring requirements, although they vary depending on rule option. The Agency also accounted for a system's start-up cost to comply with the various rule options. These costs include time to read and understand the rule; mobilization and planning; and staff training. The Agency also estimated system costs for reporting and recordkeeping of any positive source water samples.

Depending on the option, States would face increased costs from the incremental difference in sanitary survey requirements and frequency, from conducting one-time sensitivity assessments, and from tracking monitoring information. States would also incur start-up costs and annual costs for data management and training.

Household costs for systems that take corrective action to fix a significant defect or to address fecal contamination are presented in Exhibit 1-8. The average increase in annual household costs for these systems is between $2.45 to $3.86 for the first three options. The Across-the-Board Disinfection results in the highest average annual household cost of $19.37. However, household costs increase disproportionately across all options for those households served by the smallest sized systems. This occurs because they serve fewer households to share the system's fixed costs. For example, under the Multi-Barrier option, household costs would increase by approximately $5 per month for those served by the smallest size systems (<100 households) while those served by the largest size systems (>100,000 households) would face only a $0.02 increase in monthly household costs.

Although EPA estimated the cost of all the rule's components for drinking water systems and States, there are some costs that the Agency did not monetize. These nonmonetized costs result from uncertainties surrounding rule assumptions and from modeling assumptions.

Exhibit 1–8. Average Annual Household Cost for GWR Options for CWS taking Corrective Action or Fixing a Significant Defect

SIZE CATEGORIES	Sanitary Survey Option	Sanitary Survey and Triggered Monitoring Option	Multi-Barrier Option	Across-the-Board Disinfection Option
<100	$29.86	$67.19	$62.48	$191.87
101-500	$11.23	$15.02	$18.95	$81.38
501-1,000	$5.72	$6.29	$6.25	$38.79
1,001-3,300	$2.99	$2.91	$3.39	$23.45
3,301-10,000	$1.39	$1.46	$2.74	$16.78
10,001-50,000	$0.62	$0.59	$0.62	$4.87
50,001-100,000	$0.30	$0.70	$1.01	$10.37
100,001-1,000,000	$0.32	$0.20	$0.27	$1.66
TOTAL	$2.45	$3.34	$3.86	$19.37

1.7 Economic Impact Analysis

As part of the rule promulgation process, EPA is required to perform a series of distributional analyses that address the potential regulatory burden placed on entities that are affected by the various requirements of this proposed rule. EPA analyzed potential GWR impacts including those to small businesses, States, Tribes, local governments, and the private sector. Impacts on small business were analyzed as part of the requirements outlined in the Regulatory Flexibility Act as amended by The Small Business Regulatory Enforcement Fairness Act. The Agency also conducted an Unfunded Mandate Reform Act analysis because the proposed rule is expected to have an annual impact of at least $100 million on State, local, and Tribal governments in aggregate and on the private sector. As required by the Safe Drinking Water Act, a preliminary analysis of how this regulation would affect each system's capacity was also completed.

The Agency also estimated the effects of this proposed rule on children's health and environmental justice considerations. This rule is expected to disproportionally protect children from illness and death that result from ingestion of fecally contaminated ground water. For example, children less than five years of age make up only 7.2 percent of the U.S. population, while they receive 13 percent of the benefits from the Multi-Barrier option's reduction in Type B viral illness (lower infectivity viruses with higher costs-of-illness). As required in Executive Order 12898 regarding environmental justice, the proposed GWR will equally protect the health of all people served by public ground water systems, regardless of income or minority status.

1.8 Weighing the Benefits and Costs

Both costs and benefits associated with the proposed GWR rise with the successively more stringent regulatory options. With regards to monetized costs and benefits, only the Sanitary Survey and Triggered Monitoring option and the Multi-Barrier option have positive net benefits. For the Sanitary Survey and Triggered Monitoring Option, the monetized net benefits are estimated at $20.3 million using a 3 percent discount rate $9.4 million using a 7 percent discount rate. For the Multi-Barrier Option, the monetized benefits are estimated at $22.3 million using a 3-percent discount rate and $6.4 million using a 7 percent discount rate.

Of the remaining two options, the Across-the-Board Disinfection option has the largest negative net benefit at negative $494.0 million (3 percent) and negative $583 million (7 percent). The net benefits for the Sanitary Survey option are negative $40.2 million (3 percent) and negative $43.5 (7 percent).

Exhibit 1–9. Summary of Monetized National Benefits and Costs (3% Discount Rate, million $)

Regulatory Option	Benefit	Cost	Net Benefit
Sanitary Survey Option	$32.5	$72.7	($40.2)
Sanitary Survey and Triggered Monitoring Option	$177.9	$157.6	$20.3
Multi-Barrier Option	$205.0	$182.7	$22.3
Across-the-Board Disinfection Option	$283.1	$777.1	($494.0)

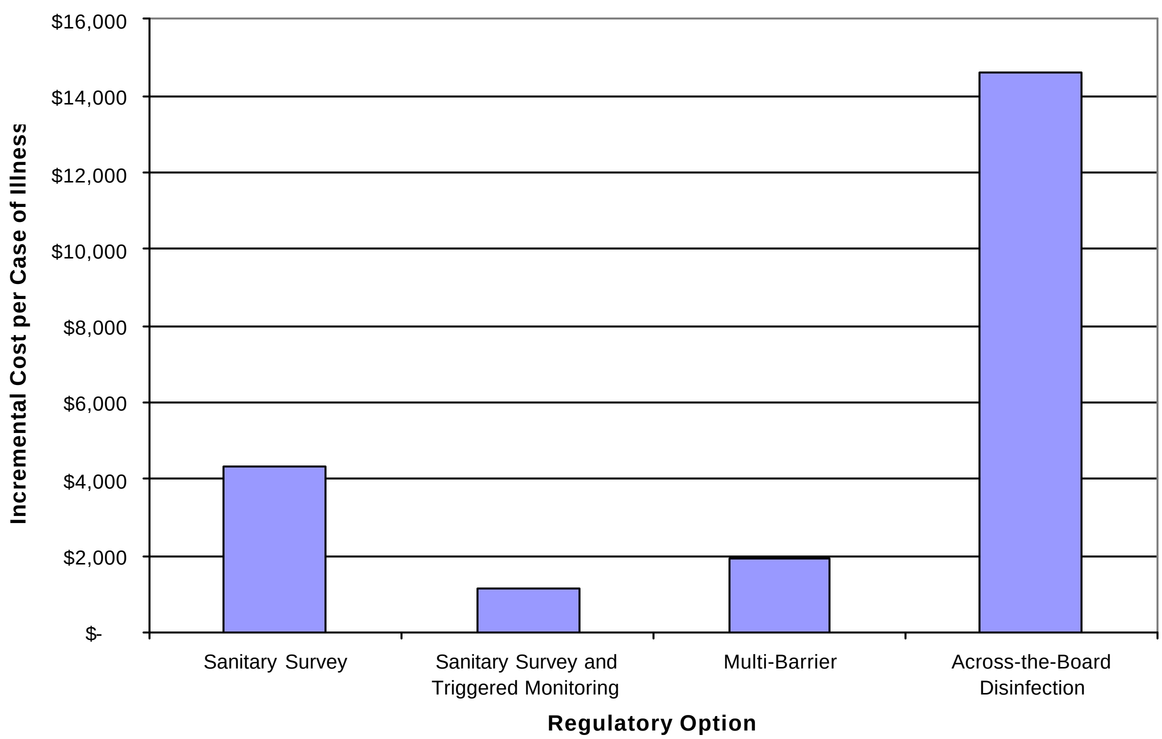
Exhibit 1–10. Summary of Monetized National Benefits and Costs (7% Discount Rate, million $)

Regulatory Option	Benefit	Cost	Net Benefit
Sanitary Survey Option	$32.5	$76.0	($43.5)
Sanitary Survey and Triggered Monitoring Option	$177.9	$168.5	$9.4
Multi-Barrier Option	$205.0	$198.6	$6.4
Across-the-Board Disinfection Option	$283.1	$866.0	($582.9)

It is important to remember that there are costs and benefits from the proposed GWR that are not included in the monetized benefits presented above. For example, the proposed GWR may provide benefits from associated with reductions in chronic illnesses caused by enteroviruses (e.g., heart disease, diabetes, post-viral fatigue syndrome, and pancreatitis). There are also non-health benefits that could not be monetized (e.g., upgrades to distribution systems, increased efficiencies, increased frequency/intensity of process surveillance). Some costs, such as land acquisition, are not included in this RIA. EPA does not have the data needed to quantify these costs benefits, but if they were, net benefits of this rule would be greater than those listed in Exhibits 1-9 and 1-10.

In addition to the benefit cost analysis, the Agency examined the cost-effectiveness of each option. As shown in Exhibit 1–11, the Sanitary Survey and Triggered Monitoring option achieves the lowest incremental cost per case of illness avoided while the Across-the-Board Disinfection option costs almost an additional $12,000 per case avoided (relative to the Multi-Barrier option). The Multi-Barrier option has the second lowest incremental cost per case of illness avoided with a cost of $1,954 per case that is only

Exhibit 1–11
Incremental Cost per Case Avoided Across GWR Options
(Relative to Next Least Stringent Option)



slightly higher than the Sanitary Survey and Triggered Monitoring option incremental cost of $1,123.

2. Need for the Proposal

2.1 Introduction

This document analyzes the impacts of the proposed Ground Water Rule (GWR). EPA intends the GWR to address microbial contamination of ground water-supplied drinking water systems in accordance with the Safe Drinking Water Act (SDWA) of 1974, as amended in 1986 and again in 1996. This regulatory impact analysis (RIA) provides background information on the rule, summarizes the key components, discusses options to the rule, and estimates costs and benefits to the public and to State governments. The RIA will be made available in conjunction with the proposed GWR.

The 1986 SDWA amendments directed EPA to establish national primary drinking water regulations requiring disinfection as treatment for the inactivation of microbiological contaminants for all public water systems, including systems supplied by ground water sources. The 1996 SDWA amendments changed the mandate to require disinfection for ground water sources "as necessary." The 1996 amendments establish a statutory deadline of May 2002. EPA, however, intends to finalize the GWR in the year 2000 to match implementation of other drinking water regulations and programs, such as the Stage 1 Disinfection Byproducts Rule, the Filter Backwash Recycling Rule (FBRR), the Radon Rule, and the Source Water Assessment Program (SWAP).

2.2 Public Health Concerns

This section describes the public health concerns to which the proposed GWR is directed. The contaminants, both bacterial and viral, and their health effects are explained first. The following sub-sections address sources, means of exposure, and effects of that exposure on sensitive populations. Finally, this section ends with a discussion of current controls used to address these concerns.

2.2.1 Contaminants and Their Health Effects

EPA is concerned about any fecally-contaminated ground water supply as well as any ground water system at risk for contamination. Fecal contamination is a general term that includes all of the bacteria and viruses found in feces. These bacteria and viruses may be non-pathogenic, which do not cause disease but serve as indicators of other bacteria or viruses, or pathogenic, which are disease-causing. The types of non-pathogenic bacterial and viral micro-organisms found in feces include many strains of *Escherichia coli*, other coliform bacteria, and the male-specific and somatic coliphage, which are viruses that infect coliform bacteria. Because of their widespread presence in fecal material, the coliform bacteria and coliphage viruses sometimes are used as indicators of fecal contamination. Total coliforms (TC) include many coliform bacteria that are free living in the environment as well as fecal bacteria. Fecal coliforms are bacteria more commonly found in human feces. Other bacteria that are used as indicators of fecal contamination include the fecal streptococci (enterococci) and *Clostridium perfringens*, a spore forming anaerobic organism that can persist for long periods of time in the environment.

Examples of common fecal pathogens include the enteroviruses (e.g., echoviruses and coxsackieviruses), rotavirus, hepatitis A virus (HAV), and bacteria such as *Salmonella*, *Shigella*, and *Campylobacter*. Unlike bacterial pathogens, viruses cannot reproduce outside the host, although they can survive and remain infectious. Also, with a few exceptions, viruses that can infect human cells typically cannot infect the cells of other animals and vice versa. This contrasts with the bacterial pathogens that sometimes can infect more than one host.

Enteric viral and bacterial microorganisms are excreted in the feces of humans and animals. The word enteric (relating to the intestines, or more specifically, the human gut) indicates that the natural habitat of these microorganisms is the intestinal tract of animals and humans (Domingue, 1983). The enteric microorganisms, sometimes referred to as intestinal microflora, can survive in sewage and leachate derived from septic tanks (septage). Therefore, when sewage and septage are released into the environment, they are sources of intestinal microflora and potential sources of viral and bacterial pathogens. Some human bacterial pathogens also are shed in the feces of infected animals.

Some enteric viruses may infect cells in tissues outside the gut, causing mild or serious secondary effects ("sequela") such as myocarditis, conjunctivitis, meningitis or hepatitis. There is also increasing evidence that the human body reacts to foreign invasion by viruses in ways that may also be detrimental. For example, one hypothesis for the cause adult onset (Type 1) diabetes is that the human body, responding to coxsackie B5 virus infection, attacks pathogens cells in an autoimmune reaction as a result of similarities between certain pancreas cells and the viruses (Solimena and De Camilli, 1995).

Once enteric pathogens are ingested, the likelihood of infection varies depending on the pathogenicity of the organism, since some pathogens are more infective at low doses than others. Once a person becomes infected, the likelihood and severity of symptomatic illness also varies with the type of pathogen, and with the level of acquired immunity and general resistance of the person.

When humans are infected by viruses that infect gut cells, these viruses become capable of reproducing. As a result, humans shed viruses in stool, typically for a period of a few weeks to a few months. Regardless of whether individuals infected by the waterborne pathogen have actual symptoms of illness, such as diarrhea, they are still shedding the virus and this may result in the infection of other people. This is called secondary spread and it can result from person-to-person contact or contact with contaminated surfaces. As a result, waterborne viral pathogens may infect others via a variety of routes. Examples of illnesses caused by known or suspected waterborne viral pathogens are shown in Exhibit 2–1.

Exhibit 2–1. Illnesses Caused by Waterborne Fecal Viral Pathogens

Enteric Virus	Illness
Poliovirus	**Paralysis**
Coxsackievirus A	Meningitis, fever, respiratory disease
Coxsackievirus B	**Myocarditis**, congenital heart disease, rash, fever, **meningitis**, encephalitis, **pleurodynia**, diabetes melitis, **eye infections**
Echovirus	**Meningitis**, encephalitis, **rash**, **fever**, **gastroenteritis**
Norwalk virus and other caliciviruses	**Gastroenteritis**
Hepatitis A virus	**Hepatitis**
Hepatitis E virus	**Hepatitis**
Small round structured viruses (probably caliciviruses)	**Gastroenteritis**
Rotavirus	**Gastroenteritis**
Enteric Adenovirus	Respiratory disease, **eye infections, gastroenteritis**
Astrovirus	**Gastroenteritis**

Bold highlights indicate diseases directly caused by the enteric virus; other illnesses are secondarily associated with the virus.
Source: 1994 Encyclopedia of Microbiology

Some waterborne bacterial pathogens cause disease by rapid growth and dissemination (e.g., *Salmonella*) while others primarily cause disease via toxin production (e.g., *Shigella*, *E. coli* 0157, *Campylobacter jejuni*). *Campylobacter*, *E. coli* and *Salmonella* have a host range that includes both animals and humans; *Shigella* is associated only with humans (Geldreich, 1996).

Most of the waterborne bacterial pathogens cause gastrointestinal illness, but some can cause other severe illnesses as well. For example, *Legionella* causes Legionnaires Disease, a form of pneumonia that has a fatality rate of about 15 percent. It can also cause Pontiac Fever, which is much less severe than Legionnaires Disease, but which causes illness in almost everyone exposed. Several strains of *E. coli* can cause severe disease, including kidney failure.

Secondary, or opportunistic pathogens such as *Pseudomonas*, usually cause illness only in immunocompromised persons, or in other sensitive subpopulations, such as the very young or the elderly. Some of the opportunistic pathogens can cause symptoms other than gastrointestinal illness, e.g., meningitis, septicemia, pneumonia (Rusin et al., 1997). Other diseases such as bacterial enteritis caused by *Salmonella*, *Shigella*, *Campylobacter jejuni*, and *Clostridium dificile* occur with greater frequency and severity in immunocompromised persons, e.g., AIDs patients (Framm and Soave, 1997). Some opportunistic bacterial pathogens can colonize and grow in the biofilm growth in water system distribution lines. Examples of illnesses caused by waterborne bacterial pathogens are shown in Exhibit 2–2.

Exhibit 2–2. Illnesses Caused by Major Waterborne Bacterial Pathogens

Bacterial pathogen	Illnesses
Campylobacter jejuni	Gastroenteritis, meningitis, associated with reactive arthritis and Guillain-Barre paralysis
Shigella species	Gastroenteritis, dysentery, hemolytic uremic syndrome, convulsions in young children, associated with Reiters Disease (reactive arthropathy)
Salmonella species	Gastroenteritis, septicemia, anorexia, arthritis, cholecystitis, meningitis, pericarditis, pneumonia, typhoid fever
Vibrio cholerae	Cholera (dehydration and kidney failure)
Escherichia coli (several species, including *E. coli* O157:H7)	Gastroenteritis, hemolytic uremic syndrome (kidney failure)
Yersinia enterocolitica	Gastroenteritis, acute mesenteric lymphadenitis, joint pain
Legionella species	Legionnaires Disease, Pontiac Fever
Source: Craun, 1999.	

EPA and the Centers for Disease Control (CDC) data provide an indication of the types of pathogens that have lead to waterborne disease outbreaks. Exhibit 2–3 presents the viral and bacterial agents implicated as the cause of waterborne outbreaks in ground water systems reported to the CDC from 1971 through 1996 (Craun, 1999). The 7 percent of outbreaks caused by protozoa (*Giardia, Cryptosporidium*) indicate that those ground water systems were under the influence of surface water. Fifteen percent of outbreaks were identified as bacterial, 9 percent were viral, and 6 percent were chemical. The majority of outbreaks are caused by unknown microbial agents. The microbial agent is difficult to determine because of the unavailability of analytical tools to identify different virus types.

Protozoan pathogens such as *Cryptosporidia* and *Giardia* are shed like bacteria and viruses in the feces of infected individuals but, because of their larger size, protozoans are not normally transported to ground water. Ground water sources found to be contaminated with either *Cryptosporidia* or *Giardia* are considered ground water under the direct influence (GWUDI) of surface water. GWUDI systems and, surface water sources in general, are regulated under the Surface Water Treatment Rule (SWTR) and Interim Enhanced Surface Water Treatment Rule (IESWTR) (for systems serving 10,000 people or more) and by the upcoming Long Term 1 Enhanced Surface Water Treatment Rule (LT1ESWTR) (for systems serving fewer than 10,000 people).

Exhibit 2–3. Etiology of Waterborne Outbreaks in Ground Water Systems, Community and Noncommunity Water Systems, 1971–96

Etiologic Agent		Percent of Outbreaks
Bacterial		15%
	Shigella	8%
	Campylobacter	3%
	Salmonella, non-typhoid	3%
	E. coli	1%
	S. typhi	<1%
	Yersinia	<1%
	Plesiomonas shigelloides	<1%
Viral		9%
	Hepatitis A	-5%
	Norwalk Agent	-5%
Protozoa		7%
	Giardia	6%
	Cryptosporidium	1%
	E. histolytica	<1%
Chemical		6%
Undetermined microbial		63%
Total		**100%**

Source: Craun, 1999.

2.2.2 Sources of Contaminants

Water obtained from ground water sources can contain microbial contaminants. These contaminants can originate from the aquifer, wellhead, or within the distribution system. This section presents a discussion of the potential sources of viral and bacterial fecal contamination of ground water supplies. It describes sources of contamination in ground water, factors that affect the survival and transport of fecal contaminants, and contamination of drinking water in distribution systems and presents outbreak data for sources and causes of ground water and drinking water contamination. Because pathogens are associated with human and animal waste, the following discussions do not necessarily focus on the specific types of microbe associated with each source, but fecal contamination in general.

In addition to the sources and characteristics of fecal contamination, the occurrence of contamination in ground water sources is highly variable due to local hydrologic, hydrogeologic, and hydraulic conditions, soil characteristics, and land use patterns. The study of how a microbe reaches a ground water source is generally termed the “fate and transport” of a contaminant. Fate and transport factors must be known when attempting to characterize the occurrence of microbial contaminants in a ground water source.

2.2.2.1 Sources of Ground Water Contamination

Human and animal fecal matter contribute to the transmission of microbial contamination. Fecal contamination of ground water can occur by several routes and at several points in the process of providing public drinking water from ground water sources. Fecal contamination from failed septic systems or sewage lagoons, leaking sewer lines, land discharge, overflowing cesspools, and animal feedlots can reach the ground water source through soils and fissures. Canter and Knox (1984) estimated the volume of septic tank waste, alone, that is released into the subsurface to be one trillion gallons per year. Other possible sources of fecal contamination include improperly treated wastewater used to recharge the ground water or irrigate crop land and improper land application of raw or treated sewage or sewage sludge.

Furthermore, solid wastes contaminated with human bacteria and viruses or animal bacteria and viruses may contaminate ground water through individual waste disposal practices, open dumping practices, and landfills (Washington State Department of Health, 1995). Improper land application of wastewaters associated with food processing or animal slaughter may also contribute to the contamination of ground water sources of drinking water. Animal wastes also carry microbial pathogens that can infect humans. Such waste may enter ground water from unlined or leaky manure lagoons, spread manure, and concentrated animal feeding operations (EPA, 1993; Washington State Department of Health, 1995).

Storm water and surface water contaminated with human or animal pathogens may transmit contamination to ground water through infiltration or direct injection. Storm water may enter improperly constructed wells or improperly abandoned wells. Likewise, contaminated surface waters carrying microbial pathogens may enter improperly constructed or abandoned wells, causing ground water contamination (Washington State Department of Health, 1995).

These sources of contamination may eventually reach the intake zone of a drinking water well. Microbial contamination can also occur at the wellhead when wells are improperly constructed, protected, and maintained. Furthermore, microbial contamination can also occur in the distribution system when cross connection controls fail or when leaking pipes allow infiltration of contaminants.

2.2.2.2 Factors Affecting Virus and Bacterial Transport in the Subsurface

Many factors apparently control the removal and persistence of viruses and bacteria in subsurface media. Because these factors are often interlinked and interrelated, defining the processes involved in the survival and migration of viruses and bacteria is a complex task. Factors such as pH, ionic strength, soil types, and type of virus, affect pathogenic adsorption to soils. In addition, these factors are likely to have a direct or indirect effect on pathogen survival. Factors that promote pathogen attachment to soils will also enhance their survival (Vaughn and Landry, 1983). Two primary groups of factors influencing microbial contaminant levels in ground water are: 1) the transport and survival of microorganisms in the subsurface; and 2) the conditions of and near ground water intake points. This section describes these factors for viruses and bacteria.

Factors Affecting the Transportation and Survival of Viruses in the Subsurface

The transport and persistence of a virus in the subsurface (i.e., the soil, unsaturated zone and saturated zone) are important aspects of ground water contamination. Locally, climatic changes, as well as agriculture and land use practices, influence and may alter the complex soil environment. For example, wetter climatic conditions may result in high water tables thereby potentially reducing the distance and time required by viruses to enter the now shallower aquifers. In addition, sewage and sludge application to land may alter the physical and chemical properties of soils and affect their capacity to impact virus migration and survival (Bitton and Gerba, 1984).

Often factors affecting virus survival are complex, interrelated, and poorly understood. Assessing virus survival is difficult because of the variety of factors influencing survival and the temporal variations within factors (Keswick and Gerba, 1980). However, according to Yates et al. (1985), most enteric viruses are stable between a pH range of 3 to 9. Yates et al. (1985) also believed that a low pH favors virus adsorption and a high pH favors virus desorption from soil particles. Other factors affecting viral transport and survival include light, temperature, hydrogeologic conditions, soil properties, inorganic ions, the presence of organic matter in the soil, the type of virus, the presence or absence of microbial activity, the iron content of the soil, and the soil moisture content.

Factors Affecting Bacterial Migration and Survival in Water and Soil

Bacterial survival varies for different types of bacteria and is dependent on a variety of factors, such as temperature, hydrogeologic conditions, soil properties, pH, inorganic ions content, organic matter content, bacterium type, microbial activity, and moisture content. How these factors influence inactivation is often unknown (Yates and Yates, 1988). Generally, it takes two to three months to reduce pathogens to negligible numbers after their application to soil; a survival time of five years, however, has been reported in literature (Gerba and Bitton, 1984).

2.2.2.3 Other Factors that Contribute to the Contamination of Drinking Water

Conditions at or near water-supply wells may contribute to the occurrence of ground water contamination. Ground water contamination may occur at the wellhead in several ways. The main causes are poor well location and/or construction, improperly abandoned wells, the presence of testholes or exploratory wells, and well location within an area of ground water development.

Poor Well Location and/or Construction

There are several ways fecal contamination can enter wells if they are inappropriately located or poorly constructed. A water-supply well located in a low-lying area is susceptible to flooding. An improperly constructed water-supply well may allow surface runoff or surface waters to enter the well through a non-existent or broken well seal. A well may be particularly vulnerable to surface water contamination if it is not adequately cased and grouted. Ground water contamination may also result from water infiltrating into the well through a contaminated gravelpack or the fill surrounding the well intake point.

In some cases, systems do not adhere to existing guidelines for the construction of water-supply wells and wells may be drilled in or near potential sources of contamination. If these wells penetrate the same aquifer as nearby domestic wells, their poor construction may allow contaminants to enter the ground water source, thereby contaminating the water used by these wells. Furthermore, since many old wells were constructed before the institution of strict well construction guidelines, these wells are often not constructed in a manner which prevents contamination.

Abandoned Wells

Historically, well abandonment and plugging have generally not been properly planned, designed and executed (EPA, 1990; Canter et al., 1987). In many cases, the well casing was pulled out if it was not too worn or corroded, thereby allowing contamination to spread to different aquifers. Other wells may not have been adequately plugged, thus providing a pathway for contamination. Occasionally, abandoned wells have also been used as disposal sites for a variety of wastes. Such wells would then serve as conduits for contaminated ground water to spread to other zones within an aquifer more rapidly or allow contaminants to enter adjacent aquifers at lower hydraulic pressures (EPA, 1990).

Test Holes, Exploratory Wells and Monitoring Wells

Many test holes and exploratory wells have been dug or drilled into the subsurface over time to search for substances such as oil, gas, coal, minerals, and water. In addition, other holes have been drilled for testing and include soil boreholes and seismic shot holes for geologic testing. Also, monitoring wells are often drilled to sample ground water quality. When these holes are not backfilled, or when monitoring wells are not properly constructed or abandoned, they provide potential conduits for contamination to enter uncontaminated ground water sources.

2.2.2.4 Contamination of Drinking Water in Distribution Systems

Contamination within the distribution system may occur whether the source water is ground water or surface water. Numerous incidents have been reported in literature of contamination of ground water sources of drinking water in the distribution system. In some cases, the ground water had not been disinfected, while in other cases waters had been treated. In a rural Missouri township, an untreated ground water distribution system became contaminated following the replacement of 45 water meters and the rupture and replacement of two water mains (Swerdlow, et al., 1992; Geldreich, et al., 1992). This system was not chlorinated after the maintenance and 243 cases of *E. coli*-induced diarrhea resulted (Swerdlow, et al., 1992).

Inadequately disinfected distribution systems, including storage towers, can develop microbial mats or biofilms. Initially biofilms may function as a filter, adsorbing pathogens (Seunghyun, et al., 1997), but the pathogens may ultimately be shed (sloughed) from the system, potentially contaminating the drinking water at the tap.

2.2.2.5 Outbreak Data for Sources and Causes of Contamination

Exhibit 2–4 summarizes EPA and CDC's *Waterborne Disease Surveillance Data* of the total number of reported disease outbreaks attributed to consumption of contaminated ground water from community and noncommunity systems. Exhibit 2–4 includes outbreaks caused by chemical or protozoan sources.

Exhibit 2–4. Waterborne Disease Outbreaks, Ground Water Sources, 1971–96

Type of Contamination	Outbreaks in Noncommunity Systems	Outbreaks in Community Systems	Total Number of Outbreaks
Source Contamination	228	72	300
Untreated Ground Water	*132*	*31*	*163*
Disinfected Ground Water	*96*	*38*	*134*
Filtered Ground Water	*0*	*3*	*3*
Distribution System Contamination	15	34	49
Inadequate Control of Chemical Feed	3	5	8
Miscellaneous, Unknown Cause	11	3	14
Total	**257**	**114**	**371**
Source: EPA and CDC, 1998. Unpublished report on Waterborne Disease Outbreaks in the U.S. from 1971–1996.			

Between 1971 and 1996, 300 of the 371 reported waterborne outbreaks (81 percent) were attributed to contaminated source water including untreated, interrupted, or inadequately disinfected and inadequately filtered ground water. The second most common cause for disease outbreaks is contamination of the distribution system, accounting for 49 (13 percent) of the 371 reported waterborne outbreaks. Accounting for the balance of the outbreaks are inadequate chemical feed resulting in chemical-related illnesses and those classified as miscellaneous. Cases reported as miscellaneous are outbreaks where insufficient data exist to accurately categorize the source of the contamination. The number of outbreaks reported to the CDC are believed to be an underestimate of the total number of waterborne outbreaks that actually occur (National Research Council, 1997). Some of the reasons for the lack of recognition and reporting of outbreaks are as follows:

- Some States do not have active disease surveillance systems. Thus, States that report the most outbreaks may not be those in which the most outbreaks occur.

- Health officials may not recognize the occurrence of small outbreaks, even in States with effective disease surveillance systems. In cities, large outbreaks are more likely to be recognized than sporadic cases or small outbreaks in which ill persons may consult different physicians.

- Some States do not always report identified waterborne disease outbreaks to the CDC. Reporting outbreaks is voluntary.

- Most cases of waterborne disease are characterized by general symptoms (diarrhea, vomiting, etc.) that cannot be distinguished from other sources.

- Only a small fraction of people who develop diarrheal illness seek medical assistance.

- Many public health care providers may not have sufficient information to request the appropriate clinical test.

- If a clinical test is ordered, the patient must comply, a laboratory must be available and be proficient, and a positive result must be reported in a timely manner to the health agency.

- Not all outbreaks are effectively investigated. Outbreaks are included in the CDC database only if water quality and/or epidemiological data are collected to document that drinking water was the route of disease transmission. Monitoring after the recognition of an outbreak may be too late in detecting intermittent or a one-time contamination event.

- The vast majority of ground water systems are noncommunity water systems (NCWSs). Outbreaks associated with NCWSs are less likely to be recognized than those in community water systems because NCWSs generally serve nonresidential areas and transient populations.

Although waterborne disease outbreaks have been linked to ground water sources, the cause and population affected may vary for each outbreak. These outbreaks, however, demonstrate that ground water sources are not free of pathogenic contaminants and thus support the need for the GWR. True incidence of waterborne outbreaks and associated illness is unknown; in addition, persistent low to moderate levels of endemic waterborne illness often go undetected by routine disease surveillance programs. This lack of knowledge stems from inadequate surveillance of disease outbreaks, insufficient outbreak detection methods, lack of epidemiologic investigation, and lack of microbial monitoring.

2.2.3 Exposure to the Contaminants

EPA has reviewed data from 13 recent or on-going studies of pathogen and fecal indicator occurrence in ground waters that supply public water systems. Each study was conducted independently and with a different objective and scope. Well selection, the number of samples collected from each well, and the sample volumes that affect interpretation of results, also varied among the studies. These data are, however, important to GWR development because they provide insight on: 1) the extent to which ground water may be contaminated; 2) possible fecal indicators for source water monitoring under the GWR; 3) a national estimate of ground water pathogen occurrence; and 4) the hydrogeologic sensitivity criteria which may influence source water vulnerability. In addition, determining the occurrence of microbial contaminants in ground water sources of drinking water can be used to yield a national estimate of public health risk. The Occurrence and Monitoring document for the GWR contains a brief summary of each of the examined occurrence studies. This chapter discusses the two studies most relevant to the economic analysis.

Each occurrence study investigated a combination of different pathogenic and/or indicator viruses and bacteria. The researchers tested the samples analyzed in each study for viral pathogens such as enteroviruses (also called "total cultureable viruses") and/or bacterial pathogens such as *Legionella* and *Aeromonas*. Several viruses and bacteria were identified using the polymerase chain reaction technique (PCR). PCR amplifies the DNA sequences so that they are detected more easily or at more sensitive levels. Although PCR detections do not necessarily indicate the presence of viable, infectious viruses, they do suggest that sources of contamination and pathways for the transmission of fecal material exist. The studies screened for bacterial indicators of fecal contamination, including enterococci (or fecal streptococci, which are closely related), fecal coliforms (or *E. coli*, which is closely related), and *C. perfringens*. Samples were also examined for bacteriophage, which are viruses that infect bacteria and serve as viral indicators of fecal contamination. Among the bacteriophage identified were somatic coliphage and/or male-specific coliphage, both of which infect the bacterium *E. coli*.

<u>American Water Works Association Research Foundation (AWWARF) Study (Abbaszadegan et al., 1998, American Water Works Service Company)</u>

The objectives of the joint AWWARF, EPA, and American Water Works Service Company study, or "AWWARF Study," include determining the occurrence of virus contamination in source water of public ground water systems, investigating water quality parameters and occurrence of microbial indicators in ground water and possible correlation with human viruses, and developing a statistically-based screening method to identify wells at risk of fecal contamination.

The AWWARF Study analyzed samples collected at 448 sites in 35 States. The researchers excluded sites known to be under the influence of surface water, sites where well records were not available, or sites where the well was poorly constructed. Preliminary results of the study show that approximately 64 percent of the wells are located in unconsolidated aquifers, 27 percent are located in consolidated aquifers, and 9 percent are located in unknown geology. Most of the sites serve a population greater than 3,300 people and most of these systems practice some form of disinfection.

The source water samples were analyzed using a variety of methods to detect pathogens and indicators. Samples were analyzed to determine the occurrence of enteroviruses, total colform and enterococci bacteria, rotavirus, hepatitis A virus, and both male-specific and somatic coliphage in ground waters of the United States. In order for researchers to use the information gathered from this study to generate national risk estimates, samples were collected from different geographical locations with a variety of physical and chemical characteristics to closely match the actual national geologic profile of ground water sources (Abbaszadegan et al., 1998). Exhibit 2–5 presents a summary of preliminary AWWARF results.

Exhibit 2–5. Preliminary Results of the AWWARF Study

Assay	Percent Positive per Site (number positive/samples analyzed)
Enterovirus (cell culture)	4.8% (21/442)
Total coliform	9.9% (44/445)
Enterococci	8.7% (31/355)
Clostridium spores	1.8% (1/57)
Salmonella WG-49	9.5% (42/440)
Somatic Coliphage (E. coli C *host*)	4.1% (18/444)
Somatic and Male Specific Coliphage (E. coli C-3000 *host)*	10.8% (48/444)
Norwalk virus (PCR)	0.96% (3/312)
Enterovirus (PCR)	15.9% (68/427)
Rotavirus (PCR)	14.6% (62/425)
Hepatitis A Virus (PCR)	7.2% (31/429)
Source: Abbaszadegan et al., 1998.	

EPA/AWWARF Study (Lieberman et al., (1994, 1999))

The study objectives included the following: 1) develop and evaluate a molecular biology (PCR) monitoring method; 2) obtain occurrence data for human enteric viruses and *Legionella* in ground water; and 3) assess the microbial indicators of fecal contamination. This was accomplished by sampling vulnerable wells nominated by States to confirm the presence of fecal indicators (Phase I) and then choosing a subset of these for monthly sampling for one year (Phase II).

In Phase I, 96 of the 180 potentially vulnerable wells were selected for additional consideration. Well vulnerability was established using historical microbial occurrence data and waterborne disease outbreak history, known sources of human fecal contamination in close proximity to the well, and sensitive hydrogeologic features (e.g., karst). Selected wells were located in 22 States and 2 U.S.

territories. Additional water quality information was then successfully obtained for 93 of the wells through use of a single one liter grab sample that was subsequently tested for several microbial indicators (See Table II-6). The wells from Phase I served as the well selection pool for Phase II sampling.

In Phase II, 23 of the Phase I wells were selected for monthly sampling for one year. Seven additional wells were selected from a list of State-nominated wells for a total of 30 wells, located in 17 States and 2 U.S. territories. The additional seven wells were based on other criteria, including historical water quality data, known contaminant sources in close proximity to the well, hydrogeologic character or to replace wells that were no longer available for sampling. Samples were analyzed for enteroviruses, *Legionella*, enterococci, *E. coli*, *Clostridium perfringens*, total coliforms, somatic coliphage, male-specific coliphage, and *Bacteriodes* phage. For each sample analyzed for enteric viruses and bacteriophages, an average of approximately 6,000 liters of water were filtered and analyzed by cell culture.

Enteroviruses were recovered in 20 samples from seven wells, and were speciated by serotyping. Coxsackievirus and echovirus, as well as reovirus, were identified. The range in virus concentration in enterovirus-positive samples was 0.9-212 MPN/100 liters (MPN, or most probable number, is an estimate of concentration).

The hydrogeologic settings for the seven enterovirus-positive wells were karst (3), a gravel aquifer (1), fractured bedrock (2), and a sandy soil and alluvial aquifer (1). The karst wells were all positive more than once. The gravel aquifer was also enterovirus-positive more than once, with 4 of 12 monthly samples positive.

2.2.4 Sensitive Subpopulations

In assessing the potential impact of waterborne disease it is important to recognize that certain sensitive individuals may be at a greater risk of serious illness than the general population. These sensitive subgroups of the population include pregnant and lactating women, the very young, the elderly, the immunocompromised, and the chronically ill. In total, these subgroups represent almost 20 percent of the current population of the United States.

Pregnant and lactating women may be at an increased risk from enteric viruses as well as act as a source of infection for neonates. Infection during pregnancy may also result in the transmission of infection from the mother to the child *in utero*, during birth, or shortly thereafter. Since very young children do not have fully developed immune systems, they are at increased risk and are particularly difficult to treat.

Infectious diseases are also a major problem for the elderly because the immune function declines with age. As a result, outbreaks of waterborne diseases can be devastating on the elderly community (e.g., nursing homes) and may increase the possibility of significantly higher mortality rates in the elderly than in the general population.

Immunocompromised individuals are an ever growing proportion of the population with the relatively new and severe problem magnified by the AIDS epidemic and the escalation in organ and tissue transplantations. Enteric pathogens take advantage of the impaired immune systems of these individuals and set up generalized and persistent infections in the immunocompromised host. These infections are particularly difficult to treat and can result in a significantly higher mortality than immunocompetent persons.

Exhibit 2–6 presents the estimates of some of the sensitive populations in the United States who are at increased risk of infection from, and the effects of, waterborne microorganisms and pathogens.

Exhibit 2–6. Sensitive Populations in the United States

Sensitive Population	Individuals
Pregnant/Lactating Women and Neonates	
Pregnancies	5,657,000
Lactating Women	2,247,635
Neonates	4,002,000
Elderly	
Elderly (over 65)	29,400,000
Residences in Nursing Homes or Related Care Facilities	1,553,000
Chronically Ill	
AIDS	581,429
Cancer Treatment Patients	1,853,795
Organ Transplant Recipients	22,736
Source: Department of Commerce, 1991; National Health Interview Survey (NHIS), Bureau of the Census' 1996 Statistical Abstract of the U.S.	

2.3 Current Control and Potential for Improvement

The underlying objective of the GWR is to build upon successful State requirements and practices. EPA intends to strengthen what is in place, not replace it with new practices. While protective practices (e.g., wellhead protection, disinfection, well siting, construction requirements, and distribution system safeguards such as cross-connection control) are used by many States, EPA recognizes the potential for improvement since few of these measures are used by all States. Moreover, the States appear to employ a variety of interpretations of the same practice (EPA, 1996).

<u>Source Protection</u>

Protecting the ground water source is an important component in assuring that the wellhead areas of all public water systems (PWSs) are free from contaminants that have adverse health affects. Source protection includes implementing measures such as wellhead protection programs and complying with well construction code requirements.

Currently, 44 States have approved wellhead protection programs. A wellhead protection program involves provisions for delineation of wellhead protection areas (WHPAs) for each public well or well field, identification of all potential anthropogenic sources within the protection area, technical and financial assistance, control measure implementation, education, training and demonstration projects to protect wellhead areas from contaminants, contingency plans for alternative water supplies in contamination cases, siting considerations for new wells, and public participation.

Recently, States have begun implementing the Source Water Assessment Program (SWAP). In accordance with the 1996 SDWA Amendments, States were required to submit a program to EPA by February 1999 and to implement the SWAP by November 2001. Intending to focus prevention resources on drinking water protection, provisions for a State SWAP include: delineating the source water protection area, conducting a contaminant source inventory, determining the susceptibility of the public water supply to contamination from the inventoried sources, and releasing the results of the assessments to the public.

Another source water protection method involves the use of well construction codes. Currently, 48 States employ some form of construction code. The standards and procedures listed in many construction codes are designed to protect a ground water source from contamination. These standards and procedures regulate the entire process from initial penetration or excavation of the ground, development of the well, equipment installation and disinfection, to final approval of the well for use as a potable water supply. Many States also designate setback distances to ensure that the well is not constructed at a site subject to current or potential contamination. Hydrogeologic data may also be used to evaluate the adequacy of the site to provide a safe and healthful supply of water to the public.

Disinfection/Treatment

Disinfection is very important in reducing waterborne illnesses in the United States. With the exception of Connecticut, all States require some form of disinfection for designated systems. The criteria for determining which systems must disinfect varies from State to State. Fourteen States require all systems to disinfect; of these States, however, at least nine have provisions allowing systems to waive their disinfection requirements. Some States base the disinfection requirements upon Total Coliform Rule (TCR) compliance; others base the requirement upon the date of construction or upon the results of a sanitary survey.

Disinfection can consist of a variety of treatment technologies or disinfectants and is used to inactivate, remove, or kill disease-causing microorganisms. Ground water disinfection usually involves the use of chlorine disinfection through chlorine gas injection or hypochlorination. Other treatment technologies include: chloramines, chlorine dioxide, mixed oxidants, ultraviolet light, ozone, reverse osmosis, or nanofiltration.

The effectiveness of these treatment technologies varies widely by technology type and by system operations. Technology effectiveness also may be dependent on whether the system specifies a minimum level of treatment (i.e., a minimum disinfectant residual), a minimum CT value, or a microbial kill reduction value. Systems also may use disinfectant residuals to protect the distribution system from re-contamination. CT refers to the product of the residual disinfectant concentration, C (in milligrams per liter [mg/L]), and the disinfectant contact time, T (in minutes). EPA considers CT a primary method for determining the level of inactivation for several treatment technologies.

System Integrity

Most States require system integrity measures, such as sanitary surveys and cross-connection control, as additional measures to prevent microbial contamination and to protect the health of the customer. Although these measures are required by almost every State, their requirements vary widely between each State. Due to this variability and difference in program strengths, waterborne disease outbreaks have occurred as a result of lapses in system integrity. EPA and CDC Waterborne Disease Outbreak data show that 137 outbreaks occurred between 1971 and 1996 in ground water systems that had treatment that was either inadequate or had failed altogether. That same data show that there were 49 distribution system-related waterborne disease outbreaks between 1971 and 1996 (Craun, 1999).

Sanitary surveys are on-site inspections of the source water, treatment facilities, distribution system, finished water storage tanks, the pumps and pump facilities, monitoring records, management and operation, and operator compliance with State requirements of a PWS. Sanitary surveys allow the PWS to identify existing or potential sources of contamination. With the exception of the State of Washington, all States currently require sanitary surveys to be performed on ground water systems. EPA found that many of these surveys are general in nature and that they differ in the types of systems surveyed, the content of the survey, and who is designated to conduct the survey. EPA also found that 46 States do not specifically require systems to correct deficiencies and that a number of States do not appear to have legal authority to require correction of defects.

With the exception of Delaware, all States currently implement some form of cross-connection control. Cross-connection control involves the inspection of service connections with respect to the risk of backflow and the consequences of backflow, provisions for eliminating cross-connections, the installment of backflow prevention devices, and provisions for violations.

2.4 Regulatory History

This section briefly describes the existing regulations applicable to ground water systems. These rules serve as the regulatory baseline for the GWR. The regulations that are discussed include the Total Coliform Rule (TCR), Surface Water Treatment Rule (SWTR) and Interim Enhanced Surface Water Treatment Rule (IESWTR), Information Collection Rule (ICR), Stage 1 Disinfection/Disinfection By-Products Rule (Stage 1 DBPR), and Underground Injection Control.

Total Coliform Rule (TCR)

The TCR, promulgated in June of 1989, is applicable to all public water systems. The rule was designed to protect public water supplies from adverse health effects associated with disease-causing organisms (pathogens) and is the only current federal regulation addressing microbial contamination of ground water systems.

Total coliforms are a group of closely-related bacteria that are generally free-living in the environment but are also normally present in water contaminated with human and animal feces. As shown in section 2.2.3, total coliforms are often associated with waterborne disease outbreaks. Generally, total coliforms do not cause disease but are indicators that other harmful organisms may be present. Specifically, coliform measurements are used to determine the efficiency of treatment, the integrity of the water distribution system, and as a screen for fecal contamination. Their presence in drinking water indicates that the system is either fecally-contaminated or potentially vulnerable to fecal contamination.

The TCR requires systems to monitor their distribution system for total coliforms at a frequency dependent upon two factors: 1) the number of people served; and 2) whether the system is a community water system or noncommunity water system. The monitoring frequency ranges from 480 samples per month for the largest systems to once annually for some of the smallest systems. If a system has a total coliform-positive sample, operators must: 1) test that sample for the presence of fecal coliform or *E. coli*; 2) collect a set of repeat samples within 24 hours and analyze them for total coliforms (and fecal coliform or *E. coli*, if positive); and 3) collect at least five routine samples in the next month of sampling.

Under the TCR, a system that collects 40 or more samples per month (generally systems that serve more than 3,300 people) violates the maximum contaminant level (MCL) if more than 5 percent of the samples (routine + repeat) are total coliform-positive. A system that collects fewer than 40 samples per month violates the MCL if two samples (routine or repeat samples) are total coliform-positive. For either size system, if two consecutive total coliform-positive samples occur at a site, and one is fecal coliform/*E. coli*-positive, the system has an acute violation of the MCL, and must report to the public immediately. The presence of fecal coliforms or *E. coli* indicates that recent fecal contamination is present in the drinking water.

The rule also requires a sanitary survey every five years for community and every 10 years for noncommunity ground water systems sampling fewer than five samples per month (about 97 percent of the systems serve 3,300 or fewer). Other provisions of the TCR include criteria for invalidating a positive or negative sample and a sample siting plan to ensure that all parts of the distribution system are monitored over time.

<u>Surface Water Treatment Rule (SWTR) and Interim Enhanced Surface Water Treatment Rule (IESWTR)</u>

The SWTR, promulgated in June of 1989, covers all systems that use surface water or ground water under the direct influence of surface water. It is intended to protect against the adverse health effects of exposure to *Giardia lamblia*, viruses, and *Legionella*, as well as many other pathogens. The rule requires all such systems to reduce the level of *Giardia* by 99.9 percent (3 logs) and viruses by 99.99 percent (4-logs). To accomplish this reduction, a system must filter its source water, unless it can meet certain EPA-specified criteria on source water quality, and disinfect. More specifically, the SWTR requires: 1) a 0.2 mg/L disinfectant dose at the treatment facility; 2) maintenance of a detectable disinfectant residual in all parts of the distribution system; 3) combined filter effluent performance standard for turbidity (e.g., for rapid filters, 5.0 nephelometric turbidity units (NTU) as a maximum and 0.5 NTU in 95 percent of the sample readings during a month); and 4) watershed protection and other requirements for unfiltered systems. The SWTR set a maximum contaminant level goal (MCLG) of zero for *Giardia,* viruses, and *Legionella.* (The MCLG is a non-enforceable level based only on health effects.)

In December 1998, EPA promulgated the IESWTR, which covers all systems that use surface water or ground water under the direct influence of surface water that serve 10,000 or more people. Key provisions include: a 2 log *Cryptosporidium* removal requirement for filtered systems; strengthened combined filter effluent turbidity performance standards; individual filter turbidity provisions; disinfection benchmark provisions to assure continued levels of microbial protection while facilities take the necessary steps to comply with new disinfection byproduct standards; inclusion of *Cryptosporidium* in the definition of ground water under the direct influence of surface water and in the watershed control requirements for unfiltered public water systems; requirements for covers on new finished water reservoirs; and sanitary surveys for all surface water systems regardless of size. The rule set an MCLG of zero for *Cryptosporidium*. EPA plans to propose a companion microbial rule for surface water systems serving less than 10,000.

Since the SWTR and IESWTR apply to ground water systems under the direct influence of surface water, the GWR will not address these systems.

<u>Information Collection Rule</u>

The ICR is a monitoring and data reporting rule that was promulgated in May 1996. The data and information provided by this rule is needed to support development of two regulations that EPA is in the early process of developing, the Stage II Disinfection Byproducts Rule and a related microbial rule, the Stage 2 Long Term Enhanced Surface Water Treatment Rule.

The ICR covers large PWSs serving populations over 100,000; a more limited set of ICR requirements pertain to ground water systems serving between 50,000 and 100,000 people. About 300 PWSs operating 500 treatment plants are involved with the extensive ICR data collection. The ICR requires systems to collect source water samples (and in some cases finished water samples) monthly for 18 months and test the samples for the following organisms: Giardia, *Cryptosporidium*, viruses, total coliforms, and fecal coliforms or *E. coli*. The ICR also requires systems to determine the concentrations of a host of disinfectant and disinfection byproduct concentrations in different parts of the system. These disinfection byproducts form when disinfectants used for pathogen control react with naturally occurring organic compounds already present in source water. Some of these byproducts are toxic or carcinogenic. The rule also requires systems to provide specified operating and engineering data to EPA. The required 18 months of monitoring under the ICR ended in December 1998.

As noted above, the only ground water systems affected by the ICR were those that serve at least 50,000 people. These systems had to conduct treatment study applicability monitoring (by measuring the level of total organic carbon) and, if necessary, treatment studies. In addition, ground water systems serving at least 100,000 people had to obtain disinfectant and disinfection byproduct occurrence and treatment data.

Stage 1 Disinfectants and Disinfection Byproducts Rule (DBPR)

The Stage 1 DBPR (63 FR 69389; December 16, 1998) (EPA, 1998) sets maximum residual disinfection level limits for chlorine, chloramines, and chlorine dioxide and MCLs for chlorite, bromate, and two groups of disinfection byproducts—total trihalomethanes (TTHMs) and haloacetic acids (HAA5). TTHMs consist of the sum of chloroform, bromodichloromethane, dibromochloromethane, and bromoform. HAA5 consist of the sum of mono-, di-, and trichloroacetic acids, and mono- and dibromoacetic acids. The rule requires water systems that use surface water or ground water to remove specified percentages of organic materials, measured as total organic carbon, that may react with disinfectants to form DBPs. Under the rule, precursor removal will be achieved through a treatment technique (enhanced coagulation or enhanced softening) unless a system meets alternative criteria.

The Stage 1 DBPR applies to all community water systems (CWSs) and nontransient noncommunity water system (NTNCWS), whether surface water systems or ground water systems, that treat their water with a chemical disinfectant for either primary or residual treatment. In addition, certain requirements for chlorine dioxide apply to transient water systems.

A ground water system that disinfects with chlorine or other chemical disinfectants must comply with the Stage 1 DBPR by December 2003. For ground water systems not under the direct influence of surface water, sampling frequency will depend upon the number of people served.

C Systems that serve 10,000 people or greater must take one sample per quarter per treatment plant and analyze for TTHMs and HAA5.

C Systems that serve fewer than 10,000 people must take one sample per year per treatment plant during the month of warmest water temperature and analyze it for the same chemicals.

C Systems must monitor for chlorine or chloramines at the same location and time that they monitor for total coliforms. Additional monitoring for other chemicals is required for systems that use ozone or chlorine dioxide.

Underground Injection Control Program

The EPA's Underground Injection Control program was established to protect aquifers that are, or might be, sources of drinking water from underground injection of fluids through wells. Owners and operators of injection wells are prohibited from allowing the movement of fluid containing any contaminant into underground sources of drinking water if the presence of that contaminant may cause a violation of any primary drinking water regulation or may otherwise adversely affect human health. To prevent such fluid movement, EPA or the appropriate State regulatory agency may, for any injection well, impose requirements for construction, corrective action, operation, monitoring, reporting, and plugging and abandonment. These regulations are designed to recognize varying geologic, hydrological or historical conditions among different States or areas within a State.

The regulations included in 40 CFR 144.6 define five classes of wells. These wells may be injected with fluids that are associated with hazardous waste or radioactive waste sites, natural gas or oil production, extraction of minerals, or other purposes. Class V wells are those most often associated with relevant ground water contamination, and include: 1) untreated sewage waste disposal wells; 2) cesspools; 3) septic systems (undifferentiated disposal method); 4) septic systems (well disposal method); 5) septic systems (drainfield disposal method); and 6) domestic wastewater treatment plant effluent disposal wells. EPA regulates only multiple dwelling, community or regional septic systems, as opposed to individual or single family residential septic systems, as Class V wells (40 CFR § 144.1(g)(1)(2)).

On July 29, 1998, EPA proposed changes to the Class V UIC regulations that would add new requirements for three categories of Class V wells that pose a high risk when located in ground water-based source water protection areas being delineated by States under the 1996 SDWA Amendments (EPA, 1996b). Class V motor vehicle sewage waste disposal wells in such areas would either be banned or would have to get a permit that requires fluids released in those wells to meet the drinking water maximum contaminant levels (MCLs) at the point of injection. Class V industrial waste disposal wells in ground water-based source water protection areas also would be required to meet the MCLs at the point of injection, and large-capacity cesspools in such areas would be banned. EPA proposed these new requirements to address three categories of wells identified as posing a high risk of ground water contamination based on available information. These include motor vehicle waste disposal wells, industrial waste disposal wells, and cesspools in ground water-based source water protection areas. EPA expects to achieve substantial protection of underground sources of drinking water by targeting the requirements to these particular wells.

2.5 Economic Rationale

This section of the RIA discusses the statutory authority and the economic rationale for choosing a regulatory approach to protect public health from drinking water contamination. The economic rationale is provided in response to Executive Order 12866, *Regulatory Planning and Review*, which States,

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

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

2.5.1 Statutory Authority for Promulgating the Rule

Section 1412(b)(8) of the Safe Drinking Water Act requires that EPA develop regulations specifying the use of disinfectants for ground water systems, as necessary. Under is provision, EPA has the responsibility to develop a ground water rule that specifies the appropriate use of disinfection. As mentioned previously, the 1996 SDWA amendments establish a statutory deadline of 2002; EPA, however, intends to promulgate the final GWR in 2000.

2.5.2 The Economic Rationale for Regulation

In addition to the statutory directive to regulate microbial contaminants in ground water, there is also a strong economic rationale for government regulation. The need for regulation is a direct result of the structure of the market for publically-provided drinking water. Economic theory suggests that society's well being is maximized when goods are produced and sold in well functioning competitive markets. A perfectly competitive market is said to exist when there are many producers of a product selling to many buyers, and both producers and consumers have complete knowledge regarding the products of each firm. In this perfectly competitive market, there must also be no barriers to entry in the industry, meaning that firms in the industry must not have any advantage over potential new producers. Two major factors in the public water supply industry do not satisfy the requirements for a competitive market and lead to market failures that require regulation.

First, the public water market has monopolistic tendencies. These monopolies tend to exist because it is not economically efficient to have multiple suppliers competing to build multiple systems of pipelines, reservoirs, wells, and other facilities. Instead, a single firm or government entity performs these functions under public control. Under monopolistic conditions, consumers are provided only one level of service with respect to the quality attribute of the product, in this case drinking water quality. Since water purveyors often operate in such a monopolistic environment they may not respond to the usual market incentive to satisfy their consumers' desire for high drinking water quality.

Second, high information and transaction costs impede public understanding of the health and safety issues concerning drinking water quality. The type of health risks potentially posed by trace quantities of drinking water contaminants involve analysis and distillation of complex toxicological data and health sciences. EPA recently promulgated the Consumer Confidence Report (CCR) Rule that makes water quality information more easily available to consumers. The CCR Rule requires community water systems to mail or make available an annual report on local drinking water quality to their customers. Consumers, however, still have to understand the information for its health risk implications. Furthermore, even if informed consumers are able to engage utilities regarding these health issues, the costs of such engagement-transaction costs (measured in personal time and commitment) present another significant impediment to consumer expression of risk preference.

SDWA regulations are intended to provide a level of protection from exposure to drinking water contaminants that would not otherwise occur in the existing market environment for public water supply. The regulations set minimum performance requirements for all public water supplies in order to protect all consumers from exposures to contaminants. SDWA regulations are not intended to restructure flawed market mechanisms or to establish competition in supply, but rather, to regulate the "product" produced within these markets. In other words, SDWA standards establish the level of service to be provided in order to better reflect public preferences for safety. Also, the federal regulations remove the high information and transaction costs that would be required for consumers to make informed purchasing decisions by acting on behalf of all consumers in balancing the risk reduction and the social costs of achieving this reduction.

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3. Consideration of Regulatory Options

3.1 Introduction

In order to address the public health concerns presented in Section 2.2 and through consultation with interested stakeholders, EPA has developed a number of regulatory options for consideration. This chapter summarizes the option development process (Section 3.2) and provides a brief description of each regulatory option considered by EPA in this economic analysis (Section 3.3).

3.2 Option Development Process

In 1992, EPA circulated a "straw man" proposal for review and comment, which began the process of developing regulatory alternatives for addressing microbial contamination in ground water systems. In 1993, EPA published a preliminary draft of the Ground Water Disinfection Rule (later renamed the Ground Water Rule). After review of the public comments, EPA recognized that additional information needed to be gathered and, in 1995, convened a GWR regulatory workgroup. EPA used the workgroup as a vehicle to obtain comments and additional information regarding the GWR. In 1996, EPA published a report on ground water- related statutes, regulations, guidance, and disinfection practices gathered from 50 State drinking water programs (EPA, 1996a). In 1997, EPA formally initiated another workgroup including members from EPA, other federal agencies, and State agencies to cooperate in the development of a proposed GWR.

In December 1997, EPA initiated stakeholder meetings. EPA invited the general public to attend via published notices in the *Federal Register*. EPA made a special effort to reach out to local citizens, environmental groups, small businesses and water suppliers. Meetings conducted in Washington, D.C.; Portland, Oregon; Madison, Wisconsin; and Dallas, Texas provided development updates and allowed the stakeholders to provide the EPA with their comments.

In addition to the public meetings with stakeholders, EPA, as part of the consultation process required by the Small Business Regulatory Enforcement Fairness Act (SBREFA), met with representatives of small ground water systems (i.e., considered to be those serving less than 10,000 people) in March and April 1998. EPA presented possible regulatory requirements and requested comments from the representatives during these meetings.

In January 1999, EPA published a preliminary draft preamble for the GWR and solicited comment. The preliminary draft preamble described regulatory alternatives and requested public comment on a number of potential modifications. EPA received 80 comments on the preliminary draft preamble.

3.3 Summary of Alternatives Considered

As a result of the input received from stakeholders, the EPA workgroup, and other interested parties, EPA constructed four regulatory options: (1) the sanitary survey option; (2) the sanitary survey and triggered monitoring option; (3) the multi-barrier option; and the (4) across-the-board disinfection option. Exhibit 3–1 summarizes the basic provisions of these options; the following sections describe each option.

Exhibit 3–1. Regulatory Options and Basic Provisions

		Regulatory Options			
		1 Sanitary Survey	2 Sanitary Survey and Triggered Monitoring	3 Multi-Barrier Approach	4 Across-the-Board Disinfection
PROVISIONS	Sanitary Survey	o	o	o	o
	Triggered[1] source water (microbial) monitoring		o	o	
	Hydrogeologic sensitivity assessment and routine source water monitoring[2]			o	
	All systems install/upgrade and maintain treatment				o

[1]triggered by a total coliform-positive sample in the distribution system
[2]for those systems determined to be hydrogeologically sensitive

3.3.1 Option 1: Sanitary Survey Only

Sanitary surveys are on-site inspections of the source water, treatment facilities, distribution systems, finished water storage tanks, monitoring records, and the management and operation of a public water system (PWS). This option would require sanitary surveys to be conducted by the State at least once every three years for Community Water Systems (CWSs) and every five years for Noncommunity Water Systems (NCWSs). In addition, the surveys would address eight elements: (1) source; (2) treatment; (3) distribution system; (4) finished water storage; (5) pumps, pump facilities, and controls; (6) monitoring, reporting, and data verification; (7) system management and operation; and (8) operator compliance with State requirements. Operators would be required to correct any significant deficiencies within 90 days of receiving the State sanitary survey report or have a State-approved schedule for correcting these deficiencies.

3.3.2 Option 2: Sanitary Survey and Triggered Monitoring

The second regulatory option includes, in addition to all the sanitary survey components of the first option, a microbial monitoring requirement for certain ground water systems. Ground water systems that do not already treat to 4-log removal/inactivation of viruses and which have a total coliform positive for any sample taken under the Total Coliform Rule must subsequently sample and analyze the source water for either enterococci, *E. coli*, or coliphage as determined by the State or primacy agent.

EPA believes source water monitoring enhances a targeted risk-based regulatory strategy by addressing those systems with a high possibility of fecal contamination (i.e., those systems with proven distribution contamination). These systems would be required to collect a source water sample within 24 hours of receiving notification of a total coliform positive in the distribution system and test the sample for the presence of one of the fecal indicators. Positive source water samples would require the system to treat the source water, eliminate the source of contamination, or provide an alternative source of safe water no later than 90 days (or longer with at State-approved plan) from the date the contamination is detected. Systems meeting the requirements through treatment could select among a number of technologies including gas chlorination, hypochlorination, chlorine dioxide, ozone, mixed oxidants, ultraviolet radiation, or chloramination. The State may waive the treatment technique requirement for positive microbial monitoring samples based on five negative samples taken within 24 hours of notification of the first source water sample positive if there has been no total coliform positives in the previous five years of system operation.

Systems that treat would also have to monitor to ensure that the treatment was effective. The type of monitoring would vary based on the treatment technology selected by the system. For example a system that selects hypochlorination would be required to monitor their chlorine residual (i.e., the concentration of the chlorine compounds available to inactivate viruses or bacteria) at the point of entry into the distribution systems and at points throughout the distribution system. Systems serving more than 3,300 people would have to monitor the chlorine residual continuously, while systems under that threshold would have to monitor one grab sample daily.

3.3.3 Option 3: Multi-Barrier Approach

The Multi-Barrier Approach builds on the sanitary survey and triggered monitoring requirements of the first two options by including a hydrogeologic sensitivity assessment. This assessment targets those systems where water can move quickly though the subsurface thereby increasing the possibility of fecal contamination. The State or primacy agent will assess the sensitivity of a system based on the well's hydrogeologic setting. EPA is currently proposing three sensitive hydrogeologies—karst, gravel, and fractured bedrock.

EPA regards the hydrogeologic sensitivity assessment as equal in importance to sanitary surveys in preventing or reducing microbial contamination; the Agency is, therefore, considering requiring States to complete the sensitivity assessment within three years of the GWR effective date for CWSs and within five years for NCWSs (i.e., six and eight years from the promulgation date). As part of these requirements, EPA is considering requiring each State to conduct a one-time sensitivity assessment since the hydrogeology (unlike sanitary survey components) should change little following the initial assessment. This assessment is proposed for all existing and new systems that do not treat to 4-log virus inactivation/removal.

As a result of this assessment, a sensitive system must monitor its source water for a fecal indicator monthly for a 12-month period. The monitoring requirement is the same as described under triggered monitoring except that 12 routine samples are proposed rather than the one-time triggered sample. EPA considers more routine sampling as necessary to identify episodic source water contamination. For example, excessive rain in one month may wash contamination quickly into a karst aquifer although it may not remain long enough to trigger a positive total coliform sample. If all samples are negative during twelve months of monitoring, this requirement allows the State to reduce the monitoring frequency to every quarter the system serves water to the public. The system may also discontinue routine source water monitoring after twelve samples if the State determines that contamination is highly unlikely or if the system switches to an alternative source that is not located in sensitive hydrogeology.

Under the Multi-Barrier Approach, systems that are found to have source water contamination (either through routine or triggered monitoring) would be required to treat to 4-log removal/inactivation, eliminate the source of contamination, or provide an alternative water supply within 90 days (or longer if the State or primacy agent approves a schedule). As discussed under the sanitary survey and triggered monitoring option, if a system chooses treatment, it would have to ensure that it was effective by monitoring for a disinfectant residual. This option also includes the one-time waiver for the treatment technique as described above.

3.3.4 Option 4: Across-the-Board Disinfection

The fourth option considered by EPA would require all public ground water systems to install and/or operate disinfection treatment processes capable of achieving a 4-log inactivation/removal of viruses. Systems disinfecting to less than 4-log removal/inactivation of viruses would be required to upgrade their treatment. Unlike the other options, the across-the-board disinfection option does not consider the quality of a system's source water or potential for contamination. Similar to options 2 and 3, systems would have to monitor their treatment practices to ensure they are effective. Also, States would be required to perform sanitary surveys of ground water systems to ensure the treatment systems are being properly operated and to ensure there are no potential sources of contamination that cannot be addressed by treatment.

3.4 References

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4. Baseline Analysis

4.1 Introduction

To develop forecasts of the benefits of the GWR, as well as forecasts of the economic and financial impacts of the GWR's regulatory options on the ground water supply industry and ultimately on customers, EPA had to develop a baseline before considering the effect of any single regulatory option. A baseline is defined as a characterization of the industry and its operations prior to the rulemaking.

The purpose of this chapter is twofold. First, Section 4.2 provides baseline information relative to the GWR including the number of public water supplies affected, the population affected, and current treatment practices. Second, Section 4.3 introduces the risk assessment modeling used to estimate baseline health effects from contamination of ground water systems (GWS) potentially affected by the GWR.

4.2 Baseline Profile of Public Ground Water Systems

EPA analyzed data on the number of ground water systems and the resources available to the systems. Data inputs included the total number of affected systems, the households and populations served by these systems, average and maximum system flow rates, operator expenses, and system revenues and expenses. This analysis involved input from knowledgeable stakeholders and incorporated the latest available research.

Prior to presenting baseline information for public ground water systems, it is necessary to first define some terms used to describe water systems. EPA uses the following classifications: A public water system is classified as either a community water system or noncommunity water system, the latter of which is further classified as either transient or nontransient. These are defined as follows:

- A public water system (PWS) is one that serves 25 or more people or has 15 or more service connections and operates at least 60 days per year. A PWS can be publically owned or privately owned.

- A community water system (CWS) is one that serves at least 15 service connections used by year-round residents or regularly serves at least 25 year-round residents.

- A noncommunity water system (NCWS) does not serve year-round residents, but serves at least 15 service connections used by travelers or intermittent users for at least 60 days each year, or serves an average of 25 individuals for at least 60 days a year. NCWSs are further sub-classified into nontransient and transient systems.

- A nontransient noncommunity water system (NTNC) serves at least 25 of the same persons over six months per year (e.g., factories, schools, office buildings, and hospitals with their own water source).

- Transient noncommunity water systems (TNC) do not serve at least 25 of the same persons over six months per year (e.g., many restaurants, rest stops, parks).

Public water systems are also classified by the source water they use as being either surface water (e.g., drawn from lakes, streams, rivers, etc.) or ground water (e.g., drawn from wells or springs). Some ground water sources (e.g., riverbank infiltration/galleries) are directly impacted by adjacent surface water bodies and are referred to as ground water under the direct influence of surface water (GWUDI). As noted in Section 2, the GWR does not address GWUDI systems, which are instead subject to the requirements of the Surface Water Treatment Rule and the Interim Enhanced Surface Water Treatment Rule.

Sources of Industry Profile Information

EPA uses the following as the two primary sources of information to characterize the universe of ground water systems:

- Safe Drinking Water Information System (SDWIS)—EPA's SDWIS contains data on all PWSs, as reported by States and EPA regions. These data reflect both mandatory and optional reporting components. States must report the system location, system type (CWS, NTNC, or TNC), primary raw water source (ground water, surface water, or GWUDI), and violations. Optional reporting fields include type of treatment and ownership type. Because providing optional data is discretionary, EPA does not have complete data on every system for these parameters; this is particularly common for noncommunity systems.

- Community Water System Survey (CWSS)—The second source of information, CWSS, is a detailed survey of surface and ground water community water systems conducted by EPA in 1995 and published in 1997 (EPA, 1997). The CWSS is stratified to represent CWSs across the U.S. The CWSS includes information such as the number of system operators, system revenues, expenses, treatment practices, source water protection measures, and capacity (i.e., the amount of water the system is designed to deliver). The CWSS contains data from 1,980 water systems, of which 1,020 are ground water systems, 510 are surface water systems, and 450 represent purchased water systems (systems that purchase water from another PWS and distribute this water to their customers).

4.2.1 Number of Ground Water Systems

Nationally, SDWIS indicates that there are over 156,000 public water systems that use ground water as their primary source. The majority of ground water systems are NCWSs, with 60 percent (93,000) transient and 12 percent (19,000) nontransient. CWSs make up the remaining 28 percent

(44,000) of all ground water systems. Although there are far more NCWSs, CWSs serve larger numbers of people.

According to SDWIS (1997), 97 percent of the 44,000 CWSs, and nearly all of the NCWSs that use ground water, serve fewer than 10,000 persons, which EPA defines as a small system. Collectively, 99 percent of drinking water systems serve fewer than 10,000 people. About 97 percent of the systems serve 3,300 people or fewer (for a total of 33.2 million people). For CWSs, 78 percent serve fewer than 1,000 people (for a total of 8.1 million people), 67 percent serve fewer than 500 people (for a total of 4.6 million people), and 33 percent serve fewer than 100 people (which is nearly 900,000 people). Exhibit 4–1 presents the number of ground water systems in the United States by system type and population served.

Exhibit 4–1. Total Number of Ground Water Systems by System Type and Service Population Category

Service Population Category	Community	Nontransient Noncommunity	Transient Noncommunity	Total
100 or Less	14,390	9,714	72,343	96,447
101–500	15,069	6,925	18,576	40,570
501–1,000	4,739	1,927	1,849	8,515
1,001–3,300	5,726	686	611	7,023
3,301–10,000	2,489	59	151	2,699
10,001–50,000	1,282	11	66	1,359
50,001–100,000	139	0	12	151
>100,000	72	0	10	82
Total	**43,906**	**19,322**	**93,618**	**156,846**

Source: EPA, 1999a.

4.2.2 Population Served by Ground Water Systems

System population characteristics are important to this analysis for several reasons. It is important to know the total population served by ground water systems so that the distribution of costs and benefits of the GWR can be addressed. As presented in Exhibit 4–2, ground water CWSs serve more than 88.7 million people, while ground water NCWSs serve about 20.2 million people. Overlaps do occur, as individuals may be served by both types of systems, as well as systems providing a combination of ground and surface water. For example, a person may be served by a surface water CWS at home and by a ground water NCWS at work or at a restaurant. It should be noted that there does not appear to be a consistent reporting standard for populations served by transient systems. In addition, some States may report the total population served by a system over a year, while others may report the average population served each day.

Exhibit 4–2. Total Population of Ground Water Systems by System Type and Size

Service Population Category	Community	Nontransient Noncommunity	Transient Noncommunity	Total
100 or Less	864,784	507,200	3,160,753	4,526,266
101–500	3,737,617	1,783,574	4,109,429	9,630,620
501–1,000	3,491,873	1,387,818	1,410,457	6,290,148
1,001–3,300	10,542,514	1,118,678	1,075,745	12,736,937
3,301–10,000	13,956,242	338,457	829,854	15,124,553
10,001–50,000	26,653,078	161,827	1,675,640	28,490,545
50,001–100,000	10,799,952	0	891,000	11,690,952
>100,000	18,668,871	0	1,782,667	20,451,538
Total	**88,708,460**	**5,297,554**	**14,935,545**	**108,941,559**
Source: EPA, 1999a.				

4.2.3 Treatment Profile

This section presents information regarding the disinfection treatment technologies that are currently implemented by ground water systems. This information is used to develop an assessment of the number of systems that may need to install or modify treatment to meet new GWR requirements. These data are also used in the RIA's cost analysis and in the determination of the compliance monitoring burden. An analysis of current treatment effectiveness is necessary to establish a baseline of finished water exposure and as a baseline to determine how much additional corrective treatment is needed to meet GWR requirements.

Because ground water systems may employ more than one water supply source, they may have more than one treatment facility. Therefore, the analysis of types of treatment in place must be performed on an entry point/treatment facility level rather than on a system level. To determine the number and percentage of entry points to community ground water systems, EPA analyzed responses to the CWSS regarding current treatment practices. EPA considered a ground water entry point with one or more disinfection treatments (e.g., chlorine gas, reverse osmosis) to be a disinfected facility. Once EPA made this determination, the Agency calculated the percentage of ground water that is disinfected for each population category. Exhibit 4–3 displays the percent of ground water treatment facilities disinfecting, flow-weighted by service population category.

Exhibit 4–3. Percent of Community Ground Water Treatment Facilities Disinfecting by Service Population Category (Flow-Weighted)

Service Population Category	% Facilities Disinfecting, Flow-Weighted
100 or less	45
101–500	73
501–1,000	76
1,001–3,300	75
3,301–10,000	74
10,001–50,000	91
50,001–100,000	64
100,000–1,000,000	81

Note: Flow-weighted calculation of the percentage of community water system flow which receives disinfection treatment.
Source: EPA, 1997.

Because there currently are no surveys equivalent to the CWSS that define treatment practices in noncommunity systems, the EPA compiled estimates from State public drinking water officials on the percentage of systems in their State that currently disinfect. Exhibit 4–4 presents the estimates for noncommunity systems. These estimates vary in their methods and levels of accuracy.

4.3 Baseline Health Effects

EPA has developed a risk assessment model to estimate the baseline number of illnesses and deaths associated with ingesting pathogenic viruses in public ground water systems. This GWR risk assessment follows the standard methodology developed by the National Research Council (NRC, 1983). The NRC defined three steps for risk assessment of contaminants in drinking water:

1) exposure assessment,
2) hazard identification, and
3) health effects assessment (risk characterization).

The method of calculating illnesses and deaths from exposures to waterborne pathogens in ground water is presented in Exhibit 4–5. As shown in the figure, both exposure factors and the pathogenicity of each organism are factored into the estimate of health effects in the exposed population.

Exhibit 4–4. Percent of Noncommunity Ground Water Systems Disinfecting by State

State	NTNC	TNC	State	NTNC	TNC
Alabama	100	82	Montana	8	4
Alaska	17[1]	4	Nebraska	8	1
Arizona	18	10	Nevada	14	~0
Arkansas	~100	~70	New Hampshire	4	2
California	8	7	New Jersey	~6	~3
Colorado	95[2]	95[2]	New Mexico		3720
Connecticut	(unknown)	(unknown)	New York	<50	<50
Delaware	17	9	North Carolina	23	2
Florida	100	100	North Dakota	0	10
Georgia	66	46	Ohio	31	12
Hawaii	100	83	Oklahoma	2	7
Idaho	~8	~2	Oregon	19	17
Illinois	11[2]	11[2]	Pennsylvania		5026
Indiana	<5	<5	Rhode Island	1	1
Iowa	~15	~5	South Carolina	16	6
Kansas	100	100	South Dakota	35	19
Kentucky	100	100	Tennessee	70	52
Louisiana	23	9	Texas	100	100
Maine	4	6	Utah	33	17
Maryland	10–15	~0	Vermont	~5	~0
Massachusetts	3	1	Virginia	14	9
Michigan	~6	~3	Washington	41	24
Minnesota	~3	~1	West Virginia	95	~50
Mississippi	46	26	Wisconsin	5	<1
Missouri	17	25	Wyoming	17	13

[1] State combined the Community and NTNC numbers.
[2] State combined the NTNC and TNC numbers.
Source: EPA, 1996.

Exhibit 4–5. Risk Assessment Process for Pathogens in Drinking Water (adapted from NRC, 1983)

EXPOSURE ASSESSMENT		HAZARD IDENTIFICATION		RISK CHARACTERIZATION
Pathogen Occurrence in Source Water (Hit Rate))				
Concentration of Pathogen in Source Water				
Concentration of Pathogen Removed or Inactivated During Treatment				
Concentration of Pathogen in Finished Water, Available for Consumption				
Potentially Exposed Population (Includes Sensitive Subgroups)				
Daily Intake (Liters per Day Consumption)				
Daily Dose	-	Infectivity: Dose-Response Relationship (Probability of Infection given Exposure)		
		Individual Daily Probability of Infection		
Annual Intake (Days per Year Exposure)	-	Individual Annual Probability of Infection		
		Morbidity [Probability of Illness Given Infection; Includes Secondary Spread]	-	Annual Number of Illnesses (Individual Risks x Population)

		Mortality [Probability of Death Given Illness]	-	Annual Number of Deaths (Individual Risks x Population)
Exposure	x	**Pathogenicity**	=	**Health Effect**

The proposed GWR is expected to reduce the current incidence of illness caused by a wide variety of viral and bacterial pathogens that are associated with fecal contamination of ground water. Different pathogens cause different illnesses and each pathogen has a different probability of causing illness or death. Medical research has not isolated all waterborne pathogens, nor has it thoroughly characterized the pathogenicity or ability of these organisms to infect humans and cause them to become ill or to die. EPA has selected two well-characterized viral pathogens having different infectivity, morbidity, and mortality rates to represent a wide range of waterborne viral pathogens for the GWR risk assessment. The selected representative viruses, rotavirus and echovirus, are described as follows.

- Rotavirus is a highly infectious virus that is a common cause of vomiting and diarrhea, especially in children, but does not frequently result in life-threatening illness in the general population of industrialized countries. For the purposes of this analysis, rotavirus represents a large group of viruses referred to hereafter as Type A viruses. These viruses are suspected to cause outbreaks of gastroenteritis in PWS drinking water supplies. These viruses include: Norwalk, Norwalk-like small round structured viruses, caliciviruses, adenovirus, astrovirus, and other enteric viruses.

- Echovirus is a small RNA enterovirus that represents the group of waterborne viruses referred to hereafter as Type B viruses that, although not highly infectious, may result in severe health effects when illness occurs. Coxsackie viruses and Hepatitis A virus (HAV) are other examples of Type B viruses.

The following sections present EPA's assumptions and methodology used in: 1) estimating exposure, 2) characterizing hazards (i.e., pathogenicity), and 3) calculating the health effects of Type A and Type B viruses under current baseline conditions.

4.3.1 Exposure Assessment

Exposure assessment is the first step in the risk assessment process. The exposure pathway addressed in this risk assessment is ingestion of drinking water from public ground water supplies that are contaminated with microbial pathogens from fecal pollution.

CDC surveillance data show that pathogens in ground water systems have often been the cause of waterborne disease outbreaks (WBDOs), clusters of cases of acute gastroenteritis or other illness that are reported to CDC through public health agencies. Low levels of pathogens also may cause endemic (unreported, acute or chronic) disease in the exposed population. EPA believes that there are three key exposure scenarios whereby drinking water delivered to consumers in public ground water systems can be contaminated with fecal pathogens:

1) source water contamination in untreated systems;
2) source water contamination in disinfecting systems with treatment failures; and
3) distribution system contamination.

The remainder of this discussion of exposure assessment for the GWR addresses only the first contamination scenario. Though not considered as significant a threat as fecal contamination of source water for untreated systems, EPA's modeling of this first scenario also includes exposure from systems that do treat (disinfect), taking into account the reduction in microbial levels from that treatment.

EPA believes there is insufficient information on the frequency and severity of drinking water treatment failures and distribution system contamination events in GWSs to directly model the latter two scenarios. However, the proportions of reported WBDOs caused by the three contamination scenarios, as shown previously in Exhibit 2–4, serve as an indicator of the relative frequency of ground water system contamination events that cause disease in exposed populations. These outbreak proportions are factored into the estimates of total annual illnesses and deaths due to ingestion of drinking water from public GWSs.

EPA distinguishes two types of ground water systems or points of entry with respect to the likelihood and severity of source water contamination:

1) those with wells constructed in accordance with State requirements (hereinafter referred to as properly-constructed wells). EPA estimates that properly-constructed wells comprise 83 percent of systems/points of entry, based upon data from ASDWA's *Survey of Best Management Practices for Community Ground Water Systems* (ASDWA, 1997); and

2) those with poorly-constructed wells, which are assumed to comprise the remaining 17 percent of ground water systems/points of entry.

Whether the systems are properly or poorly constructed, the assessment of exposures to pathogens from ground water sources requires that the following factors be quantified based on survey data or best professional judgment:

- the occurrence (presence/absence) of pathogens in source water;

- the concentration of pathogens in source water when it is contaminated;

- the level of pathogen inactivation in the system and resulting pathogen concentration in tap water;

- the size of the exposed population, including sensitive subgroups; and
- the volume of water ingested daily and how many days per year it is ingested.

EPA evaluated available occurrence and exposure data and developed assumptions regarding these exposure factors, each of which is discussed briefly below.

Concentration of Pathogen in Source Water

Virus occurrence and virus concentration assumptions for this exposure assessment are based on occurrence data from two recent U.S. ground water source surveys:

1) the AWWARF study (Abbaszadegan et al., 1998 American Water Works Service Co.): a survey of mainly properly-constructed wells; and

2) the EPA/AWWA study (Lieberman et al., 1995): a survey of known contaminated wells, assumed to be representative of poorly-constructed wells.

Both studies used a number of complementary analytical methods to detect and enumerate microbial pathogens, including: enterovirus cell-culture, nucleic acid detection by reverse transcription-polymerase chain reaction (RT-PCR), and standard fecal indicator methods. Viral occurrence is estimated as the percent of wells that were found contaminated with virus during one or more sampling events. Both studies found viral pathogens in a small fraction of the wells tested. The number of wells identified as virus-positive in the surveys tended to vary with the specificity and sensitivity of the methods used. For example, in the AWWARF study, 4.8 percent of wells were enterovirus-positive by the cell-culture assay, whereas 15.9 percent of wells were enterovirus-positive by the RT-PCR assay (final RT-PCR results are not available from the EPA/AWWA study).

Because the cell-culture method detects only intact, infective viruses, EPA used the fraction of wells positive by the enterovirus cell-culture method as the preferred measure of viral pathogen occurrence. However, because of the method's virus-specificity (i.e., only Type B viruses are typically detected by the cell-culture method used in both studies), the ratio of cell-culture to RT-PCR-positive wells was used to calculate Type A virus occurrence.

Viral occurrence estimates and supporting assumptions are summarized in Exhibit 4–6. The exhibit also presents the concentration distribution of viral pathogens in contaminated source wells as estimated using enterovirus data from the AWWARF study (for properly-constructed wells) and the EPA/AWWA study (for poorly-constructed wells). As shown in the exhibit, contaminated, poorly-constructed wells are assumed to have a mean concentration expressed in most probable number of infectious units of virus per 100 liters of water of 29.41 ± 55.7 MPNIU/100 L, in comparison with a mean concentration of 0.356 ± 0.297 MPNIU/100L in contaminated, properly-constructed wells.

EPA recognizes that there may be reasonable alternative approaches to interpreting the above data and to using these data in the occurrence assessment to support the risk analysis. For example, there may be merit to making more use of the male-specific and/or somatic coliphage results from the AWWARF and EPA\AWWA studies than is currently done in the risk analysis. Also, additional data may be available from other sources to enhance the data and analysis used here. EPA requests that interested parties provide any additional information or suggestions for alternative methods for using the existing information during the comment period following the proposal of the GWR.

Pathogen Inactivation in Ground Water Systems and Resulting Tap Water Concentrations

For the purposes of this exposure assessment, EPA assumed that the pathogen concentration in tap water from undisinfected ground water systems is the same as the pathogen concentration in source water. In contrast, properly-operating disinfecting systems are assumed to inactivate 99.99 percent, or 4-logs, of viral pathogens. Therefore, the concentration of pathogens in tap water from properly-operating disinfecting systems is assumed to be 0.01 percent of the concentration in source water.

It is possible that viruses may be naturally attenuated to some extent while passing through untreated ground water distribution systems. It is also known that treatment failures and distribution system contamination events occur from time to time in disinfecting systems. However, EPA believes there are insufficient data to directly quantify and model these events in the GWR model. Section 4.3.4 discusses the methods for indirectly estimating illness due to treatment and distribution system contamination.

Exhibit 4–6. Viral Occurrence and Concentration in Source Water

Well Quality	Virus Type	Percent of Wells Contaminated	Mean Virus Concentration when Contaminated(MPNIU[1]/100 L)
Properly-Constructed Wells (83 % of all GWSs)	Type A virus	4.4 percent[2]	0.356 ± 0.297[6,7]
	Type B virus	4.8 percent[3]	0.356 ± 0.297[7]
Poorly-Constructed Wells (17 % of all GWSs)	Type A virus	5.5 percent[4]	29.41 ± 55.7[6,8]
	Type B virus	6.0 percent[5]	29.41 ± 55.7[8]

1 Most probable number of infectious units of virus.

2 AWWARF study: The RT-PCR methods detected the presence of rotavirus nucleic acids in 14.6 percent of wells tested to which the ratio of enterovirus cell-culture to RT-PCR positive wells (0.3) was applied.

3 AWWARF study: The AWWARF study found that 4.8 percent of wells tested were positive for the presence of enteroviruses using the Buffalo Green Monkey (BGM) cell culture assay.

4 EPA/AWWA study: Because there are no rotavirus data available from the EPA/AWWA study at this time, it is assumed that rotavirus (Type A virus) and echovirus (Type B virus) occur in poorly constructed wells in the same ratio as calculated for properly constructed wells (4.4/4.8 = .92; .92 x 6.0 = 5.5).

5 EPA/AWWA study: Calculated by dividing the total number of positive BGM cell culture assays by the total number of assays performed.

6 Because there are no concentration data for rotavirus available from either study, it is assumed that the mean concentration of Type A virus in properly-constructed wells is the same as for Type B virus.

7 AWWARF study: Range of enterovirus (Type B virus) concentrations in cell-culture isolates was 0.123 to 1.86 MPNIU/100 L; data are fitted to a lognormal distribution from which the mean and standard deviation are calculated.

8 EPA/AWWA study: Range of enterovirus concentrations in cell-culture isolates was 0.9 to 212 MPNIU/100 L; data are fitted to a lognormal distribution from which the mean and standard deviation are calculated.

Potentially-Exposed Populations, Including Sensitive Subgroups

The populations served by all types of systems were presented previously in Exhibit 4–2; Exhibit 4–7 presents the numbers of persons in the general population served by undisinfected ground water systems (the subject of the GWR risk model calculations).

Exhibit 4–7. Populations Served by Undisinfected Ground Water Systems

Service Population Category	Estimated Population Served Undisinfected Ground Water[1]		
	Community Water Systems (CWS)	Nontransient Noncommunity (NTNC) Systems	Transient Noncommunity (TNC) Systems
< 100	471,214	364,978	2,616,086
101–500	1,005,419	1,283,450	3,401,284
501–1,000	852,017	998,666	1,167,404
1001–3,300	2,667,256	804,994	890,370
3,301–10,000	3,670,492	243,552	686,852
10,001–50,000	2,309,365	116,450	1,386,890
50,001–100,000	3,898,783	0	737,461
>100,000	3,472,410	0	1,475,474
Totals	18,346,956	3,812,090	12,361,821

[1] *Source:* GWR model calculation (EPA 1999a).

Within the general population, there are sensitive subgroups, that is, groups of individuals who may suffer more serious symptoms when they become ill as a result of exposure to pathogens in ground water. Sensitive subgroups also may have a higher probability of mortality when they are ill, thus suffering a disproportionate burden of the health risks from exposures to contaminated ground water. Criteria distinguishing sensitive subgroups in this exposure assessment include:

- Age: very young children (< 5 years) and elderly adults (> 65 years) are sensitive to many viral pathogens; the exposure assessment uses statistics from the Bureau of Labor, 1990 census to distribute by age the populations in each type and size of ground water system; and

- Immunocompromised health status: AIDs patients, organ transplant patients, nonhospitalized persons receiving cancer therapy, and nursing home patients are considered sensitive to viruses based on compromised immune status. The first three groups comprise approximately 1.0 percent of the general population, assumed to be divided equally among all age groups. Nursing home residents constitute another 0.6 percent of the general population, and are assumed to be older than 16 years.

Drinking Water Consumption Factors

The amount of drinking water consumed daily by individuals is a key input to the risk analyses supporting all EPA drinking water MCL and MCLG regulations and determinations. The higher the average volume of contaminated water consumed, the higher the average daily dose of pathogens.

Daily intake assumptions for this exposure assessment are age-based; that is, the amount of water consumed daily varies by age group. Custom daily intake distributions developed for the age groups used in this analysis use data from the *1994–1996 USDA, Continuing Survey of Food Intakes by Individuals*. (EPA, 2000) In this analysis, EPA selected the consumption distribution identified as "all sources, consumers only" having an overall mean of 1.24 L/day (0.30 at the 10^{th} percentile and 2.35 L/day at the 90^{th} percentile) to represent an upper bound estimate of daily consumption values. Results of alternative model calculations using USDA consumption data for "community water supply, all respondents" (mean of 0.927 L/day) are presented in Appendix A as a lower bound estimate.

In addition to daily consumption, EPA included estimates of the number of days per year tap water is consumed by users of different types of water systems. EPA's estimates for exposure days are presented in Exhibit 4–8.

Exhibit 4–8. EPA Estimates for Exposure Days[1]

Type of System	Exposure Days Per Year
Community Water Systems	350
Noncommunity Nontransient	250
Transient Noncommunity	15
[1] Number of days in which tapwater is consumed.	

4.3.2 Hazard Identification

Hazard identification is the second step of the risk assessment process. Hazard identification addresses the pathogenicity of each drinking water pathogen to the potentially exposed population. Factors considered in this assessment include:

- infectivity (the ability of a microorganism to colonize the body of the host),
- morbidity (the probability of illness given infection), and
- mortality (the probability of death given illness).

Infectivity assumptions are based on dose-response curves generated from challenge studies in healthy adult volunteers. Morbidity rates are based on epidemiological studies, and mortality is estimated on observed case-fatality ratios. Morbidity and mortality may vary with the age and overall sensitivity of the receptor population. Pathogen hazard assumptions for Type A and B viruses when ingested in ground water are summarized in Exhibit 4–9.

Exhibit 4–9. Hazard Identification of Viral Pathogens for the GWR Risk Assessment

<table>
<tr><th>Pathogen Hazards</th><th>Infectivity</th><th colspan="2">Morbidity</th><th>Mortality</th></tr>
<tr><td>Definition</td><td>Infectivity is the ability of the pathogen to colonize the host; it is defined by dose-response relationship.</td><td rowspan="2">Primary morbidity is the probability of illness given infection; can vary in sensitive subgroups.</td><td rowspan="2">Secondary spread is the probability of illness given contact with a (primary) ill person.</td><td rowspan="2">Mortality is the probability of death as a result of illness.</td></tr>
<tr><td>Model</td><td>General model of dose-response (beta-Poisson):

P (I) = 1– (1 + N/$)^{– "}

where:
P (I)= probability of infection
N = number of pathogenic viruses ingested
", $= pathogen-specific rate constants.[1]</td></tr>
<tr><td rowspan="2">Type A virus</td><td rowspan="2">Highly infective virus;
" = 0.26, $=0.42[2]</td><td>< 2 yrs old = 0.88 [4]</td><td>< 2 yrs old = 0.55 [4]</td><td rowspan="2">7.3 x 10⁻⁶ [6]</td></tr>
<tr><td>> 2 yrs = 0.1 [5]</td><td>> 2 yrs old = 0 [4]</td></tr>
<tr><td rowspan="3">Type B virus</td><td rowspan="3">Moderately infective virus;
" = 0.374, $ =187[3]</td><td>< 5 yrs old = 0.5 [7]</td><td rowspan="3">Triangular distribution (all age groups), from 0.11 to 0.55; mode = 0.35[8]</td><td>< 1 month = 0.0092 [6,9]</td></tr>
<tr><td>$ 5 to 16 years = 0.57[7]</td><td rowspan="2">$ 1 month = 0.00041[10]</td></tr>
<tr><td>> 16 years = 0.33 [7]</td></tr>
<tr><td colspan="5">1 Regli et al., 1991; 2 Ward et al., 1986; 3 Schiff et al., 1984; 4 Kapikian and Chanock, 1996; 5 Wenman et al., 1979 and Foster et al., 1980; 6 CEOH 1998; 7 Hall 1980; 8 Morens et al., 1991; 9 rate of mortality given infection; 10 Stedge, 1998.</td></tr>
</table>

For Type A viruses in children < 2 years and for Type B viruses in all age groups, the hazard identification part of the model also includes a factor for secondary spread. Secondary spread refers to contracting the illness through exposure to a person who became ill after exposure via ingestion of contaminated ground water. No secondary spread data are available for viral infections explicitly acquired via the ground water pathway. Nevertheless, secondary spread of waterborne illnesses is a reasonable assumption because the pathogens of concern for the GWR are also commonly transmitted by respiratory or direct contact (fecal-oral) pathways.

4.3.3 Sensitive Subgroups

Although it is generally believed that most persons are equally vulnerable to repeated infection (i.e., colonization) by viruses and other microorganisms during their lifetime, factors such as being very young, very old, or immunocompromised can determine whether severe illness follows infection and whether death is the outcome of severe illnesses. The hazard identification factors presented in Exhibit 4–10 and incorporated in the GWR model include higher morbidity and/or mortality rates for some age groups, typically for neonates (Type B viruses) and children (both Type A and Type B viruses).

The Very Young

The very young (e.g., infants less than one month old) are generally considered to be relatively more sensitive to severe symptomatic illness and death from gastroenteritis and other waterborne viral and bacterial illnesses. Some viral pathogens such as coxsackie virus B (a Type B virus) can be transmitted transplacentally from an infected mother to her child in utero, during birth, or shortly thereafter. This type of transmission places the infected newborn infant at risk of severe symptomatic illness from meningitis or myocarditis, for which the case fatality rates are high (Gerba et al., 1996a).

Viral gastroenteritis, caused mainly by Type A viruses, is prevalent among U.S. children. Primary or secondary transmission by the fecal-oral route contributes to high rates of illness in group settings such as day-care centers that include diapered children. CDC has determined that the incidence of rotavirus diarrhea can reach 0.30 episodes/child/year by age two, with a cumulative incidence approaching 0.80 episodes/child by age five (Glass et al., 1996). Hospitalizations for rotavirus diarrhea are most common in children six months to three years of age (Parashar et al., 1998), while self-limiting Norwalk-like virus infections are prevalent in school-age children (LeBaron et al., 1990). Although deaths from infectious diarrhea have generally declined among U.S. children since 1965 because of re-hydration therapy, newborn children, especially infants born prematurely, remain at risk of death from severe diarrheal illness (Kilgore et al., 1995).

The Elderly

The elderly (persons over 65 years of age) are also at greater risk than the general population of experiencing severe health effects from rotavirus diarrhea, hepatitis and other viral infections. Sensitivity among persons in this age group is due to declining immunity and poorer general health (Gerba et al., 1996a and b; Lew et al., 1991). Conditions such as cardiovascular disease make the elderly more susceptible to complications of diarrhea such as electrolyte imbalance, dehydration, and shock (Maasdam and Anuras, 1981, cited in Lew et al., 1991). More than half of the diarrheal deaths that occur in the U.S. are among persons older than 74 years of age, and the risk of death from diarrhea is generally higher among elderly persons confined to nursing homes and other care facilities (Lew et al., 1991; Gerba et al., 1996 b). Thirty percent of diarrheal deaths among the elderly occur in nonhospitalized patient care settings (e.g., nursing homes), although only 10 percent of persons in this age group live in such settings (Lew et al., 1991).

The Immunocompromised

Immunocompromised and immuno-suppressed persons comprise a non-age-based population sub-group who are sensitive to serious health effects from viral and bacterial infections. Although some viral pathogens (e.g., hepatitis A and Norwalk virus) do not cause more severe illness or risk of death in immunocompromised persons, chronic diarrhea is a serious complication of AIDs, and rotavirus and adenovirus are commonly isolated from stool samples from AIDs patients with diarrhea (Gerba et al., 1996a).

A limited number of available studies suggest that viral infections can contribute to deaths in immunocompromised persons. Hierholzer (1992) reported case fatality ratios of 53 to 69 percent in cancer-immuno-suppressed and bone-marrow transplant patients infected with adenovirus. Enteric rotavirus, coxsackie virus and adenovirus infections were reported as the cause of similar case fatality ratios among bone-marrow transplant patients in an earlier study (Yolken et al., 1982, cited in Gerba et al., 1996a).

At this time, the morbidity and mortality factors assigned to immunocompromised subgroups for Type A and B virus infections are the same as those used for the general population. EPA believes there are insufficient data available for these subgroups to assume higher morbidity or mortality from waterborne infections based on immune status. However, because there is a higher cost-of-illness among severely immunocompromised persons having lengthy viral illnesses, the with-rule reductions in numbers of illnesses and deaths in this subgroup are calculated by the risk model and are monitored separately in the benefits calculations.

4.3.4 Risk Characterization

The third step of the risk assessment process is risk characterization. This section summarizes the methods of calculation used to derive baseline estimates of health effects in the exposed populations. Model calculations used to estimate annual illnesses and deaths due to source contamination in undisinfected systems are presented first, followed by an explanation of the factors used to estimate additional illnesses and deaths due to treatment failures and distribution contamination. Finally, the results of the baseline (without rule) risk calculations are presented.

Risk Assessment Methodology

The modeling of baseline risks was performed using a two-step Monte Carlo simulation analysis designed to provide both a "best" estimate of the number of illnesses and deaths due to viruses in ground water, and an estimate of the uncertainty bounds around those values.

The simulation analysis was structured to incorporate two steps to separately address the variability and uncertainty aspects of the input parameters in the algorithms used to calculate risk.

The first step of the simulation analysis used information characterizing the variability of viruses in drinking water from ground water supplies together with information characterizing the variability in drinking water consumption in the exposed population to arrive at an estimate of the distribution of individual annual risks of infection. This distribution of individual risks of infection also provided an estimate of the average annual risk of infection for the overall population and of the uncertainty in that average risk.

The second step of the simulation analysis used the results of the first step along with factors characterizing morbidity (illness given infection) and mortality (death given illness), together with the number of people exposed from various types of ground water systems to arrive at the total national estimate of illnesses and deaths due to viruses in ground water. The second step combined the average annual risk of infection and its associated uncertainty with other factors to provide an estimate of the total number of annual illnesses and deaths in the exposed population, as well as an estimate of the uncertainty in those total numbers.

The following provides further detail for each of the two steps.

Step 1. <u>Estimation of the Distribution of Individual Annual Risks of Infection, Average Individual Annual Risk of Infection, and Uncertainty (Standard Error) in the Average Individual Annual Risk.</u>

The basic risk assessment algorithm used in this analysis to compute individual annual risk is shown below:

$$P_{Ann} = 1 - \left(1 - P_{Daily}\right)^{D} \qquad (4\text{-}1)$$

Specifically, this algorithm provides an estimate of the probability that an individual will become infected during a one-year period given an average daily risk of infection of P_{Daily} and D days of exposure during the year.

As discussed in the preceding section on exposure, the number of days of exposure (drinking water consumption) differs for exposure between community water systems (350 days), nontransient noncommunity systems (250) days and transient noncommunity systems (10) days.

The individual daily risk of infection, P_{Daily}, incorporated in Equation (4-1) is calculated as:

$$P_{Daily} = 1 - \left(1 + N/\beta\right)^{-\alpha} \qquad (4\text{-}2)$$

The individual daily risk of infection is the probability that an individual will become infected from consuming N viruses in water that day. The variables α and β are pathogen-specific dose-response model parameters. The values for α and β for the Type A and Type B viruses model in this analysis are shown in Exhibit 4-9.

The daily ingestion of viruses for any individual is the product of the concentration of viruses in drinking water and amount of drinking water consumed. There is, of course, variability in the expected level of viruses in ground water from one system to the next, as well as variability in drinking water consumption from one individual to the next. The Monte Carlo simulation performed in the first step of the analysis incorporated both of these exposure factors as distributions to reflect that variability.

The variability in virus concentrations in ground water systems was characterized by lognormal distributions using the mean and standard deviations for Type A and Type B viruses in properly and poorly constructed wells as shown in Exhibit 4-6 as the parameters for those distributions.

The variability in drinking water consumption was characterized by age-specific custom distributions derived from the information provided in the CSFII data discussed in the exposure section.

In addition to the occurrence distribution and consumption factors, the calculation of N also includes assumptions concerning hit rate (portion of wells with viruses present), the fractions of disinfected and undisinfected wells, the fraction of properly and improperly constructed wells, treatment effectiveness in disinfected wells, and the fraction of viable viruses (assumed in this analysis to be 1.0).

There are three key outputs from this first step of the analysis

- The distribution of individual risks, used for the risk characterization of the portion of the population expected to experience risks at various levels (including risks to sensitive subpopulations);
- The mean or average individual risk, used in the Step 2 of the analysis as discussed below to scale up the individual risks to the entire population in order to estimate the number of cases of illness;
- The standard error in the estimated mean individual risk, also used in Step 2 as a contributor to the uncertainty in the estimated number of cases of illness.

Step 2. <u>Estimation of Cases of Illness and Death in the Exposed Population and Uncertainty Bounds on the Estimated Cases.</u>

In the second step of the Monte Carlo analysis, the number of cases of illness and death in the exposed population are calculated from the average individual risk of infection obtained in Step 1, the morbidity factors that characterize the probability of becoming ill given an infection, secondary spread factors, the mortality factors that characterize the probability of death given an illness, and the total population exposed to whom the annual individual risk of infection applies.

The basic algorithm for calculating the number of illnesses in Step 2 is:

$$\Sigma Illness = Pop \times P_{AnnAvg} \times M_P \times (1 + M_s) \times (1 + M_{Dis}) \qquad (4\text{-}3)$$

In Equation 4-3, Pop is the population exposed, P_{AnnAvg} is the average annual indivdual risk of infection obtained in Step 1, M_P is the morbidity factor for primary illness given infection, M_S is the secondary spread of illness factor, and M_{Dis} is the factor for computing additional cases of illness due to treatment failure in disinfected systems and due to other distribution system sources (see further discussion later in this section).

The algorithm for calcualting deaths in Step 2 is:

$$\Sigma Death = \Sigma Illness \times M_M \tag{4-4}$$

In Equation 4-4, M_M is the mortality factor reflecting the number of deaths expected among those who become ill from viral infections. These factors are also provided in Exhibit 4-9.

In addition to providing "best" estimates of total illnesses and deaths, this second step of the analysis also provides an estimate of uncertainty in those estimates that reflect the uncertainty estimated in the average individual risk of infection obtained in Step 1, and uncertainty in one of the morbidity factors used to calculate illnesses. Specifically, the secondary spread factor for Type B viruses for all age groups was included as an uncertainty distribution (triangular distribution, see Exhibit 4-9).

Exhibit 4-10 provides an additional summary of the risk calculation factors and indicates whether they were incorporated as a variability distribution, uncertainty distribution, or constant in the Monte Carlo simulation.

Exhibit 4-10. Summary Table of Risk Calculation Factors Used & the Distribution Category (Variability, Uncertainty, Constant) Used in the Simulation Analysis

Risk Calculation Factor	Description and Use in Calculations	Distribution – Variability	Distribution – Uncertainty	Constant
Occurrence Hit Rate	Used in Step 1 to characterize the fraction of systems (and therefore of population) having viruses present in the source water.			X
Occurrence Distribution	Used in Step 1 to characterize the concentrations of viruses in source water.	X		
Fraction of Disinfecting and Undisinfecting Sytems	Used in Step 1 to separate those systems current practicing disinfection from those that do not.			X
Log Removal for Disinfecting Systems	Used in Step 1, an assumed 4-log removal of virus concentration in source water for those systems practicing disinfection.			X
Viability	Used in Step 1 to indicate the fraction of viruses in water considered to be infectious (assumed here to be 1.0).			X
Drinking Water Consumption	Used in Step 1 to characterize the daily water consumption by various age groups in the exposed population.	X		

Dose-response Equation Parameters	Used in Step 1, empirically derived parameters in equations used to calculate daily and annual risk of infection.			X
Days of Consumption	Used in Step 1 to indicate the number of days per year an exposed individual consumes water from ground water sources.			X
Average Annual Individual Risk of Infection	Product of the Step 1 calculation used in Step 2 to calculate cases of illness and death.		X	
Population Served	Used in Step 2 to scale up the annual individual infection risks to total cases of infection, and ultimately to total cases of illness and death in the exposed population.			X
Primary Morbidity Factors	Used in Step 2 to estimate the number of illnesses per infection in the exposed population.			X
Secondary Morbidity Factors	Used in Step 2 to estimate the number of additional illnesses resulting from contact with indivdiuals becoming ill through primary consumption of drinking water.		X (for Type B virus)	X (for Type A virus)
Disinfection Failure Illness Factors	Used in Step 2 to estimate an additional number of illnesses due to treatment failure in disinfecting systems added to the primary and secondary illnesses from source.			X
Distribution System Illness Factors	Used in Step 1 to estimate an additional number of illnesses due to distribution systems sources added to the primary and secondary illnesses from source water contamination.			X

It is important to recognize that the two-step procedure for calculating the number of cases of illness and death in the population from exposure to viruses in ground water was carried out separately for the Type A and Type B virus categories (reflecting different occurrence distributions and dose-response relationships), different age groups (reflecting different morbidity and mortality factors), different water system sizes (reflecting different numbers of people served), and different water system types (reflecting different exposure days of consumption per year for community and noncommunity systems). The results of these many separate estimates of risk and cases of illness and death were then aggregated to obtain the overall estimates presented in Exhibits 4-12 (for Type A viruses) and 4-13 (for Type B viruses).

In presenting the results of this two-step procedure for computing the baseline illnesses and deaths as shown in Exhibits 4-12 and 4-13, the best estimate is the mean of the iterations run in the second step. The uncertainty in that estimate is characterized by the 10th percentile and 90th percentile values obtained from those iterations. These imply that, given the uncertainty factors explicitly included in the second step, there is a 10 percent chance that the actual number of cases falls below the 10th percentile value, and a 10 percent chance that it falls above the 90th percentile value.

Illnesses and Deaths in Undisinfected and Disinfected Systems (exclusive of treatment failures)

The GWR model described above calculates annual numbers of illnesses and deaths due to source contamination in undisinfected systems and in disinfected systems (assuming 4-log removal) exclusive of outbreaks due to treatment failure. Exhibit 4–11 summarizes the model calculations, which incorporate the model assumptions regarding drinking water exposure to pathogens from contaminated sources (Section 4.3.1) and health hazards from Type A and Type B viral pathogens (Section 4.3.2).

Exhibit 4–11. Summary of GWR Baseline Risk Calculations for Undisinfected Systems

Health Effect	Calculation	Summary
Infection	Mean Individual Daily Probability of Infection	The model calculates the mean individual daily probability of infection using: the fraction of contaminated wells (virus hit rate); the potentially exposed population; variable distributions of virus concentration in undisinfected drinking water (same as source water concentration for untreated systems) and daily intake; and the rotavirus dose-response rate constants for Type A virus or the echovirus rate constants for Type B. The probability of infection given a dose of one of these pathogens is: $$P(I) = 1-(1+N/\beta)^{-\alpha}$$ where: P(I) = probability of infection, N = numbers of pathogenic viruses ingested, and α and β = pathogen-specific rate constants. The mean and standard deviation of the mean are calculated.
	Mean Annual Probability of Infection	The model calculates the annual probability that an individual in the population category will be infected at least once: $$P(I_{Ann}) = 1-[1-P(I)]^{days}$$ where: $P(I_{Ann})$ = the annual probability of infection, P (I) = the mean daily probability of infection. The cumulative geometric function incorporates the annual number of days of exposure (i.e., 350 days in CWSs, 250 days in NTNC systems, and 15 days in TNC systems).The mean and standard deviation of the mean are calculated for each age group and type and size of ground water system.
Morbidity	Annual Number of Illnesses	The annual number of illnesses is the annual number of infections multiplied by the fraction of infections causing disease (i.e., morbidity rate), calculated for each age group (see Exhibit 4–10) and type of system. This calculation incorporates a factor for secondary spread, as appropriate. The model applies the secondary spread factor by age group as follows: secondary illnesses = (the age-specific number of primary illnesses) × (rate of secondary spread).
Mortality	Annual Number of Deaths	Deaths due to Type A virus in all age groups are calculated by multiplying the annual number of primary and secondary illnesses by the case fatality rate of 7.3 per million cases of illnesses. For Type B virus, deaths in the neonate (< 1 month) population are calculated by multiplying the annual number of primary and secondary infections by 0.92 percent. Deaths in all other age groups are calculated by multiplying the annual numbers of primary and secondary illnesses by the composite case fatality rate of 0.041 percent.

Additional Illnesses and Deaths Resulting from Treatment Failures and Distribution System Contamination

The number of illnesses and deaths resulting from treatment failure and distribution system contamination is calculated using *Waterborne Disease Outbreak Data* (Craun, 1998) and the estimates from the GWR risk assessment of illness in undisinfected ground water systems. Of the viral, bacterial and unknown agent outbreak-related illnesses reported in ground water systems during 1991–1996, 2,924 occurred in populations drinking untreated tap water from nondisinfecting systems, 1,260 occurred in populations drinking from systems experiencing a treatment deficiency, and 944 were in populations drinking water from systems with distribution system contamination.

EPA believes that reported causes of contamination that result in reported outbreaks during this time period reflect the relative proportions of the causes of contamination in public ground water systems since implementation of the Total Coliform Rule in 1989. Therefore, it is estimated that for every baseline waterborne illness in undisinfected CWS, NTNC and TNC ground water systems with source contamination, there is an additional 0.43 illness in a system experiencing source contamination with treatment failure. In addition, it is estimated that for every baseline waterborne illness in undisinfected CWS or NTNC ground water systems, an additional 0.32 illness occurs due to distribution system contamination. No additional illnesses due to distribution system contamination are estimated for TNC systems because TNCs are typically connected directly to the water supply, and therefore, do not have distribution systems.

Results of the Baseline Risk Calculations

Estimated annual numbers of illnesses from ingestion of Type A and Type B viruses in PWS ground water systems are summarized in Exhibits 4–12 and 4–13. These tables present the calculated mean, as well as the 10^{th} and 90^{th} percentile estimates of annual illness and deaths for Type A and Type B viruses from the Monte Carlo simulation. Results of alternate model calculations using all the same assumptions, but with the lower drinking water consumption distribution, are presented in Appendix A.

The total number of baseline annual illnesses calculated using the upper bound intake distribution for Type A viruses (Exhibit 4–12) is about 12 percent higher than the estimate using the lower bound intake distribution. For Type B viruses, the upperbound estimate (Exhibit 4–13) is 21 percent higher than the lower bound estimate.

Exhibit 4–12. Estimates of Baseline Type A Viral Illness and Death[1]

Cause/Source of Contamination	Illnesses per Year		Deaths per Year	
	Mean	10th - 90th Percentiles	Mean	10th - 90th Percentiles
Source contamination in undisinfected GWSs	78,172	77,794 - 78,562	1	1 - 1
Source contamination in GWSs with failed disinfection	33,614	33,452 - 33,781	0	0 - 0
Contamination of distribution systems of GWSs	21,712	21,615 - 21,812	0	0 - 0
Total	**133,498**	**132,879 - 134,133**	**1**	**1 - 1**

[1] Illnesses and deaths per year are rounded to the nearest whole number.

Exhibit 4–13. Estimates of Baseline Type B Viral Illness and Death[1]

Cause/Source of Contamination	Illnesses per Year		Deaths per Year	
	Mean	10th - 90th Percentiles	Mean	10th - 90th Percentiles
Source contamination in undisinfected GWSs	19,642	19,019 - 20,253	8	8 - 8
Source contamination in GWSs with failed disinfection	8,446	8,178 - 8,709	4	3 - 4
Contamination of distribution systems of GWSs	6,069	5,869 - 6,265	3	2 - 3
Total	**34,157**	**33,062 - 35,227**	**14**	**14 - 15**

[1] Illnesses and deaths per year are rounded to the nearest whole number.

Summing the estimates of illness for both types of viruses gives a combined estimate of nearly 168,000 illnesses each year, the majority of which are attributable to the highly infective, but less lethal, Type A viruses. This estimate is about 14 percent higher overall than the total number of illnesses estimated using consumption distributions generated from the lower bound water consumption data. The estimated combined number of deaths per year is 15, the majority of those being due to the more lethal, but less infectious, Type B viruses.

Baseline Illnesses and Deaths in Sensitive Subgroups

Exhibits 4–12 and 4–13 above summarized the total estimated numbers of illnesses and deaths each year from ingestion of virally-contaminated ground water under baseline exposure conditions. The fractions of those illnesses and deaths that are estimated to occur among sensitive subgroups served by ground water systems are presented in Exhibit 4–14. The sensitive subgroups included in this analysis include:

- **Immunocompromised persons** in all age groups: AIDs patients, organ transplant patients, nonhospitalized cancer therapy recipients, and nursing home residents (all of which are assumed to be > 16 years old);

- **Infants and young children** < 5 years old; and

- **Elderly adults** > 65 years old.

Exhibit 4–14. Health Effects in Sensitive Subgroups as a Percent of All Illnesses and Deaths

Virus Type	Heath Effect	Immunocompromised	Infants and Young Children < 5 years old	Elderly Adults > 65 years old	Total Sensitive Subgroups
Type A Virus	Illness	1.6%	18.1%	11.5%	**31.2%**
	Death	1.6%	18.1%	11.5%	**31.2%**
Type B Virus	Illness	1.6%	5.1%	12.8%	**19.5%**
	Death	0.5%	9.4%	12.4%	**22.3%**

These sensitive subgroups comprise about 21 percent of the total exposed population, but account for 31 percent of the Type A illnesses due to ingestion of contaminated ground water. These results reflect the high morbidity rate (0.88) and the potential for secondary spread of Type A viruses in children < 2 years old. Sensitive subgroups also account for >22 percent of the Type B deaths. Although the observed morbidity rate of Type B illness in children < 5 is slightly lower than the morbidity rate in older children (0.5 vs. 0.57), the high mortality rate of Type B viruses among neonates (infants < 1 month old) contributes to a higher proportion of deaths in this subgroup and in sensitive subgroups overall.

<u>Distribution of Annual Individual Risk of Illness</u>

The model results were also analyzed to determine the risk of becoming ill as a result of ingesting contaminated water from a public ground water system. Risk of illness was estimated for a period of one year using daily consumption distributions based on the USDA intake data for all sources, and annual exposure periods as described previously (i.e., 350 days/yr. exposure in CWSs, 250 days/yr. in NTNCs, and 15 days/yr. in TNC systems) (see Section 4.3.1). The results of this analysis are presented in Exhibit 4–15.

Exhibit 4–15. Distribution of Annual Individual Risks of Illness by Type of System

Virus Type	System Type	(Percent of Population with Risk in Range)		Population Total (Millions)
		$< 10^{-4}$	$\geq 10^{-4}$	
Type A	CWS	98.3%	1.7%	88.9
	TNC	95.9%	4.1%	14.9
	NTNC	96.2%	3.8%	5.3
	All Systems	**97.9%**	**2.1%**	**109.1**
Type B	CWS	99.0%	1.0%	88.9
	TNC	98.8%	1.2%	14.9
	NTNC	96.6%	3.4%	5.3
	All Systems	**98.9%**	**1.1%**	**109.1**

The 10^{-4} risk level is commonly used by EPA as a criterion of risk in potable water supplies. The results indicate that 2.1 percent of the exposed population served by public ground water systems is at a 10^{-4} or greater risk of becoming ill with Type A viral illness, and 1.1 percent of the population is at a 10^{-4} or greater risk of becoming ill with Type B illness under baseline exposure conditions.

<u>Risk to a Highly Exposed Individual</u>

The annual risk of illness was also estimated for a highly exposed individual. For this calculation, it is assumed that a typical, highly-exposed individual would ingest drinking water from an undisinfected PWS ground water system having a properly-constructed well. The source water from such a system is assumed to be contaminated with viral pathogens at a concentration of 3.56×10^{-3} viruses/L (the mean concentration of viral pathogens in contaminated, properly-constructed wells). Because the source water is not disinfected, there is no inactivation of viral pathogens in the system. It is also assumed that the daily intake of drinking water is 2.345 L/day, the 90th percentile of the daily consumption distribution for all ages. Annual exposure under this scenario is 350 days/year, the same rate assumed for CWSs.

Using these assumptions for drinking water exposure, the calculated annual probability of Type A viral illness for a highly exposed individual is 0.73 for a child < 2 years old and 0.083 for an individual ≥ 2 years old. For Type B illness, the annual probability of illness is 0.003 for a child < 16 years old and 0.002 for an individual ≥ 16 years old. These results reflect the higher infectivity, morbidity and secondary spread of Type A viruses in children in comparison with the moderately infective Type B viruses.

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5. Benefits Analysis

5.1 Introduction

By reducing public exposure to waterborne viral and bacterial pathogens of concern, the proposed GWR reduces the public's risks of acute illness and death from fecal contamination of drinking water. The health-related benefits of the GWR are largely the result of avoided acute and chronic illnesses and deaths attributable to reduced endemic and outbreak risks. This chapter presents results of analysis of these health-based benefits including the monetized value of the avoided illnesses and deaths estimated for rule options. In addition, this chapter discusses non-monetized health benefits and other non-health benefits of the rule options.

5.2 Structure of the Benefits Analysis

Several recent reviews provide a general discussion of a wide range of possible ground water disinfection benefits and ground water protection benefits (NWRI 1997; NRC 1997; RTI 1997; EPA 1995). These reviews, in combination with information on ground water services in general, serve to frame the benefit categories relevant to the GWR. Two major categories, health benefits and non-health benefits, as well as components within each, are presented in Exhibit 5–1.

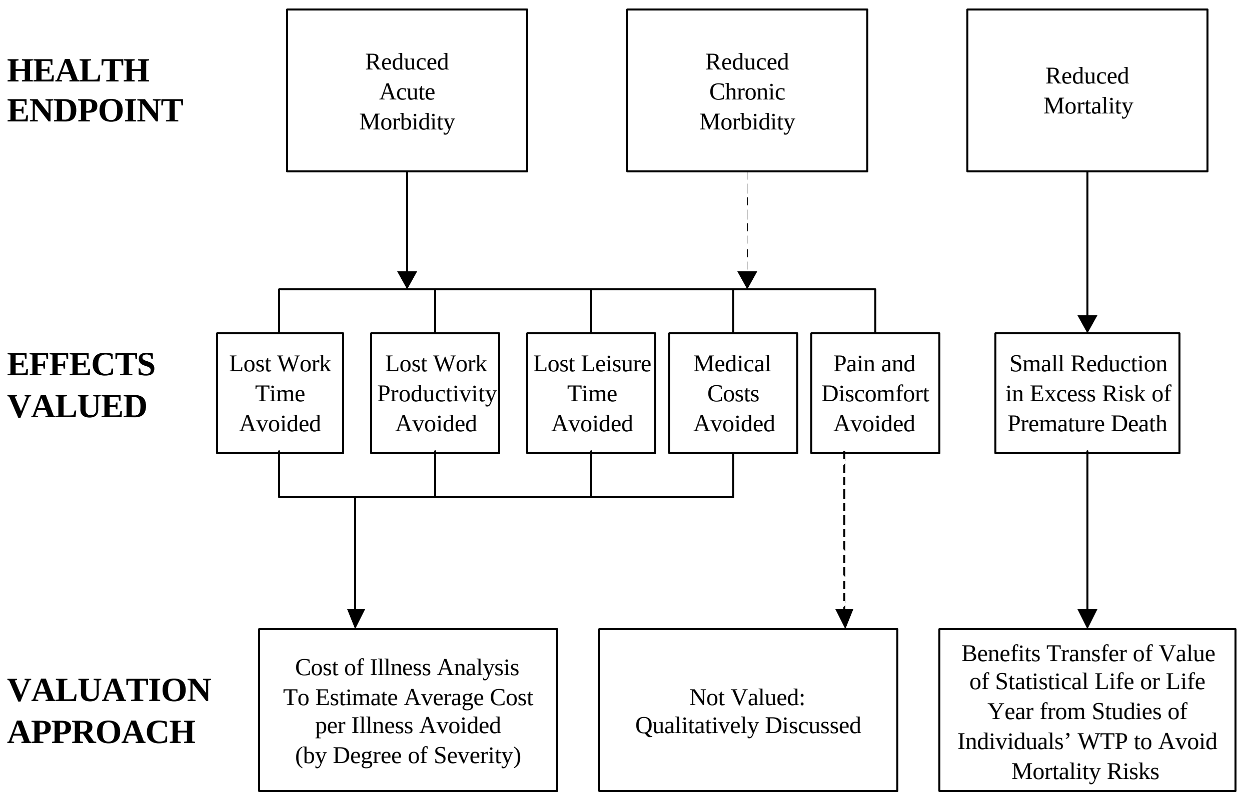
Exhibit 5–1. Overview of GWR Benefits

Health Benefits	
Reduction in acute illness incidence	< viral risk reduction (morbidity and mortality) < bacterial risk reduction (morbidity and mortality)
Reduction in chronic illness incidence	< viral risk reduction (morbidity and mortality) < bacterial risk reduction (morbidity and mortality)
Non-Health Benefits	
Reduced uncertainty	< improved perception of drinking water quality
Avoided costs of averting behavior	< bottled water, point-of-use (POU) devices, etc. < time spent on averting behavior: hauling/boiling water, etc.
Outbreak responses avoided	< avoided costs to affected water systems and local governments (provision of alternative water, issuing warnings and alerts)

5.2.1 Human Health Benefits

The quantified benefits identified in this chapter are predominantly from the economic value of avoided human health risks (i.e, morbidity and mortality). This is predicated on the concept that the health benefits associated with the promulgation of the GWR are equal to the value of the reduced risks of morbidity and mortality from microbial pathogens. Assessing the economic value of the health benefits involves a two-step process, which includes a risk assessment to quantify a health endpoint followed by a benefits valuation procedure. The process is illustrated in Exhibit 5–2.

Exhibit 5-2.
GWR Health Benefits Assessment Framework



- **Risk assessment–**This assessment is used to determine and quantify the health endpoints identified for the GWR as shown in Exhibit 5–2. These endpoints include reductions in both acute and chronic illnesses (i.e., reduced morbidity) and reductions in the number of deaths each year (i.e. reduced mortality). Health endpoints are quantified using a risk assessment to estimate the number of illnesses and deaths each year for both baseline and post-regulatory scenarios. The difference between these estimates is the avoided cases of morbidity or mortality. For this RIA, the risk assessment focuses on <u>acute</u> illnesses and associated deaths caused by <u>viral</u> pathogens ingested in tap water from ground water sources. (Chronic effects and bacterial pathogen infections, while not quantified directly using the risk assessment model, are discussed below.)

The risk assessment forecasting necessarily requires a number of assumptions to be made regarding exposures to viral pathogens in drinking water. These assumptions are presented in Section 4.3, Baseline Risk Assessment Health Effects. Additional assumptions required to assess the health effects of the four regulatory options for the GWR are presented in Section 5.3.1. The results of the risk analysis for each of the four regulatory options (i.e., in terms of illnesses and deaths avoided) are presented in Section 5.3.2.

- **Benefits valuation–**This process applies the appropriate unit values to the results of the risk assessment to estimate the value of the specific illness and clinical endpoint identified in exposed populations using the risk assessment. The assumptions and inputs used to determine the appropriate unit values are discussed in Section 5.3.3. The results of this analysis, the monetized benefits of avoided morbidity and mortality for each GWR option, are presented in section 5.3.4.

The benefits of the reduced exposure to bacteria in drinking water are also discussed in this chapter. The health effects of reduced bacterial infections are not assessed using the risk assessment model. Rather these health benefits are valued by employing a simple ratio assumption in which the monetized benefits estimated for reduced viral infections were increased by an additional 20 percent to account for bacterial infection reduction benefits.

The other potential health benefits associated with the proposed rule are the reduced risks of chronic morbidity and corresponding mortality associated with viral and bacterial contamination. These are not quantified within this RIA. As discussed in Section 5.4.2, the benefit of avoiding these chronic cases may be significant, as affected individuals incur significant costs in medical care and losses in productivity and quality of life in such instances. The reader is reminded not to discount the value associated with reducing chronic viral and bacterial illness simply because they are not quantified in this RIA, as EPA's inability to quantify them due to data limitations does not suggest they are not significant.

5.2.2 Non-Health Benefits Assessment

In addition to the health-based benefits introduced above, there are a number of non-health benefits that also arise from promulgation of the rule. Non-health benefits may result from overall system improvements (e.g., upgrades to distribution systems, increased efficiencies, increased frequency/intensity of process surveillance), from improved risk perception of drinking water quality, or from avoided outbreak response costs. While these costs are not quantified for this RIA, these potential benefits are discussed qualitatively in Section 5.4.3.

5.2.3 Potential Health Risk Associated with Other Contaminants

The Agency is aware that the proposed GWR has the potential to increase health risks in some circumstances; these risks however, can be controlled. The increased risks that may result from this rule stem from the installation of disinfection equipment by systems currently not treating. Risks may stem from either or both of the following problems.

- Start-up Contamination—When disinfection is first introduced into a previously undisinfected system, the disinfectant can react with pipe scale causing increased risk from some contaminants and water quality problems. Contaminants that may be released include lead, copper, and arsenic. It could also lead to a temporary discoloration of the water as the scale is loosened from the pipe. These risks can be reduced by gradually phasing in disinfection to the system, by routine flushing of distribution system mains and by maintaining a proper corrosion control program.

- Disinfection Byproducts—For some ground water systems, using a chlorine-based disinfectant or ozone could result in an increased risk from disinfection byproducts. Risk from disinfecting systems (including an estimate of the ground water systems, which will commence disinfection as a result of the GWR) has already been addressed in the Stage 1 Disinfection Byproducts Rule. Overall, only a small number of ground water systems with high source water organic carbon precursors are expected to have high levels of disinfection byproducts from using chlorine. However, those that do can avoid this problem by choosing an alternative disinfectant or precursor control technology (e.g., chloramination, membranes, or ultraviolet).

5.3 Value of Health Effects With Rule (Acute Impacts)

The only benefit EPA has estimated and monetized for this RIA is acute health effects of viral and bacterial infections. This chapter explains how health effects were estimated (Section 5.3.1), how they were monetized (Section 5.3.3), and presents results for each effort (Sections 5.3.2 and 5.3.4, respectively).

5.3.1 Assumptions for Health Effects Modeling of Regulatory Scenarios

In estimating the health effects of the GWR, EPA performed risk calculations for the four GWR options described in Chapter 3.: Option 1—Sanitary Surveys only; Option 2—Sanitary Surveys with Triggered Monitoring; Option 3—Multi-Barrier Approach; and Option 4 —Across-the-Board-Disinfection. The estimation procedure was two-fold as follows:

- First, using assumptions regarding reductions in viral exposure from source contamination for each regulatory option, the model was used to calculate annual numbers of illnesses and deaths in ground water systems (GWSs).

- Secondly, using CDC ratios applied to the results of the first step and assumptions for each option regarding post-regulatory reductions in rates of disinfection failure and distribution contamination, additional outbreak-related illnesses and deaths were estimated.

To model the reduction in exposure from source contamination that would result from implementation of the four regulatory options, EPA assumed reductions in the number of undisinfected ground water systems/points of entry that are potentially contaminated with viral pathogens under baseline conditions. The reduction varies with expectations regarding the effectiveness of each option in identifying and correcting significant defects at the source. Reductions in treatment failure rate and in distribution system contamination are also addressed for each option. The relevant exposure assumptions for each option and type of system are summarized in Exhibit 5–3 and are discussed in the following sections.

Exhibit 5–3. Estimated Contamination Reductions for GWR Options

Regulatory Option	Estimated Reduction in *Viral Source Contamination of Undisinfected* Ground Water Sources		Estimated Reduction in rate of *Disinfection Failure* for GWSs with viral contamination of the source	Estimated Reduction in *Distribution System Contamination* with Virus of GWSs
	Properly Constructed	Improperly Constructed		
Option 1. Sanitary Survey Only	0%	40–60%	0–26% (CWS) 0–43% (NCWS)[1]	0–25% (NA for TNC)[2]
Option 2. Sanitary Survey and Triggered Monitoring	30–54%	58–82%	77–100%	0–25% (NA for TNC)[2]
Option 3. Multi-Barrier	38–77%	63–91	77–100%	0–25% (NA for TNC)[2]
Option 4. Across-the-Board Disinfection	100%	100%	77–100%	0–25% (NA for TNC)[2]

1 Non-community water systems (NCWS), both transient and non-transient, have an estimated reduced risk of contamination of 0–43%; community water systems (CWS) reduced risk is 0–26%.

2 Reduction of risk in transient non-community (TNC) systems was not considered.

5.3.1.1 Option 1: Sanitary Survey Option

Because EPA would, under this option, require the State (or primacy agent) to conduct periodic sanitary surveys for all ground water systems (i.e., at least every three years for CWSs, and at least every five years for NCWSs), this option is expected to identify significant defects in wells, which could lead to source contamination (e.g., an improperly cased well) in the treatment process (e.g., inadequate disinfectant feed rate) and in the distribution system (e.g., uncovered storage tank). Under this option, systems would be required to correct these significant defects. Based upon data from a recent survey of ground water systems (ASDWA, 1997), EPA estimates that between 11 and 13 percent of systems will correct significant defects as a result of implementation of this option (resulting in the elimination of over 22,000 significant defects). Based on these assumptions, EPA made the following estimates of risk reduction.

- Properly constructed wells—Implementing sanitary surveys alone will result in no significant reductions in source contamination in systems with properly constructed wells.

- Improperly constructed wells—Sanitary survey inspectors will identify significant defects that are apparent from a visual inspection of the well, well construction records, or the surrounding area. Correction of these significant defects will eliminate pathways for viral contamination to reach source waters in 40 to 60 percent of the poorly constructed wells. Defects that are underground or that are not reflected in well construction records will not be detected.

- Disinfection failure— EPA estimates that correction of significant deficiencies in disinfection treatment processes will result in between 0 and 26 percent reduction in treatment failures in community water systems and between a 0 and 43 percent reduction in non-community water systems. Interrupted treatment caused by failed systems or operator error accounts for 26 percent of the reported outbreaks in community ground water systems and 43 percent of the reported outbreaks in non-community systems (Craun, 1999). EPA estimates that correction of significant defects could prevent some or all of the interruptions in disinfection. The estimated range accounts for the uncertainty as to the exact percentage.

- Distribution system contamination— EPA estimates that correction of significant defects in the distribution system identified by sanitary surveys will result in a 0 to 25 percent reduction of fecal contamination of distribution systems in both community and non-transient non-community water systems. Half of the reported ground water system outbreaks caused by distribution system contamination were specifically caused by cross connections or storage tank deficiencies (Craun, 1999). EPA estimates that as many as half of these defects will be found and eliminated as a result of sanitary surveys. The estimated range accounts for the uncertainty as to the exact percentage.

5.3.1.2 Option 2: Sanitary Survey and Triggered Monitoring Option

The sanitary survey and triggered monitoring option combines the sanitary survey and correction of significant defects with triggered monitoring of source water to identify improperly constructed systems for corrective action. Because the sanitary survey component of this option imposes identical requirements to the sanitary survey option, EPA expects the sanitary survey portion of this option to achieve the same reductions in source contamination of poorly constructed wells, of treatment failure, and of distribution systems contamination.

The additional triggered monitoring component of this option will identify systems with fecal contamination of their sources that could not otherwise be identified through a sanitary survey of the system. Under the triggered monitoring requirements, systems are required to sample their source water for the presence of a fecal indicator following the detection of total coliform in their distribution system. EPA estimated the effectiveness of the triggered monitoring requirements in identifying and eliminating source water contamination by evaluating the ability of the triggered monitoring to identify the pathogen contaminated wells. Assumptions made by EPA include the following:

- An estimated 30–54 percent of wells that are contaminated with viral pathogens will be detected through triggered monitoring. EPA made this assumption by using monitoring results of samples taken from wells that were found to contain viral pathogens in the EPA/AWWARF study (Lieberman et al., 1997, 1999). Seven wells in this study were found to contain viral pathogens in at least one of the twelve samples taken over the course of a year. Each of these wells was also tested for the presence of the three fecal indicators (*E. coli*, enterococci bacteria, or male-specific coliphage). Of the 84 samples from these seven virally contaminated wells, 42 (50 percent) tested positive for *E. coli*, 45 (54 percent) tested positive for enterococci, and 25 (30 percent) tested positive for the presence of male-specific coliphage. States are provided flexibility in determining the most appropriate of the three methods, therefore EPA has assumed a range of effectiveness in detecting fecally contaminated wells between the low and high percentages.

- Corrective action will be required for all identified contaminated sources; this will entail eliminating the source of the contamination, finding an alternative source, or installing disinfection.

Based on these assumptions and relevant assumptions from the sanitary survey option, EPA made the following estimates for risk reduction.

- <u>Properly constructed wells</u>—In wells considered to be properly constructed, EPA assumed 30 to 54 percent of the systems with pathogen contamination will be identified through triggered monitoring. As with the sanitary survey option, no source contamination reduction is expected in the properly constructed wells due to sanitary surveys.

- <u>Improperly constructed wells</u>—In improperly constructed systems, EPA assumed reduction of source water contamination by 58 to 82 percent of the baseline. This is based on the Agency's assumption that 40 to 60 percent of the contaminated poorly constructed wells will be identified through sanitary surveys, and an additional 30 to 54 percent of the remaining undetected contaminated wells will be identified through triggered monitoring.

- <u>Disinfection failure</u>—EPA estimates a reduction of 77 to 100 percent of incidences in which systems with pathogen contaminated source water inadequately disinfect or remove the pathogens. The Agency made this assumption based on the option's requirement both that systems that disinfect must achieve a 4 log removal or inactivation of pathogenic viruses and that systems ensure compliance with this inactivation level by routinely monitoring the disinfectant residual. EPA estimates that this provision will eliminate one half to all of the interruptions in treatment and will eliminate three fourths to all of the instances in which systems do not adequately disinfect their source water.

- <u>Distribution system contamination</u>—A 0 to 25 percent reduction of fecal contamination of distribution systems and the associated illnesses/deaths in community and non-transient non-community water systems (same as aforementioned sanitary survey option).

5.3.1.3 Option 3: Multi-Barrier Option

The Multi-Barrier option builds on the sanitary survey and the triggered monitoring components described above by adding routine source water monitoring to provide an effective means of identifying wells in the most sensitive hydrogeologic conditions. If the States or primacy agents determine a system's source to be hydrogeologically sensitive to microbial contamination, the system is required to perform routine source water monitoring. Routine monitoring requires the collection of source water samples monthly (at least for the first year of monitoring) to ensure that periodic fecal contamination has a greater likelihood of being detected than it would with a single sample. Specific assumptions for modeling this option include the following.

- Fifteen percent of the ground water sources will be found to be sensitive and, therefore, subject to routine source water monitoring.

- Between 20 and 50 percent of the wells with pathogen contamination are located in conditions that States will determine to be sensitive, and would therefore be subject to routine monitoring.

- Between 71 and 100 percent of pathogen contaminated ground water sources that are subject to routine source water monitoring will be found to be fecally contaminated and required to take corrective action. EPA estimated the effectiveness of routine monitoring in detecting viral pathogen contamination based on EPA/AWWARF sampling data for seven wells that were found to contain viable pathogenic viruses. EPA reviewed the test results for the three fecal indicators from which the States will choose for routine source water monitoring. Of the seven wells that were virally contaminated over the course of the year, five (71 percent) tested positive at least once for the presence of *E. coli*, all seven (100 percent) tested positive for the presence of enterococci and five (71 percent) tested positive for the presence of male specific coliphage. For the purposes of this analysis, EPA assumes that States will select *E. coli* as the fecal indicator for routine monitoring; this gave EPA the lower bound of 71 percent.

- Triggered monitoring will identify 30 to 54 percent of the source-contaminated wells as described in the sanitary survey and triggered monitoring option above.

Based on these assumptions and relevant assumptions from Options 1 and 2 above, EPA made the following estimates of risk reduction.

- <u>Properly constructed wells</u>—Between 38 and 77 percent of the properly constructed wells with pathogen contamination will be identified as a result of this rule option.

- <u>Improperly constructed wells</u>—Between 63 and 91 percent of the improperly constructed wells with pathogen contamination will be identified as a result of this rule option.

- <u>Disinfection failure</u>—As with the sanitary survey and triggered monitoring option, this option requires systems that practice disinfection to achieve a 4 log removal or inactivation of virus. It also requires systems to ensure compliance with this inactivation level by routinely monitoring the disinfectant residual. EPA anticipates that these requirements will significantly reduce the incidences in which systems with viral pathogen-contaminated source water inadequately disinfect or remove the pathogens. EPA estimated a reduction of these incidences by 77 to 100 percent (see Option 2 above).

- Distribution system contamination—A 0 to 25 percent reduction of fecal contamination of distribution systems and the associated illnesses/deaths in community and non-transient non-community water systems (see Option 1 above).

5.3.1.4 Option 4: Across-the-Board Disinfection Option

The across-the-board disinfection option will reduce viral pathogens in ground water system through three mechanisms.

- Properly and improperly constructed wells—First, because all systems would be required to install disinfection treatment, EPA assumes that 99.99 percent of the pathogenic viruses in source water would be inactivated (4 log removal) before they reach the customer's tap. Therefore, there would be a complete elimination of source contaminated, undisinfected systems.

- Disinfection failure—Second, systems would be required to monitor the disinfectant residual concentration. This will insure a consistent level of disinfection treatment, which is adequate to remove 99.99 percent of the pathogenic viruses. The Agency assumes the same level of reductions in failure of disinfection treatment systems equivalent with the previous two options (see Option 2 and 3 above), 77 to 100 percent.

- Distribution system contamination—Third, systems would be required to correct any significant deficiencies identified in sanitary surveys. This would result in reductions in contamination of distribution systems that are similar to the two previous options (see Option 2 above), i.e., 0 to 25 percent reductions.

5.3.2 Results of Risk Calculations

The results of the risk assessment for the baseline and the four regulatory scenarios are presented in Exhibits 5–4 and 5–5. The first table presents the mean numbers of illnesses and deaths estimated annually under each scenario. Because there are uncertainties in the values assigned to some model parameters (e.g, the uncertainties in the percent reductions of source contamination, disinfection failure, and distribution contamination anticipated with each option [see Exhibit 5–3]), the risk assessment model generates a distribution of estimates of annual illnesses and deaths. The calculated mean as well as the 10th and 90th percentile estimates of the number of annual illnesses and deaths were obtained from the distribution of results for each type of virus for both the baseline conditions and for each regulatory option. These outputs are summarized in Exhibit 5–4. Exhibit 5–5 presents the calculated incremental reductions in illnesses and deaths from the current baseline estimates (see chapter 4). The results presented below are based upon the USDA estimate of daily direct and indirect drinking water consumption having a mean of 1.24 L/day. Detailed results may be reviewed in Appendix A along with the results for the water consumption distribution with a mean of 0.927 L/day.

Exhibit 5–4. Remaining Viral Illnesses/Deaths for Regulatory Scenarios[1]

Scenario	Virus Type	Illnesses per Year: Mean	Illnesses per Year: 10th - 90th Percentiles	Deaths Per Year: Mean	Deaths Per Year: 10th - 90th Percentiles
Baseline	Type A	133,498	132,879 - 134,133	1	1 -1
	Type B	34,157	33,062 - 35,227	14	14 - 15
	Total	**167,655**	**165,941 - 169,360**	**15**	**15 - 16**
Option 1: Sanitary Survey Only	Type A	122,941	118,601 - 127,194	1	1 -1
	Type B	31,143	29,843 - 32,440	13	13 - 14
	Total	**154,084**	**148,444 - 159,634**	**14**	**14 - 15**
Option 2: Sanitary Survey and Triggered Monitoring	Type A	67,200	59,621 - 74,630	0	0 - 1
	Type B	17,115	15,154 - 19,010	7	6 - 8
	Total	**84,315**	**74,775 - 93,640**	**7**	**6 - 9**
Option 3: Multi-Barrier Option	Type A	56,953	45,971 - 67,492	0	0
	Type B	14,462	11,830 - 17,135	6	5 - 7
	Total	**71,415**	**57,801 - 84,627**	**6**	**5 - 7**
Option 4: Across the Board Disinfection and Sanitary Survey	Type A	28,467	21,575 - 35, 536	0	0
	Type B	7,111	5,631 - 8,570	3	2 - 4
	Total	**35,578**	27,206 - 44,106	**3**	2 - 4

1 Using Age-Based Consumption Distributions for All Sources, Consumers Only

Exhibit 5–5. Reduction[1] in Illnesses/Deaths for Regulatory Scenarios

Scenario	Net Reduction in Viral Illnesses per Year (Mean)	Net Reduction in Viral Deaths Per Year (Mean)
Option 1: Sanitary Survey Only	13,596	1
Option 2: Sanitary Survey and Triggered Monitoring	83,502	8
Option 3: Multi- Barrier Approach	96,305	9
Option 4: Across-the-Board Disinfection	132,129	12

1 Reductions for each scenario are measured as incremental difference from baseline values; value may not match differences calculated from Exhibit 5-4 due to rounding.

Option 1: Sanitary Survey Alternative–This option is estimated to reduce the number of waterborne viral illnesses in public GWSs by over 13,600 illnesses each year in comparison with the baseline (an 8 percent reduction in illnesses). The sanitary survey option is also estimated to reduce by at least one per year the number of deaths that result from waterborne illness.

Option 2: Sanitary Survey and Triggered Monitoring Alternative–This option is estimated to reduce the number of waterborne viral illnesses by approximately 83,500 illnesses each year in comparison with the baseline (about a 50 percent reduction in illnesses). This option is also estimated to reduce the number of deaths that result from waterborne illness by about eight each year, a reduction of over half the baseline rate.

The difference between the health effects estimates for this option and those for Option 1 is a net reduction of nearly 70,000 illnesses and seven deaths. This is the expected reduction that would result from actions taken in response to the results of triggered monitoring and including disinfection monitoring requirements.

Option 3: Multi-Barrier Option–The Multi-Barrier option is estimated to reduce the number of waterborne viral illnesses by just over 96,300 illnesses each year from the current baseline estimate (a 57 percent reduction in total illnesses). The Multi-Barrier option is also estimated to reduce the number of deaths that result from waterborne illness by about nine each year.

The difference between the estimates for this option and those for Option 2 is a net estimated reduction of nearly 13,000 illnesses and one death; this is the expected reduction that would result from source water monitoring and resulting corrective actions.

Option 4: Across–the–Board Disinfection Alternative–This alternative is estimated to reduce the number of waterborne viral illnesses by approximately 132,000 illnesses each year (a 79 percent reduction in illnesses). Across-the-board disinfection is also estimated to reduce the number of deaths which result from waterborne illness by about 12 each year.

The difference between the estimates for this option and those for Option 3 is an estimated net reduction of approximately 35,000 illnesses and three deaths; this is the expected reduction that would result from 100 percent of public GWSs using disinfection. Although all GWSs would treat ground water under this option, a few, less frequent treatment failure and distribution system contamination events each year would continue to cause a residual number of illnesses and deaths in the population served by ground water systems.

5.3.3 Assumptions for Monetization of Health Benefits (Acute Illnesses)

Having estimated reduced illness and mortality from the GWR's four scenarios, EPA then monetized the health benefits. Using estimates of the number of avoided illnesses and deaths expected to result from promulgation of any of the options EPA applied unit estimates of "cost-of-illness" and "value of a statistical life," respectively, to estimate the benefit of the avoided illnesses and deaths (see Exhibit 5–6). The unit costs and the bacterial infection ratio are explained in the following sections, after which the monetized results for each of the four regulatory options are presented.

Exhibit 5–6. Monetization of Health Effects

Illnesses Avoided from Reduction in Viral Infection *(From Risk Model)*	**Deaths Avoided from Reduction in Viral Infection** *(From Risk Model)*
–	–
Unit "Cost-of-Illness" *(Introduced in Section 5.3.3.1)*	**Unit "Value of Statistical Life"** *(Introduced in Section 5.3.3.2)*
–	–
Bacterial Infection Ratio *(Introduced in Section 5.3.3.3)*	**Bacterial Infection Ratio** *(Introduced in Section 5.3.3.3)*
–	–

Total Monetized Value of Health Benefits
(Results presented in Section 5.3.4)

5.3.3.1 Unit Cost-of-Illness

> An appropriate value for a reduction in risk of an illness experienced by all exposed individuals in a population is the sum of these individuals' WTP to avoid the illness before it occurs. Conversely, one could use an "ex post" or damage function approach to value reduction in risk. The damage function approach multiplies the mean WTP to avoid a case of the illness by the expected number of cases avoided.) Estimates of WTP for specific risk reductions or estimates of WTP to avoid a case of certain illnesses are, however, often unavailable. This is true with regard to the waterborne illnesses that may be avoided as a result of this proposed rule. Cost-of-illness was, therefore, used as a proxy for WTP.

EPA chose to use cost-of-illness (COI) as the best available means of valuing illnesses avoided by application of the GWR. In theory, the cost of an illness is the present discounted value of the lifetime stream of costs that result from the illness. The COI estimates described in this section also consider the associated direct and indirect costs incurred due to illness. Direct costs describe the cost burden of medical care to affected individuals. Indirect costs describe the opportunity costs associated with illness, such as productivity and leisure losses. Note, however, that COI underestimates total willingness-to-pay (WTP) because it does not address the pain and suffering associated with the illness.

Apogee/Hagler Bailly (1998) describes the general method used to calculate COI, and provides the derivations of direct and indirect costs for all of the COI values used in this analysis. The discussion below explains why the values differ across three factors—victim age, illness severity, and immune status.

Cost-of-illness: Factors Affecting Estimates

For the viruses of concern under the GWR, a review of the medical and epidemiological literature revealed that the nature and extent of the acute health effects varied by severity and by population subgroup for each virus. Due to data limitations in the risk assessment, these viruses of concern were categorized as Type A (represented by Rotavirus) and Type B (represented by Echovirus). The former describes highly infective pathogens with less expensive costs of illness (such as rotavirus), while the latter describes less infective pathogens (such as echovirus) that are associated with more costly illnesses.

Victim Age: In general, the annual health benefits for the GWR were calculated by multiplying the annual number of acute illnesses avoided by the COI per case. Age categories were created based on the different clinical manifestations of disease or where differences in indirect costs of illness could be identified. For Type A pathogens, the age groups involved were: less than two, two to five, five to 16, and over 16. Because of the nature of illnesses associated with Type B enteroviruses (e.g., sepsis-like illness in neonates), the under-five-year-old age groups for Type B pathogens had to be further segregated into the following categories: less than one month, one month to one year, and one to five years.

Severity of Illness: The COIs for the enteroviruses varied not only by age, but also by illness severity. Since unit COIs vary widely between severity categories, they had to be segregated into three severity classifications of illness prior to valuation. These severity classes (i.e., mild, moderate, and severe) were used only for Type B viruses (See Exhibit 5–7).

Exhibit 5–7. Classification for Clinical Severity in Type B (Echovirus) Illnesses

Severity of Type B Viral Infection	Conditions Affecting all Ages for each Severity Level	Age Specific Clinical Severity	
		Neonates (<1 month)	Children (1–5 years)
Mild	non-specific febrile illness, respiratory illness, gastrointestinal illness	exanthum (skin eruptions)	herpangina (throat lesions), pleurodynia (affection of thoracic tendons/muscles)
Moderate	aseptic meningitis	encephalitis	(none)
Severe	myopericarditis	sepsis-like illness (with hepatitis)	(none)
Source: Dirckx (1997)			

The aggregate number of avoided illnesses were divided into three categories, each describing a different illness severity level that is associated with different direct and indirect cost components. Severity was assigned using weights derived from two studies (Morens 1978; Melnick, 1996) in which the distributions of various clinical symptoms were described among a group of affected individuals (see Exhibit 5–8).

Exhibit 5–8. Weighting for Clinical Severity in Type B (Echovirus) Illnesses

Age Group	Mild	Moderate	Severe
Neonates (<1 month)	26%	50%	24%
New borns (1 month–1year)	52%	46%	2%
Children (1–5 years)	52%	46%	2%
Others (>5years)	52%	46%	2%

(%) indicates the portion/weighting of the total number of illnesses assigned between the severity categories of each age category.

<u>Victim Immune Status:</u> Certain segments of the population are more likely to develop more severe symptoms due to their compromised immune systems. Therefore, for each immunocompromised individual who becomes ill, a higher unit COI estimate is assumed. Unit COI estimates for Type A viruses were specifically developed for immunocompromised individuals also using rotavirus. Due to data limitations concerning the effect of rotavirus infection on the immunocompromised population, these unit COI estimates were derived using a modified version of the COI framework. Most of the same inputs were used as for healthy individuals, except that the percentage of ill individuals seeking inpatient and outpatient care was increased and assumed to be 100 percent. Due to similar data limitations, Type B viral illnesses among immunocompromised subpopulations were assigned the “severe enterovirus” COI for the appropriate age categories.

<u>Cost-of-Illness: Estimates for Unit Costs</u>

Unit COIs were developed for each virus of concern by age, level of severity, and health status; these are presented in the Exhibits 5–9 and 5–10. The unit costs are in May 1999 dollars, direct costs having been updated using the “medical care services” expenditure category of the Consumer Price Index among all urban consumers and indirect costs using the CPI-U for all items (BLS 1999).

Exhibit 5–9. Type A (Rotavirus) Unit Cost-of-Illness Estimates by Victim Age and Health Status

	Cost-of-Illness (Direct & Indirect)[1]	
Victim Age	Healthy	Immuncompromised
Age < 2	$921	$4,666
2 # Age < 5	$507	$4,666
5 # Age < 16	$212	$4,637
Age $ 16	$349	$4,912

[1]Costs do not include pain and suffering.
Source: Apogee/Hagler Bailly (1998)

As indicated in Exhibit 5–9, the Type A viral infections have cost impacts to immunocompromised populations that are from five to 20 times more severe compared to healthy populations. Also of note, impacts to healthy infants, including in this case neonates, new borns, and one to two year olds, have a cost impact of two to four times more than other age groups.

Exhibit 5–10. Type B (Enterovirus) Unit Cost-of-Illness Estimates by Victim Age and Illness Severity

Victim Age	Cost-of-Illness (Direct & Indirect)[1]		
	Mild	Moderate	Severe
Age < 1 mo.	$ 347	$11,283	$19,711
1 mo. # Age < 5	$ 311	$ 8,856	$ 8,742
5 # Age < 16	$ 158	$ 7,283	$ 8,742
Age $ 16	$ 285	$ 7,626	$ 9,703

[1]Costs do not include pain and suffering.
Source: Apogee/Hagler Bailly (1998).

Review of the Type B viral cost-of-illness, as presented in Exhibit 5–10, indicates even more pronounced impacts on one select subpopulation, that of neonates. In the case of severe cases of enteroviral infection, costs of illness to treat neonates is more than double that of all other age groups.

5.3.3.2 Unit Value of a Statistical Life

EPA chose to use "value of a statistical life" as the best available means of valuing deaths avoided by application of the GWR. Conceptually, the value of mortality is measured as an individual's WTP to reduce mortality risk, aggregated across all affected individuals. It also reflects the value of morbidity that precedes death. The dollar amount a person would be willing to pay for mortality risk reduction does not indicate the value that he places on his life. Rather, it reflects an individual's value of small reductions in the probability of death distributed over a large population, referred to as the "value of a statistical life" (VSL).

Determining VSL

To better understand VSL, consider a drinking water regulation that reduces, for a population of 10,000, the mortality rate associated with contamination by microorganisms from ten out of 10,000 to five out of 10,000. This regulation, therefore, would save, on average, five "statistical lives" (so-called because there is no way to predict which members of the total population would be saved by the regulation). If each of the 10,000 individuals in the "population" is willing to pay $500 for this reduction in the probability of death, then the "willingness to pay" for the population as a whole is $5 million. Since an average of five lives are saved by implementing the regulation, the VSL per life saved equals $1 million.

Valuation of avoided mortalities due to the GWR involves identifying VSL estimates that represent similar types of mortality risks as those associated with waterborne risks and possibly adjusting VSL estimates to better fit the waterborne risk context. For purposes of this RIA, EPA reviewed several studies. One, a 1997 EPA study, was based on a best-fit distribution of 26 "policy-relevant value-of-life studies." The VSL in 1990 dollars was characterized as a Weibull distribution with a mean of $4.8 million per life and a standard deviation of $3.24 million; these results were updated to 1999 dollars. For this RIA, the mortality benefits of the GWR were calculated by multiplying the number of avoided deaths by the updated VSL, which was estimated at $6.3 million.

5.3.3.3 Reduction in Bacterial-Related Illnesses

In addition to the expected benefits from reducing viral infections, the GWR is expected to provide benefits related to the potential reduction of illnesses and deaths due to waterborne bacteria. The avoided cost-of-illnesses may be as substantial as those seen for viruses.

Impacts of Bacterial Outbreaks

Serious bacterial health effects are common in outbreak situations and pose significant burdens on community health and non-health resources. For example, in a 1993 *Salmonella typhimurium* waterborne outbreak in Gideon, MO, the health and non-health effects were widespread. Approximately 44 percent of individuals were ill, and of those surveyed, 29 percent sought medical attention and four percent were hospitalized (Angulo et al., 1997). Absenteeism from school increased by 250 percent, and the sales of anti-diarrheal medicines increased

Bacterial Infections: Background

The extent to which a bacterial illness develops depends on various pathogenic characteristics of the organism, including the strain and virulence of the organism, and on various host characteristics such as age or immune status. Such factors help to explain, for example, why *Campylobacter* cases are among the most common, yet cause the least number of hospitalizations in outbreak situations. Understanding the nature and severity of the illness helps to frame the economic impact of waterborne outbreaks, illnesses and deaths caused by bacteria.

Craun (1999) conducted a study of microbial waterborne outbreaks reported to the Center for Disease Control for ground water systems in the United States during the 26-year period from 1971–1996. Of the outbreak illnesses in ground water systems caused by bacteria observed during the 1971–1996 period, the majority (53 percent) were due to *Shigella*, followed by *Salmonella* (23 percent), *Campylobacter* (11 percent), and *Escherichia coli* O6:H16 (10 percent). Highlighted below in Exhibit 5–11 are the typical clinical characteristics as well as any associated complications and the annual incidence of these four bacteria.

Most frequently, these bacteria cause acute gastroenteritis, although some have been shown to cause chronic conditions. For example, *E. coli* O157:H7 infection is the leading cause of hemolytic uremic syndrome (HUS), the most common cause of acute kidney failure in children, *Salmonella* infections may lead to reactive arthritis, and *Campylobacter* infections can lead to Guillain-Barre syndrome, one of the most common causes of paralysis.

Impacts on Sensitive Populations

Young children are more likely to develop HUS from *E. coli* O157:H7 hemorrhagic colitis (approximately eight percent of children). When diagnosed, they would consistently require blood transfusions or kidney dialysis during their prolonged hospital stays.

Similar requirements exist for AIDS patients who tend to suffer more severe salmonellosis not only about twenty times more often than the general population, but also suffer more recurrent episodes (Altekruse et al., 1997). This indicates that unlike viral and other bacterial infections, rates of salmonellosis are reportedly higher in sensitive populations than in the general population, and would therefore be associated with higher costs.

Exhibit 5–11. Summary of Clinical Characteristics of Selected Bacterial Waterborne Pathogens

Organism	***Campylobacter* spp.**	***Escherichia coli***	***Salmonella* spp.**	***Shigella* spp.**
Common types	*C. jejuni*, *C. fetus*	O157:H7	*S. typhi, S. paratyphi, S. typhimurium, S. enteritidis*	*S. sonnei, S. flexneri, S. boydii, S. dysenteriae*
Acute Disease	gastroenteritis	hemorrhagic colitis	gastroenteritis, typhoid fever	bacillary dysentery
watery diarrhea	F	Ž	Ž	Ž
bloody diarrhea	Ž	Ž	Ž	Ž
vomiting	™	™	™	™
fever	™	F	Ž	Ž
Illness Duration	7–10 days	5–10 days	2–7 days	4–7 days
Treatment	self-limiting antibiotics in severe cases	oral rehydration; avoid anti-diarrheal agents; antibiotics not recommended	self-limiting; oral rehydration; antibiotics not recommended	self-limiting; oral rehydration or antibiotics in severe cases
Annual Cases of Illness from All Exposure Pathways	2 to 4 million	10,000–20,000	40,000–50,000	25,000–30,000
Complications	< relapse in 20% of cases < 0.1 case-fatality < arthritis, hemolytic uremic syndrome (HUS), meningitis, recurrent colitis, Guillain-Barre syndrome	< up to 50% mortality seen in the elderly, 3–5% in HUS patients < HUS, renal failure, coma	< 10% fatality in typhoid fever vs. 1% in other cases < reactive arthritis, Reiter's syndrome	< 10–15% fatality < Reiter's disease, reactive arthritis, HUS

Ž = typical feature ™ = common finding F = occasionally reported

Source: Rivera-Matos (1996); Fauci (1998); NFID (1996); US FDA (1998)

Estimates for Unit Costs of Illness: Bacterial Infections

The clinical profiles of the bacteria highlighted above suggest that unit COI estimates for bacterial illnesses in the general population would primarily be driven by the indirect cost component, as few direct medical costs are associated with the favorable prognoses of acute bacterial illnesses described. Medical attention is usually not required for simple oral rehydration treatment, and antibiotics are usually not recommended due in part to the emerging drug-resistant nature of many bacterial strains. Given the self-limiting nature of bacterial disease, the direct cost component of a single case is expected to be relatively low. In contrast, the indirect cost component for a typical case is high due to the number of caretaker and work loss days the victim accumulates until the symptoms subside.

In the relatively few cases in which symptoms are severe, however, the direct costs will be higher due to the medical attention and the specific medical treatment (e.g., antibiotics, dialysis, colectomy, hospital costs) sought by victims suffering from illnesses lasting over a week, or from complications that develop into chronic conditions. For example, because of such costs associated with the bloody nature of hemorrhagic colitis and the likelihood of HUS complications as a result of *E. coli* O157:H7 illness (about 2 to 7 percent of infections lead to this complication), the base unit COI estimate for *E. coli* O157:H7 is likely to be higher than that of *Campylobacter*, *Salmonella*, or *Shigella*, mainly as a result of the higher percentage of victims that would seek medical attention and treatment. Similarly, the indirect costs would be higher in severe cases as a result of the prolonged duration of illnesses.

These bacterial profiles provide a summary of the clinical nature of illness, as well as of the likely treatment course for an affected individual. This information was useful in defining the potential magnitude of a case of bacterial illness. However, due to data limitations in both the risk assessment and the COI estimates, a simplified assumption was used to monetize these health benefits from avoided bacterial illnesses under the GWR.

In the aforementioned study of microbial waterborne outbreaks from 1971–1996 (Craun, 1999), outbreaks caused by bacterial agents caused 12,860 reported illnesses during this period, compared to 69,572 illnesses which were attributed to viral or unknown etiologic agents. Assuming that all illnesses classified as unknown etiologies are viral in nature, EPA estimates the ratio between waterborne bacterial illness and viral illness in ground water systems to be 0.2. EPA therefore assumed, for this analysis, that the additional health benefits associated with avoided bacterial illnesses are proportionally equal to 20 percent of the benefits due to reduced viral risk.

5.3.4 Results of Monetization of Health Benefits (Acute Illnesses)

The results of the monetization of health benefits for each of the four regulatory scenarios are presented in the following exhibit. Following that summary are four tables that present a comparison of the distribution of acute health benefits across the four regulatory options. The distribution of benefits are presented by pathogen type, by the health status of the consumer, by the size of the system, and by the type of system. More detailed results (e.g., including percentiles, breakouts among pathogens, and health effects types) may be reviewed in Appendix B.

As shown in Exhibit 5–12, total benefits for the three risk-based regulatory scenarios range from $32.5 million for Option 1, sanitary survey alone, to $205.0 million for Option 3, the Multi-Barrier approach. The fourth option, in which all GWSs are subject to disinfection, results in benefits of $283.1 million. The largest increase in benefits is between Options 1 and Option 2 with a total difference of $145.4 million. Option 2 and 3 differ by just over $27 million, and Options 3 and 4 differ by just under $78 million.

Exhibit 5–12. Health Benefits for Regulatory Scenarios ($Millions)

GWR Regulatory Options	Mean Benefits (10th to 90th percentile)		
	Morbidity	Mortality	Total
Option 1: Sanitary Survey Only	$21.9 ($6.8 to $37.9)	$10.6 ($2.0 to $19.7)	$32.5 ($8.8 to $57.6)
Option 2: Sanitary Survey and Triggered Monitoring	$120.4 ($100.6 to $140.4)	$57.5 ($46.8 to $68.2)	$177.9 ($147 to $208.6)
Option 3: Multi-Barrier Approach	$138.8 ($114.7 to $163.2)	$66.2 ($53.8 to $78.7)	$205.0 ($168.5 to $241.9)
Option 4: Across-the-Board Disinfection	$192.0 ($173.7 to $210.2)	$91.1 ($81.3 to $100.9)	$283.1 ($255.1 to $311.1)

In all cases the majority of the total benefits are from morbidity benefits. For all four options, the proportion of the benefits that is attributable to reduced mortality is approximately one-third of the total benefit.

Exhibit 5–13 presents the breakout of total benefits among the control of the three types of pathogens, Type A viral, Type B viral, and bacterial infections. The benefits received from controlling Type B infections make up the majority of the total benefits, as may be expected given the severity of the health impacts from this agent.

Exhibit 5–13. Distribution of Mean Total Benefits: By Pathogen Type

Option/Regulatory Scenario	Percent of Total, by Pathogen			Mean Total Benefits ($Millions)
	Type A	Type B	Bacterial	
Option 1: Sanitary Survey Only	19%	64%	17%	$32.5
Option 2: Sanitary Survey and Triggered Monitoring	20%	63%	17%	$177.9
Option 3: Multi-Barrier Approach	20%	63%	17%	$205.0
Option 4: Across-the-Board Disinfection	20%	63%	17%	$283.1

Exhibit 5–14 presents the breakout of total benefits between healthy population and the immunocompromised populations. The immunocompromised populations make up approximately 5 percent of the total benefits for all options.

Exhibit 5–14. Distribution of Mean Total Benefits: By Health Status

Option/Regulatory Scenario	Percent of Total, by Subpopulations		Mean Total Benefits ($Millions)
	Healthy	Immunocompromised	
Option 1: Sanitary Survey Only	95%	5%	$32.5
Option 2: Sanitary Survey and Triggered Monitoring	95%	5%	$177.9
Option 3: Multi-Barrier Approach	95%	5%	$205.0
Option 4: Across-the-Board Disinfection	95%	5%	$283.1

Exhibit 5–15 presents the breakout of total benefits among the eight sizes of systems, as defined by number of individuals served by each system. The benefits accrued are roughly proportional to the population served, although for all options, the three smaller categories tend to receive a somewhat lesser portion of the benefits (i.e., given that 12.5 percent of benefits to each size category would be proportionally even) than four of the five categories representing larger populations systems.

Exhibit 5–15. Distribution of Mean Total Benefits (Viral Only): By System Size

Option/Regulatory Scenario	Percent of Total, By System Size								Mean Total Benefits ($Millions)
	<100	100–500	500–1,000	1K to 3.3K	3.3K to 10K	10K to 50K	50K to 100K	100K to 1M	
Option 1: Sanitary Survey Only	3%	9%	7%	15%	18%	12%	18%	16%	$27.1
Option 2: Sanitary Survey and Triggered Monitoring	4%	10%	8%	15%	18%	11%	18%	16%	$148.2
Option 3: Multi-Barrier Approach	4%	10%	8%	15%	18%	11%	18%	16%	$170.8
Option 4: Across-the-Board Disinfection	4%	10%	8%	15%	18%	11%	18%	16%	$235.9

Exhibit 5–16 presents the breakout of total benefits among the three types of systems (i.e., community versus non-community, and of the latter, transient versus non-transient). The benefits accrue in the majority to the community water systems and least of all to the non-community, non-transient systems.

Exhibit 5–16. Distribution of Mean Total Benefits: By System Type

Option/Regulatory Scenario	Percent of total, by System Type CWS	NTNC	TNC	Mean Total Benefits ($Millions)
Option 1: Sanitary Survey Only	86%	12%	1%	$32.5
Option 2: Sanitary Survey and Triggered Monitoring	82%	13%	5%	$177.9
Option 3: Multi-Barrier Approach	82%	13%	5%	$205.0
Option 4: Across-the-Board Disinfection	82%	13%	5%	$283.1

5.4 Other Benefits (Unquantified)

EPA recognizes that, in addition to the benefits associated with reductions in acute illness and death from viral and bacterial infection, the GWR will provide other benefits. As illustrated in Exhibit 5–1, total benefits also include chronic heath benefits as well as non-health benefits. EPA was not able to monetize either of these. The benefits gained, however, are not inconsequential, merely unable to be assigned a dollar value. The following discussions are presented to provide the reader with some understanding of the potential magnitude of these benefits.

5.4.1 Reduced Pain and Suffering

As mentioned earlier in this chapter, the true value of reducing acute morbidity is an individual's willingness-to-pay (WTP) to avoid a case of illness. Like the cost-of-illness estimates used in this RIA, WTP estimates include the direct medical costs and indirect productivity losses associated with an illness. However, WTP estimates also include some costs that the cost-of-illness approach is unable to capture; including the value of avoiding the pain and suffering associated with acute microbial illness. Cost-of-illness estimates do not include the value of reduced pain and suffering because the disutility of illness is not associated with a market cost. Since pain and suffering is not associated with a market cost, placing a value on it is not possible without resorting to primary survey based research, such as a contingent valuation study.

When considering the self-limiting nature of viral and bacterial illness, especially in healthy adults, it is reasonable to assume that the value of reducing the pain and suffering associated with acute microbial illness is a significant portion of the total WTP to avoid the illness. Therefore, the agency recognizes that this analysis may significantly underestimate the true value of reduced acute morbidity resulting from the proposed GWR.

5.4.2 Reduced Chronic Illness

While chronic illnesses were not included in the monetized benefits summarized in Section 5.3, a review of related health impacts reveals that the potential benefits from avoiding these chronic impacts may in fact be substantial. While this RIA does not quantify in dollar terms the benefit of avoiding chronic illness and deaths, this section discusses the potential benefits qualitatively and illustrates the significance of these secondary benefits.

Although a review of the medical and epidemiological literature identified several potential chronic diseases resulting from illnesses caused by enteroviruses (e.g., heart disease, diabetes, post-viral fatigue syndrome, and pancreatitis), the strongest evidence for a viral role appears to exist for the development of diabetes and myocarditis (inflammation of the muscular walls of the heart).

Because the causal relationship is not well established and the number of cases associated with drinking water is unknown, the Agency was not able to quantify benefits from the GWR on reducing these diseases. Nonetheless, as illustrated in Exhibit 5–17, the total number of these conditions from all pathways in the United States is substantial. Additionally, 3.5 percent of heart disease deaths (study was for 1993) were due to cardiomyopathy (NHLBI, 1996). The potential benefits of avoiding some of these health effects cannot be overlooked, and may be significant.

Exhibit 5–17. Annual Number of People with Selected Disease

Selected Disease	Number of people[1]
Diabetes (of all kinds)	6,962,000
Chronic Heart Disease (including myocarditis and cardiomyopathy)	4,148,000

1 Average annual number of people with disease for three year period from 1990–1992.
Source: Collins, 1997

Although enteroviruses are suspected to play a role in the development of chronic illnesses as discussed, sufficient data are not available to forecast the number of avoided chronic cases resulting from the proposed GWR. An extensive literature review proved, however, that costs of a single case of diabetes or heart disease are significant. Cost estimates for a case of diabetes and a case of chronic myocarditis (using the cost per case of an "average case of heart disease" as a proxy for chronic myocarditis) are presented below to demonstrate the magnitude of potential benefits per avoided case of chronic illness.

5.4.2.1 Type I Diabetes

The potential involvement of enteroviral infection in Type 1 insulin-dependent diabetes mellitus (IDDM) has previously been suggested (Nakao, 1971) and is being researched by the American Diabetes Association (ADA, 1996). In some people, autoimmune reactions to enterovirus have been observed to destroy the pancreatic cells, which produce insulin. This autoimmunity appears to develop in less than 5 percent of the general population and progresses to diabetes in less than 1 percent of the general population.

Enteroviral infection during pregnancy of the mother has also been observed as a risk factor for childhood-onset diabetes (Dahlquist et al., 1995). It is suggested that an enterovirus infection initiates and accelerates the autoimmune process typical of IDDM cases, rather than actually causing the clinical illness (Hyöty et al., 1995).

Costs of Illness: Diabetes

The most comprehensive work regarding the economic burden of diabetes in the United States was conducted for the American Diabetes Association. In their report "Economic Consequences of Diabetes Mellitus in the United States in 1997," Fox et al. (1998) presented the direct medical and indirect costs attributable to diabetes, as well as a total and per capita estimate of expenditures of people with and without diabetes. Improving on their estimates and methodology from their 1992 effort (Fox et al., 1993), this national prevalence-based COI study also compares the health care expenditures of diabetics in 1997 to non-diabetics.

The authors created a holistic estimate of the health care expenditures attributable to diabetes in 1997, by including: 1) medical expenditures attributable to diabetes (i.e., the cost due to the excess of prevalence of diabetes related chronic complications and general medical conditions in people with diabetes), and 2) total medical expenditures incurred among people with diabetes (i.e., the cost for all services for people with diabetes). Annual per capita expenditure estimates were also calculated and defined as the sum of the expenditures among diabetics in 1997, divided by the 1997 diabetic population. The estimates do not, however, include pain and suffering nor do they include lost productive and leisure time

The per capita medical expenditures for people with diabetes is $10,825 for people with diabetes versus $2,869 among people without diabetes. Therefore the annual cost of diabetic care is therefore $7,956 per person.[1] The net productivity loss for each person due to diabetes totaled $1,567 for 18–64 year olds and $502 for those 65 and older.[2] These are sums of costs attributable to diabetes from productivity loss from work, from restricted-activity and from bed-disability.

According to the 1980–1987 Hospital Cost and Utilization Project (HCUP), a national sample of more than 500 hospitals, which represent an unweighted 20 percent sample of discharges, the mean age of diagnosis for a case of diabetes mellitus within the study was 53 (Elixhauser et al., 1993). Assuming that a patient incurs treatment for diabetes each year throughout the duration of his expected

[1] Costs updated from January 1995 dollars to May 1999 dollars using the CPI-U for "medical care services" (= 254.0 ÷ 236.3 = 1.0749).

[2] Costs updated from January 1997 dollars to May 1999 dollars using the CPI-U for "all items" (= 166.2 ÷ 159.1 = 1.0446).

life from age 53,[3] the present value of the direct medical costs and indirect costs of illnesses would be $101,775 (7 percent discount rate). This figure could be even greater if the cost of premature death or pain and suffering were incorporated. While this is a simple approximation of the magnitude of a COI value for this illness, it captures the lifetime costs of diabetes in those who survive the first year through their life expectancy period from the age of diagnosis.

5.4.2.2 Chronic Myocarditis

The enteroviruses are reportedly responsible for approximately 50 percent of the myocarditis cases in North America (Luppi et al., 1998). Coxsackievirus B infections are increasingly the primary cause of myocardial disease in both adult and children populations. Melnick (1996) reported that up to 39 percent of persons infected with coxsackievirus develop cardiac abnormalities. Furthermore, about 5 percent of all symptomatic coxsackievirus patients induce heart disease, affecting the myocardium (the heart muscle), the pericardium (the membranous sac around the heart), the endocardium (the interior lining of the heart), or all three.

While many of these cases resolve without complication, it is believed that some acute cases resurface as chronic conditions (Sainani et al., 1968, Abelmann, 1978, Archard et al., 1987, Luppi et al., 1998, Hufnagel, 1998). This may occur in infected individuals, depending on viral or host factors such as the virulence of the virus strain, the character of the virus, or the immunity of the patient (Okuni et al., 1975).

Clinically, it is difficult to differentiate between cardiomyopathy and chronic myocarditis (Okuni et al., 1975). Therefore, it is thought that viral myocarditis actually may be responsible for some of these cases that are diagnosed as cardiomyopathy (Abelmann, 1978). For example, the Idiopathic Cardiomyopathy Research Committee of Japan reported that 40 percent of patients suffered myocardial sequelae and about 4 percent of them showed dilated cardiomyopathy-like features (Kawai et al., 1987). In fact, Archard et al. (1987) suggested that group B coxsackieviruses may actually play a role in the development of dilated cardiomyopathy. Therefore, it is not uncommon for a patient to be suffering chronic myocarditis and to only be diagnosed with it after death (Kline and Saphir; 1960, Smith, 1966; Morimoto et al., 1992). They will have received treatment throughout life for conditions such as congestive heart failure or dilated cardiomyopathy, and not for chronic myocarditis (Smith, 1966; Morimoto et al., 1992; Luppi et al., 1998).

<u>*Costs-of-Illness: Chronic Myocarditis*</u>

The annual direct cost-of-illness associated with an "average case of heart disease" was estimated to be $4,559.[4] This estimate was derived from data originally computed by Thomas

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[3] 26.9 years: *Life Tables*. Table 6–3. "Expectation of Life at Single Years of Age, by Race and Sex: United States, 1995." (NCHS, 1998).

[4] Cost updated from January 1995 dollars to May 1999 dollars using the CPI-U for "medical care services" (= 254.0 ÷ 219.8 = 1.1556).

Hodgson[5] (Hodgson, 1984; Hodgson, 1998) of the National Center for Health Statistics (NCHS) for "heart disease" (which includes International Class of Diseases, 9th Revision (ICD–9) codes 391–398, 402, 404, 410–416, 420–429). Since no specific cost data were available for chronic myocarditis, or cardiomyopathy (ICD–9 code 425), annual per capita costs for an "average case of heart disease" were computed using his data on "heart disease" in conjunction with prevalence numbers from the 1995 National Health Interview Survey.[6,7]

Indirect costs of "other heart disease" were estimated by Cropper and Krupnick (1990) who used information from the 1978 Social Security Survey of Disabled and Work to model the effects of disease on labor participation and earnings. Cropper and Krupnick found that the annual indirect cost ranged from $3,264 to $6,699 depending on the age of the individual and the age of illness onset.[8] Again, it is important to note that these costs do not include pain and suffering.

According to the 1980–1987 HCUP study of 500 hospitals, the mean age of diagnosis for cardiomyopathy was 60 (Elixhauser et al., 1993). Using this diagnostic category as a proxy for chronic myocarditis,[9] the lifetime cost-of-illness could be substantial. For example, the present value of both direct and indirect costs for a patient with the condition would be $52,971 given an average life expectancy of 21.1 years (7 percent discount rate). This figure could be even greater if the costs of lost earnings and of premature death were incorporated.

5.4.3 Non-Health Benefits

In addition to the quantified and unquantified health-based benefits discussed above, there are a number of non-health benefits that also arise from promulgation of the rule. Non-health benefits may result from overall system improvements (e.g., upgrades to distribution systems, increased efficiencies, increased frequency/intensity of process surveillance), from improved risk perception of drinking water quality, or from avoided outbreak response costs.

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[5] Chief economist and acting director, Division of Health and Utilization Analysis, NCHS, CDC.

[6] Chronic illness prevalence rates (cases per 1,000 individuals) for "heart disease" were multiplied by the total United States population to obtain the total number of heart disease cases in 1995. The "average case of heart disease" per person in 1995 was subsequently calculated by dividing the total cost of heart disease in 1995 by the total number of heart disease cases in 1995. Prevalence figures were from *Current Estimates of the National Health Interview Survey, 1995* (Benson and Marano, 1998), and the total United States population as of January 1, 1996 was obtained from the Census Bureau.

[7] Without more detailed information, this simplified method assumes that the cost of any heart disease, whether ischemic or other, would be the same within this major disease group. This is a major limitation of these estimates, as hospital costs for coronary heart disease may not be the same for hypertensive disease, for example.

[8] Costs updated from January 1977 dollars to May 1999 dollars using the CPI-U for "all items: (= 166.2 ÷ 58.5 = 2.8410).

[9] As previously mentioned, group B coxsackieviruses are suspected to play a role in the development of dilated cardiomyopathy.

These non-health benefits are not quantified for this RIA. The Agency has considered these benefits, however, and presents the following discussion to illustrate their potential magnitude.

5.4.3.1 Reduced Uncertainty

To the extent that the GWR decreases consumers' uncertainty about expected health outcomes from consumption of drinking water, the rule should provide direct benefits independent of risk reduction benefits. In other words, drinking water consumers may be willing to pay a risk premium for regulatory action if it reduces their uncertainty about whether they will become ill or not (Moore, 1990).

Conceptually, whether or not consumers would be willing to pay something extra to reduce uncertainty in the GWR context depends on several complicated factors, including consumers' degree of risk aversion, their perceptions about drinking water quality, and the expected probability and severity of human health effects associated with microbial contamination of drinking water. For example, risk premiums would be expected only for consumers who are risk averse. Further, the magnitude of any premium would be expected to be positively related to the probability and severity of expected health outcomes, and the degree to which consumers' perceive them to be affected by regulatory action.

5.4.3.2 Costs to Households to Avert Infection

To the extent that the GWR can be expected to reduce a household's perceptions of the health risks associated with drinking water, regulatory action should reduce household averting actions and costs. Any such cost savings would represent a regulatory benefit. A number of factors, however, limit the relevance of this potential benefit in the GWR context. One is the possibility that regulatory action may not affect household perceptions of health risks enough to motivate them to forego averting actions. A related factor is that many households that undertake averting action for health reasons may be especially risk averse (e.g., households with infants or immuncompromised persons). These households might be expected to pursue averting actions regardless of the level of regulatory control if they believe such actions may provide added protection against microbial risks. Should this be the case, households would also be excluded from the quantified benefit analysis.

Examples of Household Avoidance

Individual households often take steps to avoid potential microbial contamination of publicly-supplied drinking water, including: 1) securing drinking water from alternative sources (e.g., bottled water), 2) installation of home treatment systems (e.g., point-of-use and point-of-entry treatment), and 3) boiling tap water used for consumption. These actions can involve significant cash outlays and implicit costs (e.g., time costs).

5.4.3.3 Outbreak Response Costs Avoided

> **Examples of Outbreak Response Costs**
>
> Affected water systems and local governments can incur costs associated with providing alternative water supplies and issuing customer water use warnings and health alerts. Commercial establishments (e.g., restaurants) and their customers can incur costs due to interrupted and lost service (i.e., lost producer and consumer surplus). Local businesses, institutions (e.g., schools), and households can all incur costs

While outbreak prevention generates the health benefits discussed above, it also results in significant non-health benefits. To the extent that the GWR reduces the likelihood of illness outbreaks, these avoided response costs are potentially numerous and varied. A literature review identified five studies that use the averting cost approach to estimate household and other costs resulting from short-term contamination episodes of drinking water supplies (Abdalla, 1990; Abdalla et al., 1992; Harrington et al., 1985; Sun et al., 1992; RTI, 1997). The most relevant of these for the GWR analysis is a study by Harrington et al. (1985) in which the resulting costs of drinking water contamination by *Giardia* in Luzerne County, Pennsylvania, were evaluated (see Exhibit 5–18). The outbreak provides a theoretical and empirical example of how outbreak costs are incurred by individuals, businesses, and local governments, in an overall exposed population of 75,000.

Exhibit 5–18. Case Study of Outbreak Costs–1984 Lucerne County Outbreak[1]

Explanation	Costs (Millions)[2]
Losses due to actions taken by individuals to avoid the contaminated water. The predominant cost was due to time losses involved in boiling water.	$ 21.11 to $62.81[3]
Cost of providing alternative water for restaurants, bars, schools and other businesses during the outbreak.	$ 1.06
The burden for government agencies.	$ 0.37
The burden for the water supply utility.	$ 3.0

[1]*Source:* Harrington et al. (1985)

[2] All costs were updated to May 1999 dollars using the CPI-U for "all items," from 1984 dollars (= 166.2 ÷ 101.9 = 1.6310

[3] Depending upon the assumed method of estimating the implicit after-tax wage rate of the unemployed, homemakers, and retirees

The primary concern of the study was on the total losses resulting from the outbreak including the value of lost work time and the value of reduced leisure time activities due to illness, the cost of medical care, the costs of actions taken to avoid drinking contaminated water, such as the cost of bottled water and boiling water, the costs of epidemiological and water system surveys, and the costs of temporary measures taken by the water utilities to ensure safe water supplies. Unfortunately, the study was not able to address any losses associated with pain and suffering, or "with anxiety over the possibility of contracting giardiasis, and with diminished intrinsic value, resulting from the loss of a 'pure' water supply for drinking." (Harrington, 1985). Outbreak effects on businesses regarding lost sales or lost productivity were also not investigated. These additional factors could add significantly to the cost of waterborne disease outbreaks, therefore the benefit from avoiding outbreaks could be even greater.

5.4.4 Benefits From the Reduction of Co-Occurring Contaminants

If a system chooses to install treatment, it may choose a technology that would also address other drinking water contaminants. For example, when using packed tower aeration to treat radon, it is the accepted engineering practice, and in some States an existing requirement, to also install disinfection treatment for removal of microbial contaminants introduced in the aeration treatment process. Depending on the dosage and contact time, the routine disinfection would also address possible or actual fecal contamination in the source water. If systems had an iron or manganese problem, the addition of an oxidant and filtration can treat this problem as well as fecal contamination. Also, some membrane technologies installed to remove bacteria or viruses can reduce or eliminate many other drinking water contaminants including arsenic. EPA is currently proposing rules to address both radon and arsenic. Because of the difficulties in establishing which systems would have all three problems of fecal contamination, radon, and arsenic or any combination of the three, no estimate was made of the benefits from the overlap of these rules.

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6. Cost Analysis

6.1 Introduction

This chapter presents the national cost estimates for the proposed Ground Water Rule (GWR). It presents the unit costs, identifies the underlying assumptions used to prepare the cost estimates, and describes the methodology used to compile these assumptions to estimate the cost of the four GWR options.

Section 6.2 presents an introduction to the unit costs and costing assumptions that EPA has made for each of the rule components (Section 6.2.1) and the methodology used by the cost model to develop national estimates (Section 6.2.2). Section 6.3 presents the national cost estimates and Section 6.4 presents the average household costs.

6.2 Costing Methodology

This section presents a summary of EPA's assumptions made to prepare estimates of the national costs of the proposed GWR and other regulatory options. It contains a description of the estimates of unit costs (the cost that would be incurred by each State, individual treatment facility or system) and the predicted actions that systems and States will make to comply with the proposed GWR.

6.2.1 Cost Model Inputs

The proposed GWR and other rule options are composed of rule components that identify and/or correct conditions that permit fecal contamination to reach ground water system consumers' taps. Exhibit 6-1 identifies the components of each GWR option. Several of these components are included in more than one of the GWR options.

Exhibit 6–1. Components Included in Each Regulatory Options

Rule Scenario Components	Option 1: Sanitary Survey Only	Option 2: San. Survey and Triggered Monitoring	Option 3: Multi Barrier Approach	Option 4: Across-the-Board Disinfection
Monitoring and Assessment				
Sanitary Survey	U	U	U	U
Triggered Monitoring		U	U	
Sensitivity Assessment			U	
Routine Monitoring			U	
Corrective Action				
For Significant Defects	U	U	U	U
For Fecal Contamination		U	U	U
Compliance Monitoring		U	U	

The unit costs applicable to each may be either costs incurred by the State in establishing the component's requirements or by the water system to comply with the regulations; for some components both entities incur costs. Exhibit 6–2 presents, for each of the components, where the costs are incurred. Following that are brief discussions regarding the components' unit costs or cost assumptions. Greater detail regarding these inputs may be found in Appendix C, Inputs to Cost Modeling. Only summary unit costs are presented in this document; more detailed descriptions of the assumptions and methodologies used to develop these cost estimates are presented in the *Cost and Technology Document for the Ground Water Rule* (EPA, 1999a).

Exhibit 6–2. Assignment of Components' Costs

Rule Scenario Components	Costs to State	Costs to System
Monitoring and Assessment		
Sanitary Survey	U	U
Triggered Monitoring	(A)	U
Sensitivity Assessment	U	(N)
Routine Monitoring	(A)	U
Corrective Action		
For Significant Defects	(A)	U
For Fecal Contamination	(A)	U
Compliance Monitoring	(A)	U
(A) Administrative Costs only (N) No costs, States are expected to make assessments without system involvement		

Although EPA estimated the cost of all the rule's components for drinking water systems and States, there are some costs that the Agency did not monetize. These nonmonetized costs result from uncertainties surrounding rule assumptions and from modeling assumptions. For example, EPA did not estimate a cost for systems to acquire land if they needed to build a treatment facility or drill a new well. This was not estimated because many systems will be able to construct new wells or treatment facilities on land already owned by the utility. In addition, if the cost of land was prohibitive, a system may chose another lower cost alternative such as connecting to another source. In addition, the Agency did not develop cost estimates for all conceivable corrective actions or significant deficiencies that a system may encounter. Instead, a representative sample was chosen, as discussed below under corrective action.

6.2.1.1 State Agency Costs

As indicated above in Exhibit 6–2, States incur costs for all components; for all but two of the components the costs are strictly administrative costs. In addition to the administrative costs the following discussion addresses costs incurred by required provisions for sanitary surveys and hydrogeologic sensitivity assessments.

State Costs—Administrative Costs

States will incur administrative costs of implementing the GWR. These administrative costs are not directly required by specific provisions of GWR options, but are necessary for States to ensure the provisions of the GWR are properly carried out. States will need to allocate time for their staff to establish and then maintain the programs necessary to comply with the GWR. Staff time resources are estimated in terms of full-time equivalents (FTEs). EPA assumed a cost of $64,480 for one FTE, including overhead and fringe benefits. Time requirements for a variety of State agency activities and responses are estimated for this RIA. Exhibit 6–3 lists activities required to start the program following promulgation of the GWR as well as the annual activities that a State will require to continue implementation of the GWR.

Exhibit 6–3. Examples of State Administrative Activities

Start Up Activities
Public Notification
Regulation Adoption and Program Development
Upgrade Data Management Systems
Initial Lab Certification and Training
System Training and Technical Assistance
Staff Training

Annual Activities
Coordination with EPA
Lab Certification
On-Going Technical Assistance
SDWIS Reporting
Clerical
Supervision

In addition to the administrative costs of developing and maintaining a program for GWR compliance, States will be required to spend time responding to ground water sources that are found to be fecally contaminated. These costs include time to review plans and specifications, prepare violation letters, and conduct data entry.

State Costs—Sanitary Survey

The GWR options increase both the scope and the frequency of sanitary surveys. EPA estimated that on average, States currently conduct sanitary surveys of community ground water systems once every five years and noncommunity ground water systems once every 10 years. EPA assumed that, under the GWR, sanitary surveys will be conducted by the State (or primacy agent) on all noncommunity ground water systems once every five years. For community ground water systems, EPA assumed that all of the community ground water systems that achieve a 4-log inactivation or removal of virus will have sanitary surveys conducted every five years, and the remaining community ground water systems will have sanitary surveys conducted once every three years.

The scope of sanitary surveys are expanded to address eight specific components of a PWS. EPA estimated the incremental increase in cost for performing and preparing a sanitary survey. These incremental costs range from as low $30 per survey for systems serving under 100 individuals to $700 per survey per system for the largest systems.

State Costs—Hydrogeologic Sensitivity Assessment

The hydrogeologic sensitivity assessment, a component only of the multiple-barrier option, will be performed by States (or other primacy agent) on each ground water source to determine if the source is sensitive to microbial contamination and requires monitoring to ensure there is no fecal contamination. EPA assumes hydrogeologic sensitivity assessments would be performed on all ground water sources that are not providing 4-log inactivation or removal of virus. EPA estimates that 15 percent of the systems that are assessed will be determined to be sensitive, based upon data collected for the AWWA Study (Abbaszadegan et al., 1998, 1999).

EPA estimated the time for States to locate existing hydrogeologic data, such as a well construction record, and for a State assessor to inspect and review these data. These average costs increase in relative proportion to the system size, ranging from as low as $62 per assessment for systems serving under 100 individuals to $3,224 per survey per system for the largest systems.

6.2.1.2 Public Water System (PWS) Costs

PWS Costs—Sanitary Survey

As discussed under State costs above, sanitary surveys will increase both in scope and in frequency. The only incremental increase in costs that a system will incur as a result of this component is the additional time it will take to accompany the State inspector conducting the survey. Noncommunity water systems' sanitary survey frequency will be once every five years versus once every 10 years under current requirements. Community water systems which do not achieve a 4-log inactivation of virus will assist in sanitary surveys once every three years instead of once every five years. There is no change in frequency for community ground water systems which achieve 4-log inactivation of viruses. In addition to the increased frequency, the scope of the sanitary survey is increased to address eight specific components of a PWS. EPA estimated the cost increase to PWSs to meet the requirements of the GWR for sanitary survey as ranging from as low $110 per survey for systems serving under 100 individuals to $1,900 per survey per system for the largest systems.

PWS Costs—Triggered Source Water Monitoring

Triggered source water monitoring is a component of two regulatory options: Options 2 and 3. Only systems that do not achieve 4-log inactivation of virus will be subject to this provision. Triggered monitoring requires collection and analysis of samples at the ground water systems source, following the detection of total coliform in one or more samples collected for compliance with the Total Coliform Rule. While States have the option of requiring the triggered source water samples to be tested for the presence of one of three fecal indicators, for the purpose of this cost analysis, EPA assumed that States will select *E. coli* as the indicators of contamination for analysis. EPA estimated the cost for triggered monitoring to be $53 per sample, including laboratory analysis ($25) and one hour of the system operator's time (at an estimated cost of $28 per hour) to collect the sample, arrange for delivery to the laboratory and to review the results of the analysis. No additional costs are assumed for installation of a tap or re-piping of wells to permit sampling, as EPA assumed all wells are equipped with existing taps for sampling.

If a system detects the fecal indicator at its source, then the system must take a corrective action to either eliminate the contamination, obtain a new uncontaminated source, or install treatment to achieve a 4-log removal or inactivation of virus. Several compliance estimates are necessary to develop estimates of the cost associated with triggered monitoring: the frequency with which systems will have to perform triggered monitoring; the frequency that a waiver will be granted; the duration of the triggered monitoring; and the number of systems that are expected to test positive for the fecal indicator. These factors are discussed in greater detail below.

Frequency of Performing Triggered Monitoring: EPA estimated the probability of a ground water system's total coliform sample testing positive, which would therefore, trigger the monitoring requirements, as a part of its regulatory impact analysis for the Total Coliform Rule (EPA, 1989). EPA calculated the frequency of total coliform positives per year per system by multiplying the number of TC samples required per year by the probability of a TC positive. All community water systems serving under 3,000 individuals and all noncommunity water sources are estimated to have zero to three triggered source water samples per year. Larger community water systems vary, with the estimate for largest system at 7 to 22 triggered sources water samples per year.

Waiver from Triggered Monitoring: The option allows States to waive the triggered monitoring requirements if a PWS demonstrates that the total coliform contamination is not source water related. EPA assumed that the probability of a PWS receiving this waiver for a single entry point is 10 percent. Also, a one-time repeat sampling waiver exists for both triggered monitoring and routine monitoring. Once a PWS finds a single positive sample, they may take five repeat samples, and if all five repeat samples are negative, the source water is considered not to be contaminated. For the purposes of this analysis, it is assumed that all PWSs that have a positive source water sample will make use of this one-time sampling waiver.

Duration of Triggered Monitoring: For the purposes of the cost model, EPA assumed that all contaminated entry points will be discovered in the first year. Therefore, the entry points with no source water positive samples, or those with a single positive sample and five negative follow-up samples in the first year, will continue to undertake triggered monitoring sampling for the remainder of the period of analysis. The number of samples they will take each year is assigned using a uniform distribution based on the number of expected total coliform violations they might have per year.

Number of Systems Testing Positive: EPA estimated the number of systems that will test positive in triggered monitoring by reviewing indicator occurrence data. The AWWARF study (Abbazadegan et al, 1998, 1999) found enteroccocci bacteria in 9 percent of the wells sampled. Wells were selected for the study to be representative of hydrogeologic conditions for public water supply wells in the United States, and most wells in the study were only sampled once. EPA determined that the enterococci occurrence from the AWWARF study provides the best estimate of the percentage of wells that will be found to test positive for the presence of a fecal indicator in triggered source water sampling and, therefore, assumed that 9 percent of the systems tested will be found to contain fecal contamination.

PWS Costs—Routine Source Water Monitoring

Routine source water monitoring, a component only of Option 3, the Multi-Barrier Option, involves monthly sampling of those ground water sources that are determined to be at high risk for the presence of fecal contamination. The hydrogeologic sensitivity assessment performed by the State is used to determine which wells are at high risk of contamination. Only systems that do not achieve 4-log inactivation of virus will be subject to this provision. Similar to triggered monitoring, several compliance assumptions were needed to model the cost of routine monitoring and they are described below.

Frequency of Performing Routine Monitoring: High risk wells would be sampled routinely each month and tested for the presence of fecal contamination using one of three possible indicators as selected by the State. EPA assumed that States will select *E. coli* as the indicator of contamination for analysis. States may reduce the frequency of monitoring for high risk ground water sources after one year of monitoring if there are no samples that test positive. States may also waive source water monitoring altogether after the first year if the State determines that fecal contamination of the well is highly unlikely.

Duration of Routine Monitoring: EPA assumed that all contaminated entry points will be discovered in the first year of routine monitoring. EPA also assumed that the entry points either with no source water positive samples or with a single positive sample and five negative follow-up samples in the first year will continue to undertake routine sampling once a quarter for the remainder of the period of analysis.

Waiver from Corrective Action: A waiver could be granted by the State if the system collects five repeat samples from the well that tested positive within 24 hours and does not find the fecal indicator in any of five samples. This waiver can only be granted once per source. Because of the high costs associated with corrective actions, EPA assumed that all systems with a routine source water positive sample will resample their source within 24 hours of detecting the fecal contamination. EPA estimated that 20 percent of the systems that perform the repeat sampling will not find fecal indicators in any of the repeat samples and will receive waivers from the State.

Number of Systems Testing Positive: Using EPA/AWWARF study data (Abbazadegan et. al., 1998, 1999), EPA estimated that 15 percent of the sources for ground water systems will be determined to be sensitive and therefore subject to routine monitoring (See Appendix C for more details). Of these wells, EPA estimates that 50 percent will test positive for the presence of a fecal indicator based upon an *E. coli* occurrence in wells vulnerable to contamination (Lieberman et. al., 1994, 1999). Ground water systems with wells that test positive for the presence of a fecal indicator would be required to take action to correct the contamination unless the system were able to obtain a one-time waiver from the State. As for triggered monitoring analysis (see above), EPA estimated the cost for triggered monitoring to be $53 per sample and assumed that all wells are equipped with existing taps for sampling.

PWS Costs—Corrective Action For Significant Defects

The primary purpose of conducting sanitary surveys is to identify significant defects in public water systems for correction. The costs for correction of significant deficiencies are dependent almost entirely upon the nature of the deficiency. Because States have the authority to define significant deficiencies under the proposed GWR and options, EPA must predict the types of deficiencies that will be found and corrected as a result of the rule. EPA consulted with experts from within the Agency and from States to develop a list of corrective actions to address deficiencies that are likely to be identified in sanitary surveys of ground water systems (EPA, 1996a). These are as follows:

<u>Correction of Significant Deficiencies at the Source</u>

- Replace a sanitary well seal,
- Rehabilitate an existing well, and
- Drill a new well

<u>Correction of Significant Deficiencies in Treatment Systems</u>

- Adjust disinfection chemical feed rate
- Increase contact time prior to first customer

<u>Correction of Significant Deficiencies in Distributions System</u>

- Install backflow prevention device
- Replace/repair cover on a storage tank
- Install security measures at storage tank site
- Install a redundant booster pump

Costs were developed for each of these (See Appendix C for unit costs and details); these costs are one-time expenditures that occur in the year the significant deficiency is found, except for adjustments to the disinfection feed rate, which are ongoing costs.

Each of the regulatory options requires each PWS to correct any significant defect found during a sanitary survey. The assignment of any significant deficiency is done as a two-step process within the cost analysis model, and is done independently for each sanitary survey over the 20-year period of analysis. First, a PWS is designated as having or not having the potential to have one or more significant defects resulting from a single sanitary survey based on a probability estimate.

Second, each PWS that is predicted to have a significant defect, in a single sanitary survey, may be assigned one or more of the six potential significant defects according to a probability distribution (See Appendix C for the probability distribution). Because the corrections of significant defects are dependent upon the defects defined as significant by States and the conditions at the facilities, both of which are unknown, EPA used a high scenario/low scenario estimating procedure to bound the uncertainty. The low cost scenario assumes a greater percentage of the systems with significant defects will have defects which are less expensive to correct (e.g., more systems will have to replace their sanitary well seal than will have to perform a complete rehabilitation of their well). This high/low bounding should provide a reasonable estimate of the uncertainty with respect to the types of defects that will have to be corrected.

This two-step process is repeated for each sanitary survey the PWS undertakes over the 20-year period of analysis. Since the timing of the sanitary surveys are not known, an average annual PWS cost of correcting significant defects is calculated by summing the cost of correcting all significant defects over the 20-year period of analysis and then dividing by 20. The average annual PWS cost of correcting significant defects includes the cost of developing engineering plans for submission to the State (See Appendix C for details).

PWS Costs—Corrective Action For Fecal Contamination

Detection of fecal indicators in the source of undisinfected ground water systems requires corrective action under Options 2 and 3. Corrective action includes eliminating the contamination from the source, obtaining an alternative source of water, or providing disinfection treatment that achieves 4-log inactivation or removal of viruses. Because costs are based on the corrective action which may vary (i.e., the corrective action is selected by the system after consultation with the State and based upon the size of the system), EPA assumed that a variety of corrective actions could be implemented by ground water systems that detect fecal contamination within their source waters. The corrective actions include eliminating the contamination from the source water (address contamination source or replace source) or treating the water to achieve a 4-log inactivation/removal of virus.

Eliminate Contamination: EPA developed unit cost estimates for four corrective actions to eliminate contamination from the system's source of water (detailed unit costs are presented in Appendix C). Depending on the corrective actions, there may up to three different cost estimates: capital cost (the cost of constructing/installing the equipment), replacement cost (cost of replacing significant components of the system after several years operation, and operation and maintenance costs (or O&M) (annual cost of operating equipment and performing routine maintenance). The four options EPA considered for eliminating contamination from the source are:

- rehabilitate an existing well;
- remove/relocate existing source of contamination (septic tank);
- construct a new well; and
- purchase water from a nearby system.

Disinfect Source Water to Achieve a 4-log Inactivation/Removal of Virus: Additionally, EPA developed costs for installing and operating eight types of disinfection systems to achieve required standards (detailed unit costs are presented in Appendix C). Included in this analysis are costs for capital, annual operation and maintenance, and year 10 replacement cost. Year 10 replacement costs are estimated for the systems that will require replacement of a significant component half way through the design life of the system. The Agency developed costs for these eight disinfection technologies:

- chlorine gas disinfection,
- hypochlorination,
- chloramination,
- chlorine dioxide disinfection,
- mixed oxidants disinfection,
- ozonation,
- reverse osmosis filtration, and
- ultraviolet disinfection.

EPA developed estimates of corrective actions that ground water systems with fecal contamination would undertake to eliminate or treat their contamination. These estimates considered the current implementation of treatment types, the cost of the corrective action, and the need for systems to comply with provisions of the Disinfection Byproducts Rule (DBPR).

Current implementation of treatment types: EPA assumed that the portion of systems that will choose treatment versus nontreatment corrective actions is proportional to the percentage of systems in each service population category that currently perform disinfection treatment. Because of the uncertainty inherent in projecting the number of systems that would undertake each corrective action, EPA assumed varying percentages of the nontreatment corrective actions to provide upper and lower cost bounds.

Distribution of Corrective Action: Each entry point that is predicted to require a corrective action is assigned one of 13 potential corrective actions according to a probability distribution (See Appendix C for the probability distribution). In order to determine the sensitivity of the cost estimates to these probabilities, two scenarios were considered. Under the first scenario, entry points were assigned to low cost corrective actions with greater probability (known as the Low CA scenario), while in the second scenario, entry points were assigned to high cost corrective actions with greater probability (known as the High CA scenario). After the model assigns each entry point a specific corrective action, the costs, both capital and operations & maintenance (O&M) costs, are determined using the aforementioned unit costs (details of these costs are in Appendix C).

6.2.2 General Structure of the Cost Model

In order to calculate the national and system-level costs of compliance, the agency used the following information: the technology unit cost information and compliance forecast, both described above; information on the inventory of drinking water systems; national occurrence information; and various baseline characteristics of PWSs, such as technology in-place.

The national cost of compliance was estimated using a Monte-Carlo simulation model specifically developed for the GWR. The GWR cost model was developed in Microsoft Excel© using the Crystal Ball© Monte-Carlo simulation add-in. The main advantage to this modeling approach is that, in addition to providing average compliance costs, it also estimates the range of costs within each PWS size and type category. Hence, the GWR cost model allows for variability in PWS configuration, current treatment in-place, and source water quality to be captured in the compliance cost estimates. This information is ideal for examining PWS level impacts and technology affordability.

6.2.2.1 PWS Configuration and Occurrence

Each PWS is defined in the GWR cost model by the population it serves and the number of entry points to the distribution system it has, as entry points are used as a proxy for potential or actual points of treatment. The simulation was conducted using a sample of 3,000 PWS populations for each of the 62 PWS size/type/ownership categories (up to nine size categories; three PWS types—CWS, NTNC and TNC; matrixed against three ownership types—public, private, and ancillary) taken from the Safe Drinking Water Information System (SDWIS). The Agency developed distribution of the number of entry points for each size category using information from the Community Water System Survey (EPA, pending) (see Exhibit 4–4). A limitation of these data is that they were developed from data collected from community water systems only.

Each Community Water System's design flow (DF) and average daily flow (ADF) were calculated as a function of population served by the PWS using the following flow equations (Geometrics and Characteristics of Community Water Systems. EPA, 1999):

Publicly Owned CWS:

$$DF(kgpd) = 0.5499 xPop^{0.9554}$$
$$ADF(kgpd) = 0.0858 xPop^{1.0584}$$

Privately Owned CWS:

$$DF(kgpd) = 0.4168 xPop^{0.9608}$$
$$ADF(kgpd) = 0.0667 xPop^{1.0628}$$

Average flow for NCWS was estimated based upon average flow rates of 27.7 gal/day per person for TNC systems and 30.5 gal/day per person for NTNC systems. Utilizing data from SDWIS, EPA prepared estimates of the number of noncommunity water systems by their service area types (e.g., the number of noncommunity water systems serving restaurants), and an estimate of the average flow per person (See Appendix C). Design flow rates were calculated based upon the ratio of design to average flow rates from the above equations for community water systems.

Both system design flow and average daily flow are assumed to be divided equally among all of a PWS's entry points, therefore, the design flow and average daily flow per entry point are easily calculated. Each entry point is then designated as currently providing inactivation treatment or not currently providing inactivation treatment according to the percentage of systems achieving 4-log inactivation. This is done independently for each entry point within a given PWS. For example, a given PWS can have one entry point that currently treats, while having two entry points that currently have no treatment in place.

6.2.2.2 Discounting and the Cost of Capital

For the purposes of this analysis, PWS and State implementation costs are tracked over a 20-year period. This time frame was chosen because most of the capital equipment included in the analysis has a 20-year useful life, and PWSs often finance their capital improvements over a 20-year period. However, the capital and O&M costs of each rule option are incurred at different points in time over the course of the period of analysis.

Two different adjustments are made in this analysis in order to render future costs comparable with current costs, reflecting the fact that a cost outlay today is a greater burden than an equivalent cost outlay sometime in the future. The first adjustment is made when the cost estimates that are derived are being used as an input in benefit-cost analysis. In this instance, costs are annualized using a discount rate so that the costs of each regulatory option can be directly compared with the annual benefits of the corresponding regulatory option. Annualization is the same process as calculating a mortgage payment; the result is that we have a constant annual cost to compare with our constant annual benefits.

The choice of an appropriate discount rate is a very complex and controversial issue among economists and policy makers alike. Therefore, the Agency compares costs and benefits using two alternative discount rates, in part to determine the effect the choice of discount rate has on the analysis. The annualized costs of each regulatory option are calculated and displayed using both a seven percent discount rate required by the Office of Management and Budget (OMB) and a three percent discount rate which the Agency believes more closely approximates the social discount rate.

The second adjustment is made when the cost estimates that are derived are used as an input into an economic impact analysis, such as an affordability analysis, an analysis of PWS-level costs, or household-level costs. In these cases, rather than use a discount rate when determining the annualized costs, an after tax cost-of-capital rate is used. This rate should reflect the true after-tax cost of capital PWSs face, net of any government grants or subsidies.

6.2.2.3 Calculating Household Costs

Household level costs are considered a good proxy for the affordability of rule compliance on CWSs, since affordability at the household level is necessary for CWS cost recovery through increased water rates. This of course assumes that nonresidential customers of CWSs, such as businesses, can pass along any increase in water costs to their customers through increased prices on their goods or services. Household costs are calculated for each CWS that is either publically or privately owned.

In order to calculate the average household-level cost of compliance for a single CWS, the CWS's annual compliance cost is first divided by the CWS's average daily flow (1,000 gallons per day), and then multiplied by 365 days, to determine the CWS's cost of compliance per 1,000 gallons produced. Finally, the CWS's cost of compliance per 1,000 gallons (kg) is multiplied by the average annual consumption per residential connection (kg) to arrive at the average annual cost of compliance per household for the CWS. The estimates of average annual consumption per residential connection used in this analysis are provided in Appendix C.

6.3 National Costs

This section details the results of the national compliance cost modeling. For each regulatory option considered, the following information is provided:

- The number of PWS undertaking each rule component;
- The national annual PWS compliance costs;
- The national annual State implementation costs.

Appendix D provides further detail on the distribution of national compliance costs across system sizes and types.

6.3.1 Comparison of Annual Compliance Costs Across Regulatory Options

Exhibit 6–4 provides a comparison of the total annual cost of compliance across the four regulatory options. The costs steadily increase as one moves from the sanitary survey option, to the sanitary survey and triggered monitoring option, to the multi-barrier option. However, the costs increase by almost a factor of five from Option 3, the Multi-Barrier Approach, to Option 4, Across-the-board disinfection. This increase in costs results from the fact that the first three regulatory options are targeted, to differing degrees, at PWSs that have a demonstrated potential, either through sanitary surveys or through source water monitoring, to provide their customers contaminated drinking water. Option 4, Across-the-board Disinfection option, as the name implies requires all PWSs to treat their source water, even if there is no demonstrated potential or actual contamination. This means that costs are being incurred by many more PWSs. Exhibit 6–5 and Exhibit 6–6 show the comparison of total annual costs across the four regulatory options, by system size category and system type respectively.

Exhibit 6–4. Comparison of National Annual Compliance Costs Across Regulatory Options (millions of dollars, 1998)

Option/Regulatory Scenario	Mean Compliance Costs ($Millions)	
	At 3%	At 7%
Option 1: Sanitary Survey Only	**$72.7** ($71.1 to $74.4)	**$76** ($74.3 to $77.7)
Option 2: Sanitary Survey and Triggered Monitoring	**$157.6** ($152. 8 to $162.4)	**$168.5** ($163.0 to $174.0)
Option 3: Multi Barrier Approach	**$182.7** ($177.0 to $188.4)	**$198.6** ($191.7 to $205.5)
Option 4: Across-the-Board Disinfection Option	**$777.1** ($743.9 to $810.3)	**$866.0** ($822.7 to $909.4)

Exhibit 6–5. Comparison of Mean Annual Compliance Costs Across Regulatory Options by System Size Category (millions of dollars, 1998)

Option/Regulatory Scenario	Mean Cost by System Size								Mean Total Costs ($Millions)
	<100	100 - 500	500 - 1,000	1K - 3.3K	3.3K - 10K	10K - 50K	50K - 100K	100K - 1M	
Option 1: Sanitary Survey Only	$23.5	$14.6	$5.9	$7.7	$4.7	$3.8	$1.0	$1.8	$72.7
Option 2: Sanitary Survey and Triggered Monitoring	$73.5	$34.5	$10.2	$11.9	$7.5	$6.1	$3.0	$1.1	$157.6
Option 3: Multi-Barrier Approach	$79.5	$42.7	$12.7	$14.9	$11.8	$6.1	$3.7	$1.6	$182.7
Option 4: Across-the-Board Disinfection	$198.0	$197.0	$76.6	$106.1	$89.9	$44.4	$44.0	$11.3	$777.1

* 3% discount rate

Exhibit 6–6. Comparison of Mean Annual Compliance Costs Across Regulatory Options by System Type (millions of dollars, 1998)

Option/Regulatory Scenario	Percent of Total Cost by System Type*			Mean Total Costs ($Millions)
	CWS	NTNC	TNC	
Option 1: Sanitary Survey Only	$35.9	$5.1	$22.1	$72.7
Option 2: Sanitary Survey and Triggered Monitoring	$56.5	$14.6	$76.7	$157.6
Option 3: Multi-Barrier Approach	$66.8	$17.3	$88.8	$182.7
Option 4: Across-the-Board Disinfection	$391.5	$85.8	$290.0	$777.1

* 3% discount rate

6.3.2 Option 1: Sanitary Survey Only

6.3.2.1 Total National Costs

Under all of the regulatory alternatives under consideration, all PWSs must perform the minimum requirement of conducting sanitary surveys and correcting significant defects discovered through the sanitary survey. Exhibit 6–7 below shows that all of the PWSs are expected to conduct sanitary surveys under this option, and approximately 60 percent of the PWSs will be required to correct significant defects over the 20-year period of the cost model simulation. As shown in Exhibit 6–8, this regulatory option produced a range of total national compliance costs among PWSs from $71 to $74 million at a three percent discount rate, and from $74 to $77 million at a seven percent discount rate.

Exhibit 6–8 also shows that unlike system costs, the costs remain fairly constant between compliance scenarios because of annual fixed State costs of approximately $10 million, for annual costs ranging from $17.5 to $18 million, depending on the discount rate. Note, that these values do not include State costs incurred for lab certification as no lab certification is required under this regulatory option.

6.3.2.2 Cost of Rule Components

Given the range of total annual national costs of PWSs described above, the High Corrective Action/Low Significant Defect scenario presents an approximate mid-range value of the expected compliance costs. Exhibit 6–9 demonstrates that 89 percent of the overall system costs are due to correction of significant defects, while the remaining 11 percent of PWS costs are from other compliance activities, such as monitoring, record-keeping or conducting surveys.

Exhibit 6–7. Number of Affected Systems by Rule Component (High Corrective Action/Low Significant Defect Scenario) Option 1: Sanitary Survey Only

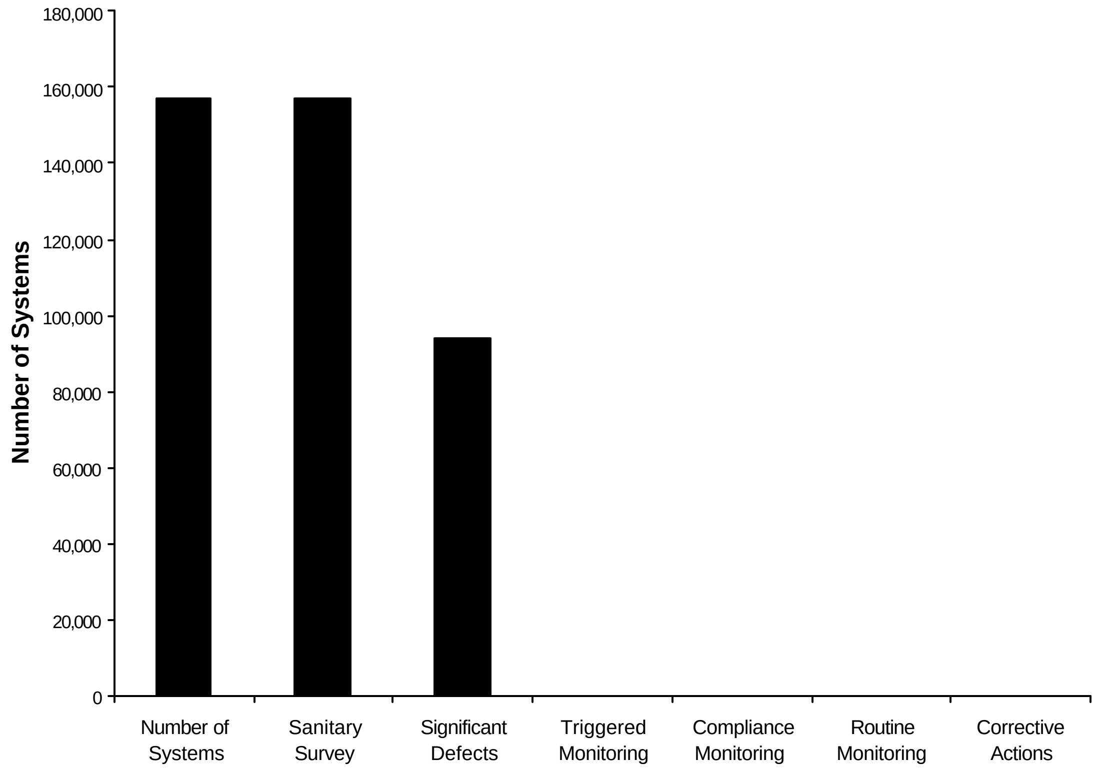
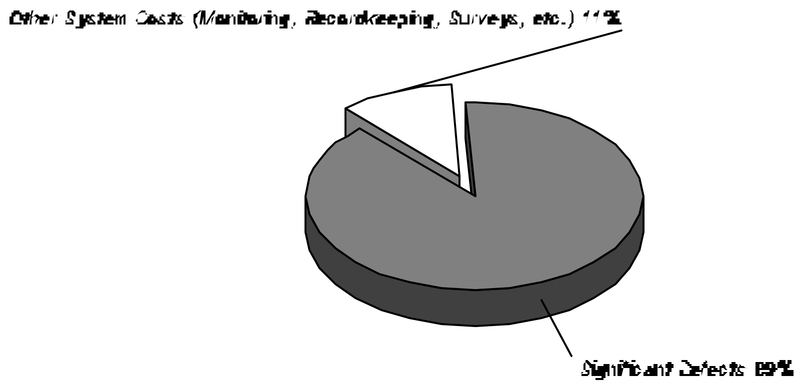


Exhibit 6–8. Total National Costs: Option 1--Sanitary Survey Only

	Mean Compliance Costs ($Millions)	
Cost Type	**At 3 %**	**At 7%**
System Costs	**$55.2** ($53.7 to $56.8)	**$57.9** ($56.2 to $59.5)
State Costs:	**$17.5** ($17.5 to $17.6)	**$18.1** ($18.1 to $18.2)
Total Costs	**$72.7** ($71.1 to $74.4)	**$76.0** ($74.3 to $77.7)

Exhibit 6-9. National PWS Compliance Costs of the GWR by Rule Component
Option 1: Sanitary Survey Only



6.3.3 Option 2: Sanitary Survey and Triggered Monitoring

6.3.3.1 Total National Costs

The Sanitary Survey and Triggered Monitoring Option builds significantly upon the Sanitary Survey Option. The Exhibit 6–10 addresses components included in this regulatory alternative including source water monitoring, corrective action, (including system modifications to currently treating entry points that do not achieve 4-log removal) and compliance monitoring. Over 120,000 PWSs are expected to undergo triggered monitoring under Option 2, Sanitary Survey and Triggered Monitoring. As shown in Exhibit 6–11, these additional requirements increase the total national cost of compliance for PWS to $153 million to $162 million at a three percent discount rate, and $163 million to $174 million at a discount rate of seven percent.

Exhibit 6–11 also shows that the overall annual State costs are also increased under this regulatory option, ranging from $19 to $20 million depending on the discount rate, despite the same annual fixed State costs previously described. This is, in part, a result of the lab certification costs previously omitted, as well as the cost to the States associated with tracking PWS monitoring and reviewing corrective action and system modification engineering plans and permits.

Exhibit 6–10.
Number of Affected PWSs by Rule Component
(High Corrective Action/Low Significant Defect Scenario)
Option 2: Sanitary Survey and Triggered Monitoring

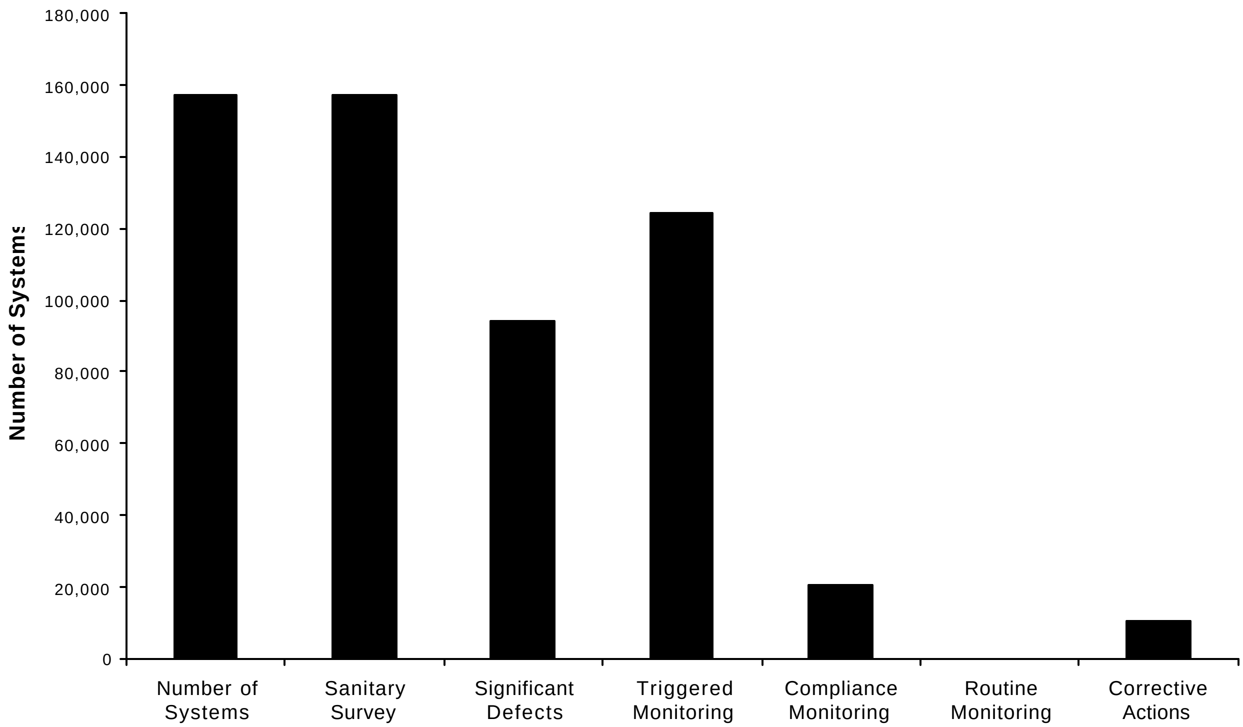


Exhibit 6–11. Total National Compliance Costs
Option 2: Sanitary Survey and Triggered Monitoring (million $)

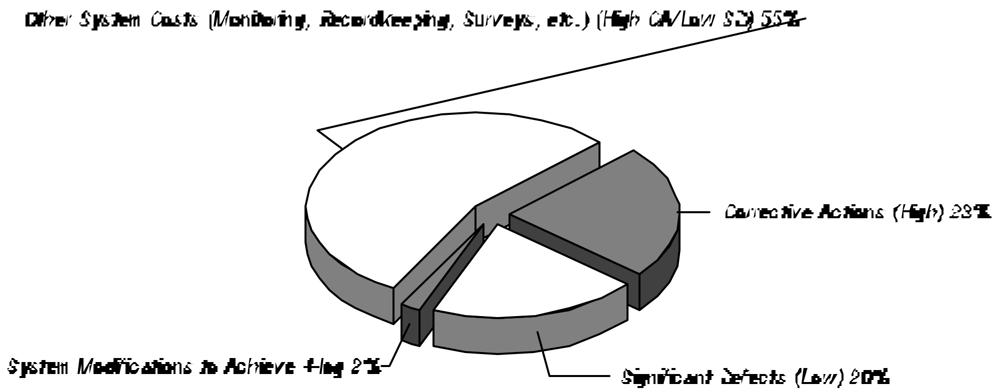
	Mean Compliance Costs ($Millions)	
Cost Type	**At 3%**	**At 7%**
System Costs	**$138.7** ($133.9 to $143.5)	**$148.7** ($143.2 to $154.3)
State Costs:	**$18.9** ($18.8 to $18.9)	**$19.8** ($19.7 to $19.8)
Total Costs	**$157.6** ($152.8 to $162.4)	**$168.5** ($163.0 to $174.0)

6.3.3.2 Cost of Rule Components

Given the High Corrective Action/Low Significant Defect scenario example, the national PWS compliance costs are composed mostly of monitoring, recordkeeping and survey costs (55 percent) (Exhibit 6–12) (note that system modifications indicated in the exhibit refer to systems which must modify their existing disinfection practices to achieve 4-log inactivation of virus as a corrective action).

The remainder is distributed between corrective actions (23 percent) and correction of significant defects (20 percent). This is in sharp contrast to the Sanitary Survey Option in which 89 percent of the PWS's cost was the result of significant defect correction.

Exhibit 6-12. National PWS Compliance Costs of the GWR by Rule Component
(High Corrective Action/Low Significant Defect Scenario)
Option 2: Sanitary Survey and Triggered Monitoring



6.3.4 Option 3: Multi-Barrier Approach

6.3.4.1 Total National Costs

The regulatory components of the Sanitary Survey and Triggered Monitoring Option and the Multi-Barrier Option are very similar, with one notable exception. Under the Multi-Barrier Option, a hydrogeological sensitivity assessment is included in the compliance scenario, a regulatory component which provides more targeted source water monitoring. Rather than requiring all entry points to undergo triggered monitoring, those deemed sensitive by the hydrogeological assessment must practice a more stringent routine monitoring regime. From Exhibit 6–13 below, most of the PWSs affected under the Multi-Barrier Option are expected to conduct triggered monitoring, as under the Sanitary Survey and Triggered Monitoring Option, but approximately 20,000 PWSs are expected to conduct routine monitoring. This results in total annual national PWS compliance costs ranging from $177 to $188 million at a three percent discount rate, and from $192 to $206 million at a seven percent discount rate (Exhibit 6–14 below).

Exhibit 6–13. Number of Affected Systems by Rule Component (High Corrective Action/Low Significant Defect Scenario) Option 3: Multi-Barrier Approach

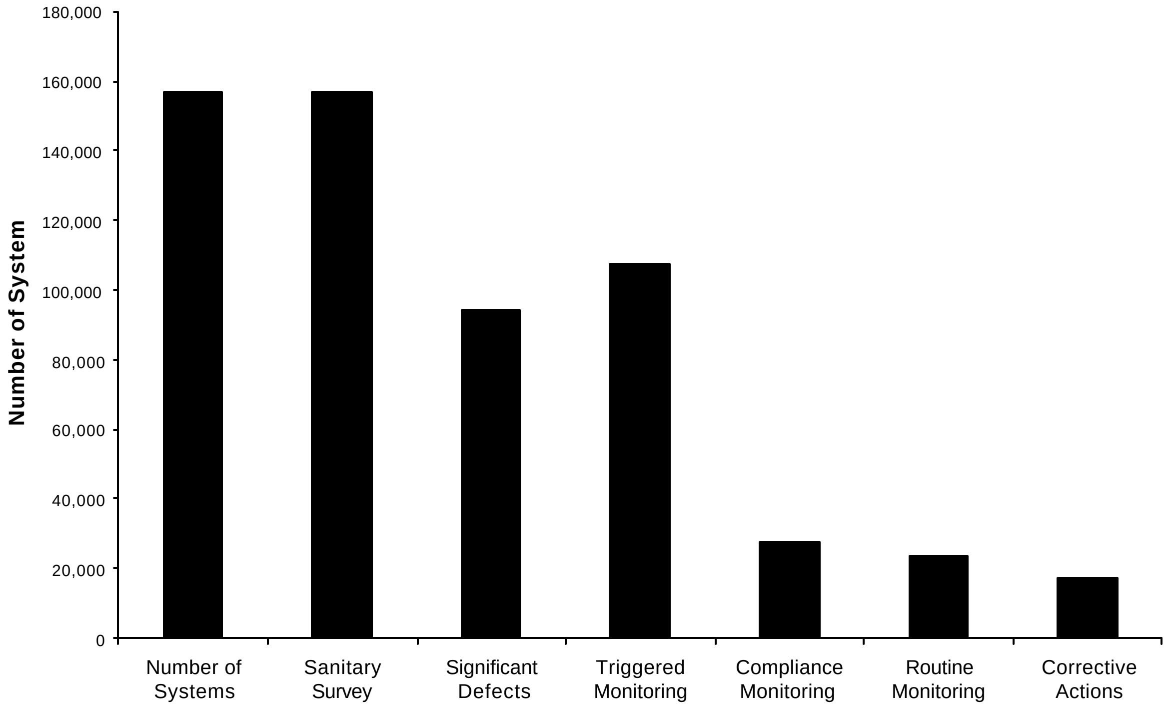


Exhibit 6–14. Total National Compliance Costs Option 3: Multi-Barrier Approach (million $)

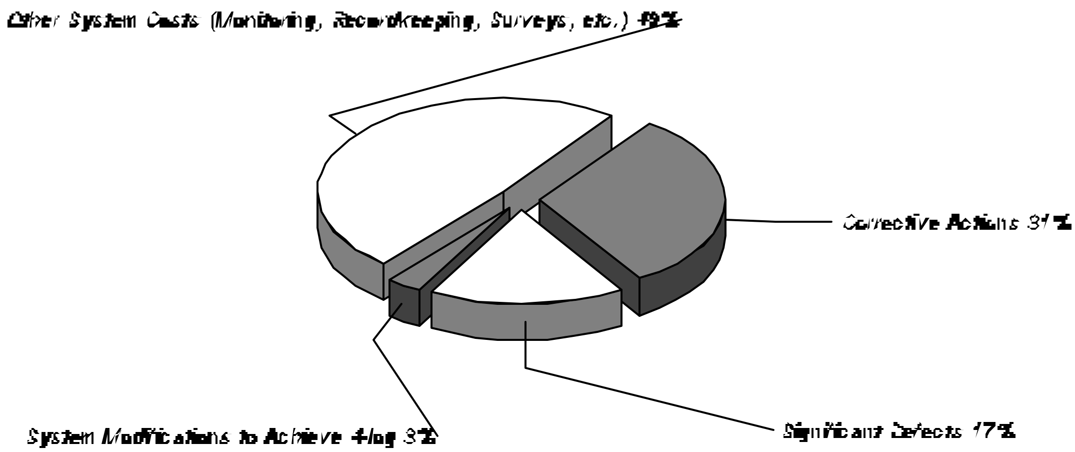
	Mean Compliance Costs ($Millions)	
Cost Type	**At 3 %**	**At 7%**
System Costs	**$162.2** ($156.4 to $167.9)	**$176.5** ($169.6 to $183.4)
State Costs:	**$20.6** ($20.6 to $20.6)	**$22.1** ($22.1 to $22.1)
Total Costs	**$182.7** ($177.0 to $188.4)	**$198.6** ($191.7 to $205.5)

Also shown in Exhibit 6–14, unlike PWS costs, few cost components change between scenarios at the State level under the Multi-Barrier Option. This is largely due to the $10 million annual fixed State costs that remain consistent between compliance scenarios. The annual State costs are approximately $21 million at a three percent discount rate, and $22 million at a seven percent discount rate.

6.3.4.2 Cost of Rule Components

Using the High Corrective Action/Low Significant Defect scenario as a mid-range example of the overall distribution of PWS costs described above, Exhibit 6–15 shows that greatest portion of the costs result from monitoring, record keeping, and sanitary surveys (note that system modifications indicated in the exhibit refer to systems which must modify their existing disinfection practices to achieve 4-log inactivation of virus as a corrective action). The second largest component of the cost burden is attributed to correction actions taken by water systems (31 percent). Correction of significant defects accounted for only 17 percent of the overall PWS costs of this compliance scenario.

Exhibit 6-15. National PWS Compliance Costs of the GWR by Rule Component
(High Corrective Action/Low Significant Defect Scenario)
Option 3: Multi-Barrier Approach

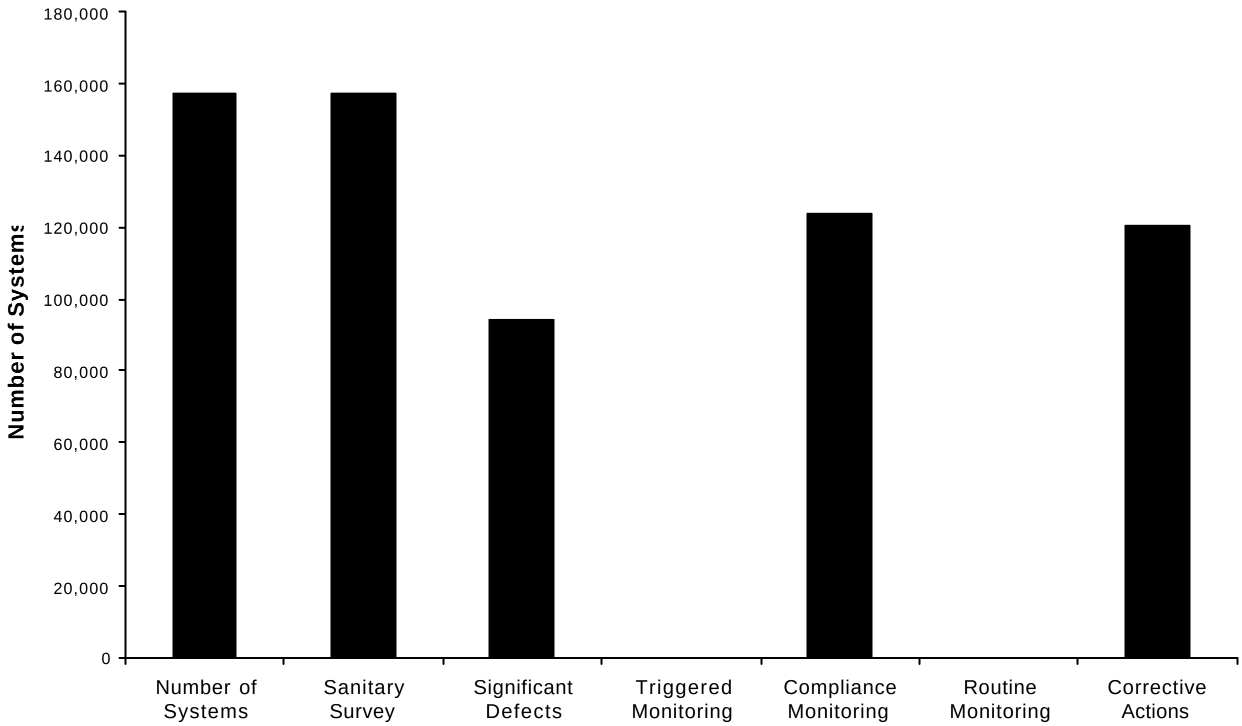


6.3.5 Option 4: Across-the-Board Disinfection

6.3.5.1 Total National Costs

Under the Across-the-Board Disinfection Option, all entry points not currently achieving a 4-log removal standard will be required to either 1) undertake a corrective action (which may not necessarily include fixing an existing well or drilling a new well), or 2) modify their treatment technique to achieve 4-log. Since all PWSs are expected to achieve the 4-log standard, there is no source water monitoring component of this alternative. Exhibit 6–16 below shows the distribution of PWSs expected to undertake the various rule components.

**Exhibit 6–16.
Number of Affected Systems by Rule Component
(High Corrective Action/Low Significant Defect Scenario)
Option 4: Across-the-Board Disinfection**



As Exhibit 6–17 below demonstrates, this option results in the highest compliance costs at both the PWS and the State levels. Total annual PWS costs across the nation range from $744 million to $810 million at a discount rate of three percent, and from $823 million to $909 million at a seven percent discount rate. Annual State costs, including the same annual fixed costs as previously discussed, amount to over $25 million (three percent discount rate) or over $28 million (seven percent discount rate).

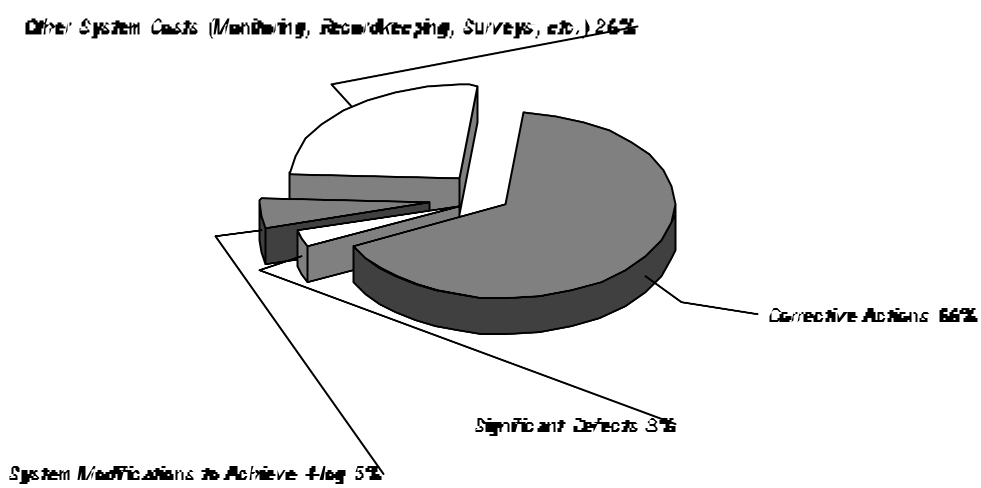
**Exhibit 6–17. Total National Compliance Costs
Option 4: Across-the-Board Disinfection (million $)**

	Mean Compliance Costs ($Millions)	
Cost Type	**At 3 %**	**At 7%**
System Costs	**$751.8** (718.7 to $785.0)	**$837.4** ($794.1 to $880.7)
State Costs:	**$25.2** ($25.2 to $25.2)	**$28.6** ($28.6 to $28.6)
Total Costs	**$777.1** (743.9 to $810.3)	**$866** ($822.7 to $909.4)

6.3.5.2 Cost of Rule Components

The high PWS costs are largely due to corrective actions (66 percent) and other PWS costs, such as conducting surveys (26 percent), as shown in Exhibit 6–18 below (note that system modifications as indicated in the exhibit refer to systems which must modify their existing disinfection practices to achieve 4-log inactivation of virus as a corrective action.). Five percent of PWS costs are due to system modifications to achieve 4-log removal. Of the four regulatory options discussed, the percentage of PWS costs from correction of significant defects are the lowest under the Across-the-Board Disinfection Option (only 3 percent).

Exhibit 6-18. National PWS Compliance Costs of the GWR by Rule Component
(High Corrective Action/Low Significant Defect Scenario)
Option 4: Across-the-Board Disinfection



6.4 Household Costs

Exhibits 6–19 and 6–20 show the range of household costs for each of the four regulatory options by PWS size category. Exhibit 6–19 presents average household costs for all community water systems, including those systems which do not have to take corrective action for significant defects or fecal contamination. Exhibit 6–20 presents average household costs only among systems which must take corrective action. Household costs tend to decrease as system size increases, due mainly to the economies of scale for the corrective actions. Cumulative distribution of household costs for each option are in Appendix C.

Exhibit 6–19.
Mean Annual Household Costs of the GWR Across Regulatory Options
All Public and Private CWSs

SIZE CATEGORIES	Sanitary Survey Option	Sanitary Survey and Triggered Monitoring Option	Multi-Barrier Option	Across-the-Board Disinfection Option
<100	$16.79	$51.88	$46.30	$156.20
101-500	$5.59	$10.88	$12.84	$54.45
501-1,000	$2.87	$4.04	$4.15	$26.22
1,001-3,300	$1.50	$1.93	$2.27	$16.52
3,301-10,000	$0.72	$0.97	$1.74	$12.30
10,001-50,000	$0.30	$0.43	$0.46	$3.34
50,001-100,000	$0.17	$0.49	$0.73	$9.12
100,001-1,000,000	$0.18	$0.15	$0.20	$1.44
TOTAL	$1.26	$2.40	$2.67	$13.98

Exhibit 6–20.
Mean Annual Household Costs of the GWR Across Regulatory Options for Public and Private CWSs Taking Corrective Action or Fixing Significant Defects

SIZE CATEGORIES	Sanitary Survey Option	Sanitary Survey and Triggered Monitoring Option	Multi-Barrier Option	Across-the-Board Disinfection Option
<100	$29.86	$67.19	$62.48	$191.87
101-500	$11.23	$15.02	$18.95	$81.38
501-1,000	$5.72	$6.29	$6.25	$38.79
1,001-3,300	$2.99	$2.91	$3.39	$23.45
3,301-10,000	$1.39	$1.46	$2.74	$16.78
10,001-50,000	$0.62	$0.59	$0.62	$4.87
50,001-100,000	$0.30	$0.70	$1.01	$10.37
100,001-1,000,000	$0.32	$0.20	$0.27	$1.66
TOTAL	$2.45	$3.34	$3.86	$19.37

6.5 References

Abbaszadegan, M., P.W. Stewart, M.W. LeChevallier, Rosen, Jeffery S. and C.P. Gerba. 1998/1999. *Occurrence of viruses in ground water in the United States.* American Water Works Association Research Foundation. Denver, CO, 157 p.

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7. Economic Impact Analysis

7.1 Introduction

As part of the rule promulgation process, EPA is required to perform a series of distributional analyses that address the potential regulatory burden placed on entities that are affected by the various rule requirements. This chapter contains EPA's analysis and statements with regard to five federal mandates: Executive Order 12886 (Regulatory Planning and Review); the Regulatory Flexibility Act (RFA) of 1980, as amended by the Small Business Regulatory Enforcement Fairness Act (SBREFA) of 1996; the Unfunded Mandates Reform Act (UMRA) of 1995; Executive Order 13045 (Protection of Children From Environmental Health Risks and Safety Risks); and Executive Order 12989 (Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations). A summary of an additional analysis, conducted to fulfill requirements set forth by the Paperwork Reduction Act, is addressed within this chapter, but the actual analysis is contained in a separate document, *Information Collection Request for the Ground Water Rule*.

Several of these directives contain provisions requiring an explanation of why the rule is necessary, the statutory authority upon which it is based, and the primary objectives it is intended to achieve. A complete discussion of the background information and the statutory authority for this rulemaking is located in Chapter 2, "Need for Proposal." Specifically, section 2.5.1 addresses the statutory authority for promulgating this rule. The RFA and SBREFA analyses are contained in section 7.2 while the UMRA analysis is in Section 7.3. Issues such as the paperwork burden of this proposed rule, children's health and safety, and environmental justice are addressed in sections 7.4, 7.5, and 7.6, respectively.

7.2 Regulatory Flexibility Act and Small Business Regulatory Enforcement Fairness Act

Under the Regulatory Flexibility Act (RFA), 5 U.S.C. 601 <u>et seq</u>., as amended by the Small Business Regulatory Enforcement Fairness Act (SBREFA), EPA is required to prepare a regulatory flexibility analysis unless the Agency certifies that the rule will not have "a significant economic impact on a substantial number of small entities." A regulatory flexibility analysis describes the impact of the regulatory action on small entities as part of the rule promulgation process. The Agency must also consult with small entity representatives (SERs) and convene a Small Business Advocacy Review (SBAR) Panel prior to publication of the proposed rule if the Agency is unable to certify that the rule will not have a significant economic impact on a substantial number of small entities. The SBAR Panel has 60 days to consult with SERs likely to be impacted by the rule and to make recommendations designed to reduce the impact of the proposed rule on small entities. The Agency must consider these recommendations when drafting the proposed rule. Because the Agency was unable to certify the GWR, the Agency convened a SBAR Panel.

The SBAR Panel members for the GWR were the Small Business Advocacy Chair of the Environmental Protection Agency, the Director of the Standards and Risk Management Division in the Office of Ground Water and Drinking Water (OGWDW) within EPA's Office of Water, the Administrator for the Office of Information and Regulatory Affairs of the Office of Management and Budget (OMB), and the Chief Counsel for Advocacy of the Small Business Administration (SBA). The Panel convened on April 10, 1998 and met seven times before the end of the 60-day period on June 8, 1998. The culmination of these meetings was the SBAR Panel's report, *Final Report of the SBREFA Small Business Advocacy Review Panel on EPA's Planned Proposed Rule for National Primary Drinking Water Regulations: Ground Water*. The SER comments on components of the GWR, and the background information provided to the SBAR Panel and the SERs are available for review in the water docket. This information and the Agency's response to the Panel's recommendations in developing the proposed GWR are summarized below.

7.2.1 Definition of Small Entity for the GWR

The Agency has taken comment on and finalized its intent to define "small entity" as a public water system that serves 10,000 or fewer persons for purposes of its regulatory flexibility assessments under the RFA for all future drinking water regulations. See Consumer Confidence Reports (CCR) Final Rule, 63 FR 44511, Aug. 19, 1998 and Proposed Rule, 63 FR 7620 Feb.13, 1998. The Agency discussed at length in the preamble to the proposed rule, the basis for its decision to use this definition and to use the single definition of small public water system whether the system was a "small business," "small nonprofit organization," or "small governmental jurisdiction." EPA also consulted with the Small Business Administration on the use of this definition as it relates to small businesses. Subsequently, the Agency has used this definition in developing its regulations under the Safe Drinking Water Act. In defining small entities in this manner, EPA recognizes that baseline conditions in source water and treatment and operational practices may differ for systems serving fewer than 10,000 people when compared to systems serving 10,000 or more persons.

7.2.2 Requirements for the Initial Regulatory Flexibility Analysis

The Regulatory Flexibility Act requires EPA to complete an Initial Regulatory Flexibility Analysis (IRFA) addressing the following:

- The need for the rule;
- The objectives of and legal basis for the proposed rule;
- A description of, and where feasible, an estimate of the number of small entities to which the rule will apply;
- A description of the proposed reporting, record keeping, and other compliance requirements of the rule, including an estimate of the types of small entities, which will be

subject to the requirements and the type of professional skills necessary for preparation of reports or records;

- An identification, to the extent practicable, of all relevant federal rules that may duplicate, overlap, or conflict with the proposed rule; and

- A description of "any significant regulatory alternatives" to the proposed rule that accomplish the stated objectives of the applicable statutes, and that minimize any significant economic impact of the proposed rule on small entities; the analysis is to discuss significant regulatory alternatives such as:

  - Establishing different compliance or reporting requirements or timetables that take into account the resources of small entities;
  - Clarifying, consolidating, or simplifying compliance and reporting requirements under the rule for small entities;
  - Using performance rather than design standards; and
  - Exempting small entities from coverage of the rule or any part of the rule

To assist the SERs and the SBAR Panel in their deliberations, OGWDW prepared an IRFA to provide some background on the need for the proposed rule and the possible components of a rule. Prior to convening the SBAR Panel, OGWDW consulted with a group of 22 SERs likely to be impacted by a GWR. The SERs included small system operators, local government officials, small business owners (e.g., a bed and breakfast with its own water supply), and small nonprofit organization (e.g., a church with its own water supply for the congregation). The SERs were provided with background information on the rule, on the need for the rule and the potential requirements. The SERs were asked to provide input on the potential impacts of the rule from their perspective. All 22 SERs commented on the information provided in the IRFA. These comments were provided to the SBAR Panel when the Panel convened. After a teleconference between the SERs and the Panel, the SERs were invited to provide additional comments on the information provided. Three SERs provided additional comments on the rule components after the teleconference.

In general, the SERs consulted on the GWR were concerned about the impact of the rule on small water systems (because of their small staff and limited budgets), the additional monitoring that might be required, and the data and resources necessary to conduct a hydrogeologic sensitivity assessment or sanitary survey.

The SBAR Panel suggested that, given the number of systems that could be affected by the rule, EPA consider focusing compliance requirements on those systems most at risk of fecal contamination. From this perspective, the panel suggested that EPA evaluate whether it would be appropriate to establish different rule requirements for systems based on system type, size or location. The Panel also suggested providing States with maximum flexibility, consistent with ensuring an appropriate minimum level of public health protection, to tailor specific requirements to individual system needs and resources.

The SBAR Panel's recommendations to address the SERs Ground Water Rule concerns were considered in developing the regulatory options analyzed in this rulemaking. The results of an updated analysis of the impact of the preferred regulatory option on small water systems options is presented below.

7.2.3 Small Entity Impacts

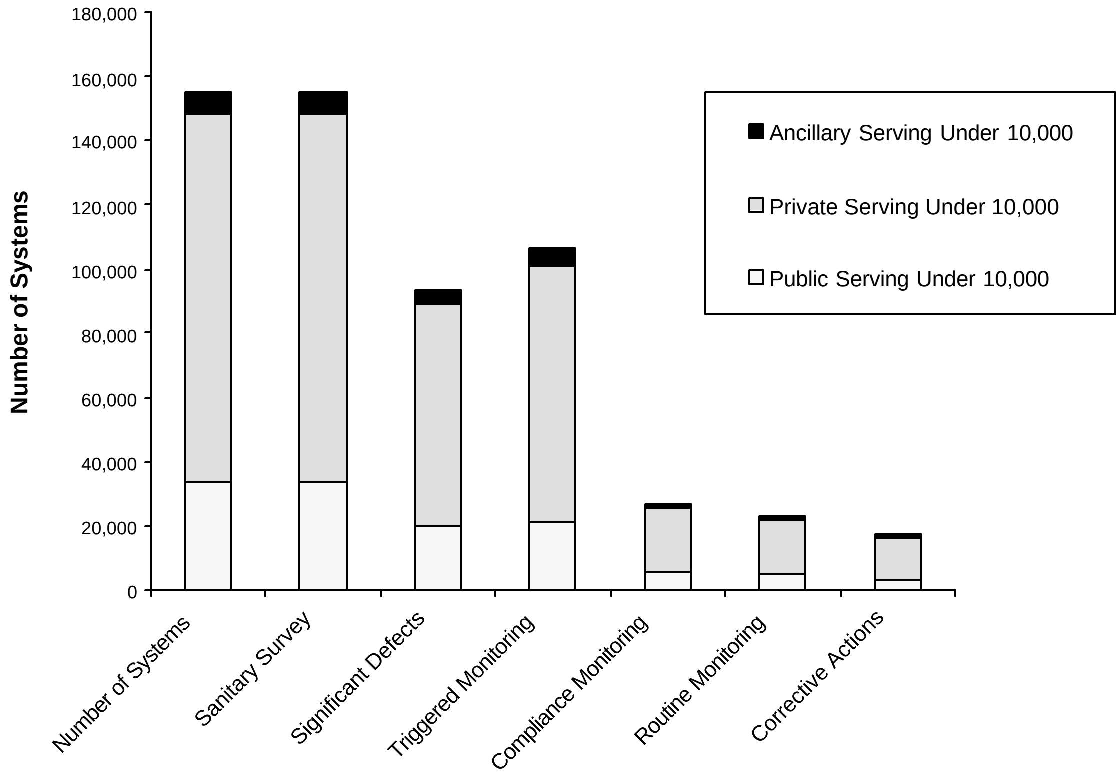
For purposes of this regulatory flexibility analysis, the results of the economic impact analysis for small water systems under the proposed Multi-Barrier option are summarized. Estimates of the number of small entities affected and the cost of complying with each component of the Multi-Barrier approach are presented. The estimated impacts for this preferred option are based on the national mean compliance cost across the four compliance scenarios. Since taking an arithmetic mean of the system-level impacts across compliance scenarios is not possible, system-level impacts are investigated using various corrective action and significant defects scenarios. The high correction action/low significant defect scenario is considered a middle-of-the-road cost scenario in the following discussion.

7.2.3.1 Number of Small Entities Affected

According to the December 1997 data from EPA's Safe Drinking Water Information System (SDWIS), there are 156,846 community water systems and noncommunity water supplies providing potable ground water to the public, of which 155,254 (99 percent) are classified by EPA as small entities. These are presented in Exhibit 4-1 and 4-2. EPA estimates that these small ground water systems served a population of more than 48 million. Roughly one-quarter of these systems were estimated to be community water systems serving fixed populations on a year-round basis.

Under the proposed option, all community and noncommunity water systems are affected by at least one requirement of the GWR, namely, the sanitary survey provision. The other GWR components are estimated to affect different numbers of small systems. Exhibit 7–1 shows the estimates of affected systems for each component of the proposed Multi-Barrier GWR option.

Exhibit 7-1. Number of Small Systems Effected by the GWR (By Rule Component)



7.2.3.2 Reporting and Recordkeeping

Under the preferred option, Option 3—Multi-Barrier Approach, there are a number of recordkeeping and reporting requirements for all ground water systems (including small systems). To minimize the burden with these provisions, the EPA is proposing a targeted risk-based regulatory strategy for the GWR whereby the monitoring requirements are based on system characteristics and are not directly related to system size. In this manner, the Multi-Barrier option takes a system-specific approach to regulation, although a sanitary survey is required of all community and nontransient noncommunity water systems. However, the implementation schedule for this requirement is staggered (e.g., every three to five years for CWSs and every five years for NCWSs), which should provide some relief for small systems because there are proportionately more NCWSs.

To address the SBAR's concern for the potential cost of additional monitoring for small systems, the proposed GWR leverages the existing TCR monitoring framework to the extent possible (e.g., by using the results of the routine TCR monitoring to determine if source water monitoring is required). In this proposal, a system is required to test for the presence of *E.coli,* coliphage, or enterococci in the source water within 24 hours of a total coliform positive sample in the distribution system.

Only systems determined to be sensitive that do not already treat to 4-log inactivation or removal are required to conduct the additional routine monitoring. These systems must test their source water monthly for a year. If no fecal indicators are found after 12 months of monitoring, the State may reduce the monitoring frequency for that system. Similarly, if a nonsensitive system does not have a distribution system, any sample taken for TCR compliance is effectively a source water sample so an additional triggered source water sample would not be required. In both cases, however, if the system has a positive sample for *E.coli*, coliphage, or fecal coliform, the system is required to conduct the necessary follow-up actions.

The estimated record keeping and reporting burden associated with these provisions of the rule are presented in Section 7.5 (Paperwork Reduction Act) below.

7.2.3.3 Small Entity Compliance Costs

When determining the costs and benefits of this proposed rule, EPA considered the full range of both potential costs and benefits for the rule. The flexibility of the risk-based targeted approach of the rule aims to reduce the cost of compliance with the rule. Small systems, in particular, benefit from this design. Estimates of compliance costs of the Multi-Barrier approach to these systems are presented below in Exhibit 7–2.

Given the available data, EPA determined that an expenditure test was the most reliable method to gauge the potential economic impact of the proposed GWR on small systems. Using information on current, or baseline, CWS expenses from the 1995 CWSS and the estimated cost impacts of the proposed GWR, EPA developed a Monte Carlo simulation model to estimate the effect of GWR compliance expenditures on total small water system expenses. Exhibit 7–2 provides the basic results of this analysis. For each CWS size category, the mean system-level baseline expenses, mean system-level GWR compliance costs, the mean system-level after-rule total expenses, and the mean percentage increase in system-level total expenses is shown. This analysis shows that the smallest water systems, those serving populations of fewer than 100 persons, will experience the greatest adverse impact, relative to current expense levels (12%increase). Meanwhile, on average, systems serving over 1,000 people will see a very modest increase in total expenses (1% increase).

Of course, examining average impacts masks the distributional impacts of the proposed GWR. Exhibits 7–3 through 7–7 show the detailed results of the simulation model, which estimated the distribution of baseline expenses and projected expenses after compliance with the Multi-Barrier option (preferred rule option). The percentage increase in expenses is also provided. These charts illustrate two important points. First, in the smallest CWS size category, half of the systems will see their total expenses rise by more than 10 percent as a result of the GWR. Ten percent of these smallest of systems will see their annual expenses double after compliance with the proposed rule. On the other hand, in a somewhat larger CWS size category (i.e., those serving 1,000 to 3,300 people), half of the systems will have an increase in total expenses of about one percent, while only two percent of systems will see their annual expenses double.

Exhibit 7–4. Comparison of CWS Baseline and Post-Compliance Expenses (Systems Serving 101–500 People)

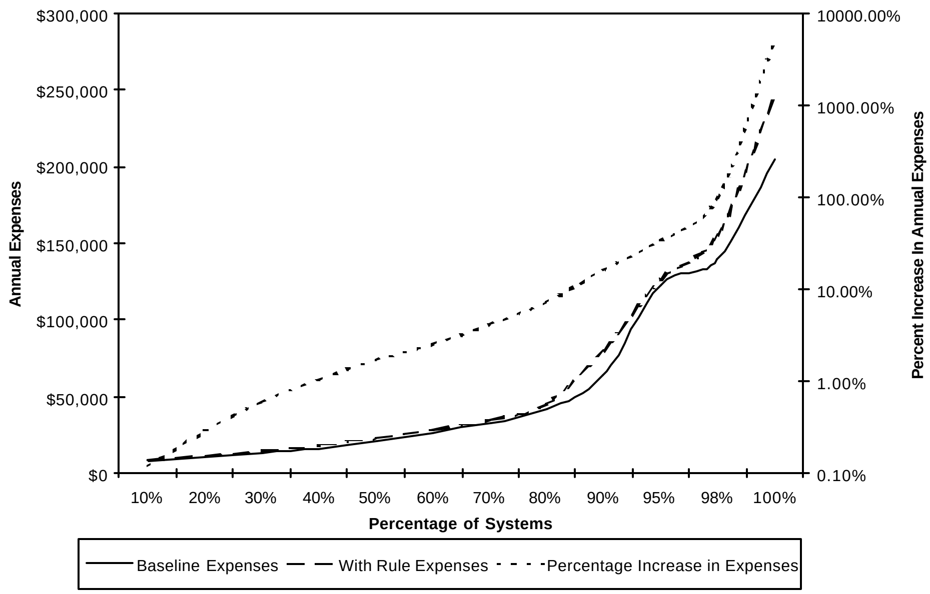


Exhibit 7–5. Comparison of CWS Baseline and Post-Compliance Expenses (Systems Serving 501–1,000 People)

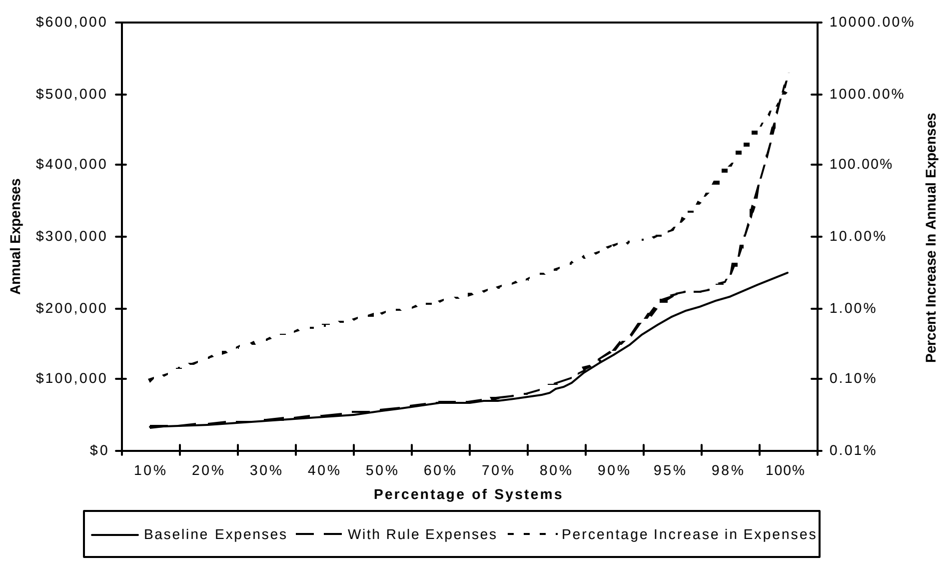
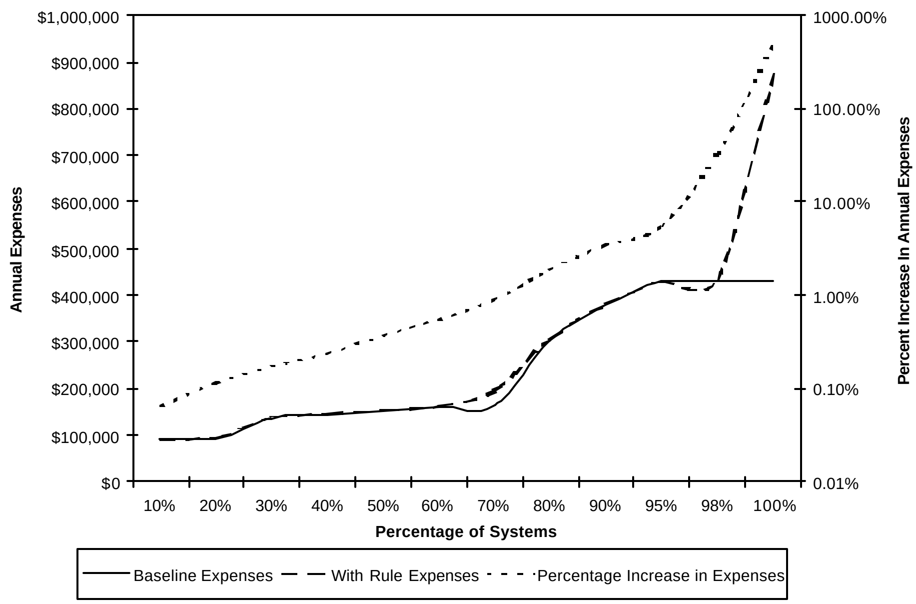


Exhibit 7–6. Comparison of CWS Baseline and Post-Compliance Expenses (Systems Serving 1,001–3,300 People)



7.2.4 Coordination With Other Federal Rules

To avoid duplication of effort, the proposed GWR encourages States to use their source water assessments, which are being developed by each State, when the assessment provides data relevant to the sensitivity assessment of a system. The schedule for the sensitivity assessment (within three years for CWS and five years for NCWS) should allow States to complete the assessment and the first round of sanitary surveys concurrently if they choose to do so.

EPA has structured this GWR proposal as a targeted, risk-based approach to reducing fecal contamination. The only regulatory requirement that applies to all ground water systems is the sanitary survey. The required frequency for community systems is once every three years, which may be changed by the State to once every five years if the system either treats to 4-log inactivation for removal of virus or has an outstanding performance record documented in previous inspections and has no history of total coliform MCL or monitoring violations since the last sanitary survey under current ownership. The required frequency for sanitary surveys is every five years for noncommunity systems. The majority of the small systems are noncommunity systems so the majority of systems will only have a sanitary survey once every five years. At this frequency, EPA believes that the requirements will not be burdensome for even the smallest systems. Similarly, the only additional monitoring requirements in today's proposal are for undisinfected systems that are either located in sensitive hydrogeologic settings or have a total coliform positive sample in the distribution system. The monitoring required for a total coliform positive sample under the TCR would be a one-time event while the monitoring for sensitive systems would be on a routine monthly basis for at least a year.

Finally, the SBAR Panel noted that disinfection of public water supplies may result in an increase in other contaminants of concern, depending on the characteristics of the source water and the distribution system. Of particular concern were disinfection byproducts, lead, copper, and arsenic. EPA believes that these issues, when they occur will be very localized and may be addressed through selection of the appropriate corrective action. EPA has provided States and systems with the flexibility to select among a variety of corrective actions. These include options such as UV disinfection, or purchasing water from another source, which should avoid problems with other disinfection.

7.2.5 Minimization of Economic Burden

On an annual basis, the cost of the preferred alternative is $182.7 million, assuming an interest rate (i.e., cost of capital) of three percent (or $198.6 million, assuming an interest rate of seven percent). In developing this proposal, however, EPA considered the recommendations of the SBAR to minimize the cost impact to small systems. The proposed multi-barrier, risk-based approach was designed to achieve maximum public health protection while avoiding excessive compliance costs associated with Across-the-Board Disinfection regulatory compliance requirements.

To mitigate the associated compliance cost increases across water systems, the proposed GWR also provides States with considerable flexibility when implementing the rule. This flexibility, recommended also by the SBAR, will allow States to work within their existing program, but give systems and the general public a clear understanding of what constitutes a significant deficiency. Similarly, the rule allows States to consider the characteristics of individual systems when determining an appropriate corrective action. States have the flexibility to use any disinfection treatment technology, provided it achieves 4-log inactivation or removal of pathogens.

To determine the costs and benefits of this proposed rule, EPA considered the full range of potential costs and benefits for the rule. The flexibility in the rule is designed to reduce the cost of compliance with the rule, particularly for small systems. While determining the costs of the various technologies, EPA estimated the percentage of systems in consultation with the States that will choose between the different technologies, in part based on system size. EPA also considered a range of benefits from reduction in illness and mortality to avoided cost of averting behavior, reduced uncertainty, and avoided outbreak costs. However, only reductions in acute viral and bacterial illnesses and mortality from virus are monetized. More detailed information is included in Chapter 5 ("Benefits Analysis") and Chapter 6 ("Cost Analysis") of this RIA.

EPA further recognized that the operational characteristics of water systems' are highly variable. In this proposal, State's have considerable flexibility when working with systems to address significant deficiencies and take corrective action.

7.3 Unfunded Mandates Reform Act

Title II of the Unfunded Mandates Reform Act of 1995 (UMRA), P.L. 104-4, establishes requirements for Federal agencies to assess the effects of their regulatory actions on State, local, and Tribal governments and the private sector. Under UMRA section 202, EPA generally must prepare a written statement, including a cost-benefit analysis, for proposed and final rules with "Federal mandates" that may result in expenditures to State, local, and Tribal governments, in the aggregate, or to the private sector, of $100 million or more in any one year. Before promulgating an EPA rule, for which a written statement is needed, section 205 of the UMRA 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. 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 on why that alternative was not adopted.

Before EPA establishes any regulatory requirements that may significantly or uniquely affect small governments, including Tribal governments, it must have developed, under section 203 of the UMRA, a small government agency plan. The plan must provide for notification to 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 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, and the private sector in any one year. Accordingly, under Section 202 of the UMRA, EPA is obligated to prepare a written statement addressing:

- The authorizing legislation;

- Cost-benefit 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;

- Macro-economic 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; and

- 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 authorizing legislation, item one, is described in section 2.5.1. Items two through five are addressed below, with the exclusion of future compliance costs, which are discussed in Chapter 6. Regulatory alternatives, item six, are addressed in Chapter 3 and Chapter 6. Chapter 8 shows the cost effectiveness analysis for each option.

7.3.1 Social Costs and Benefits

The social benefits are those that primarily accrue to the public through an increased level of protection from viral and bacterial illness due to exposure to microbial pathogens in drinking water. To assign a monetary value to the illness, EPA used cost-of-illness by several age categories to estimate the benefits from the reduction in viral illness that result from this rule. This is considered 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 benefit analysis, which includes both qualitative and monetized benefits of improvements to health and safety. The estimated annual benefit of the proposed GWR is $205 million under the Multi-Barrier Option.

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 GWR. Under the preferred option of the GWR, the likely compliance scenario is expected to result in a total annualized cost of approximately $182.7 million using a three percent discount rate (or $198.6 million using a seven percent discount rate).

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 Grants Program. Additional funding is available from other programs administered either by EPA or other Federal agencies. These include EPA’s Drinking Water State Revolving Fund (DWSRF), U.S. Department of Agriculture’s Rural Utilities’ Loan and Grant Program, and Housing and Urban Development’s Community Development Block Grant Program.

For example, SDWA authorizes the Administrator of the EPA to award capitalization grants to States, which in turn can provide low cost loans and other types of assistance to eligible public water systems. The DWSRF assists public water systems with financing the costs of infrastructure needed to achieve or maintain compliance with SDWA requirements. Each State has considerable flexibility in determining 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 to the Drinking Water State Revolving Fund from the Clean Water State Revolving Fund.

Furthermore, a State can use the financial resources of the DWSRF to assist small systems the majority of which are ground water systems. In fact, a minimum of 15 percent of a State’s DWSRF grant must be used to provide infrastructure loans to small systems. Two percent of the State's grant may be used to provide technical assistance to small systems. For small systems that are disadvantaged, up to 30 percent of a State's DWSRF may be used for increased loan subsidies. Under the DWSRF, tribes have a separate set-aside which they can use.

In addition to the DWSRF, money is available from the Department of Agriculture's Rural Utility Service (RUS) and Housing and Urban Development's Community Development Block Grant (CDBG) program. RUS provides loans, guaranteed loans, and grants to improve, repair, or construct water supply and distribution systems in rural areas and towns up to 10,000 people. In fiscal year 1997, the RUS had over $1.3 billion in available funds. Also, three sources of funding exist under the CDBG program to finance building and improvements of public faculties such as water systems. The three sources of funding include: 1) direct grants to communities with populations over 200,000; 2) direct grants to States, which they in turn award to smaller communities, rural areas, and colonies in Arizona, California, New Mexico, and Texas; and 3) direct grants to U.S. Territories and Trusts. The CDBG budget for fiscal year 1997 totaled over $4 billion.

7.3.2 Disproportionate Impacts

This analysis examines disproportionate impacts upon geographic or social segments of the nation. In general, the costs that a public water system, whether publicly or privately owned, will incur to comply with this rule will depend on many factors that are not generally based on location. However, the data needed to confirm this assessment and to analyze other impacts of this problem are not available; therefore, EPA looked at three other factors:

- The impacts of small versus large systems and the impacts within the five small system size categories;
- The costs to public versus private water systems; and
- The costs to households (See Section 6.4).

The first measure of disproportionate impact considers the cost incurred by small and large systems. Small systems will experience a greater impact than large systems under the GWR. The higher cost to the small ground water systems is mostly attributable to the large number of these types of systems (i.e., 99 percent of ground water systems serve <10,000 people). Other reasons for the disparity include: 1) large systems are more likely to already disinfect their ground water (disinfection exempts a system from triggered and routine monitoring), 2) they typically have greater technical and operational expertise, and 3) they are more likely to engage in source protection programs. The potential economic impact among the small systems will be the greatest for systems serving less than 100 persons, as shown in Exhibits 6–19 and 6–20.

The second measure of impact is the relative total cost to privately owned water systems compared to that incurred by publicly owned water systems. Exhibit 7–8 reveals that 28 percent of the system compliance costs are borne by publicly owned PWSs, while 61 percent is borne by privately owned PWSs. This is a result of the fact that 73 percent of PWSs are owned by private entities. EPA has no basis for expecting cost per system to differ systematically with ownership.

The costs to households has been examined and is summarized in Section 6.4 of this document.

Exhibit 7-8. Annual Compliance Cost Impacts by PWS Ownership

3 Percent Discount Rate		
SYSTEM TYPE	**Cost (million $)**	**% of Total Cost**
Public System Cost	$52.0	28%
State Cost	$20.6	11%
Total Public Cost	$72.6	39%
Private System Cost	$103.8	57%
Ancilliary System Cost	$6.4	4%
Total Private Cost	$110.2	61%
7 Percent Discount Rate		
SYSTEM TYPE	**Cost (million $)**	**% of Total Cost**
Public System Cost	$56.5	28%
State Cost	$22.1	11%
Total Public Cost	$78.7	39%
Private System Cost	$113.0	57%
Ancilliary System Cost	$7.0	4%
Total Private Cost	$119.9	61%

7.3.3 Macro Economic Effects

Under UMRA Section 202, EPA is required to estimate the potential macro-economic effects of the regulation. Macro-economic 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 Gross Domestic Product (GDP). In 1998, real GDP was $7,552 billion so a rule would have to cost at least $19 billion 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 macro-economic effects on the national economy from the proposed GWR should be negligible based on the fact that the total expected annual costs of the preferred regulatory option for this rule are estimated to be $182.7 million using a three percent discount rate (or $198.6 million using a seven percent discount rate).

7.3.4 Consultations with State, Local, and Tribal Governments

Consistent with the intergovernmental consultation provisions of section 204 of UMRA section 204 of the UMRA and Executive Order 12875 "Enhancing the Intergovernmental Partnership," EPA has initiated consultations with the governmental entities affected by this rule. EPA held four public meetings for all stakeholders and two Association of State Drinking Water Administrators early involvement meetings. Because of the Rule's impact on small entities, the Agency convened a Small Business Advocacy Review (SBAR) Panel in accordance with the Regulatory Flexibility Act (RFA) as amended by the Small Business Regulatory Enforcement Fairness Act (SBREFA) to address small entity concerns, including small local governments specifically. EPA consulted with small entity representatives prior to convening the Panel to get their input on the GWR. Of the 22 small entity participants, five represented small governments. EPA also made presentations on the GWR to the national and local chapters of the American Water Works Association, the Ground Water Foundation, the National Ground Water Association, the Rural Water Association, and the National League of Cities. Twelve State drinking water representatives also participated in the Agency's GWR workgroup.

In addition to these consultations, EPA circulated a draft of this proposed rule and requested comment from the public through an informal process. Specifically, on February 3, 1999, EPA posted on the EPA's Internet web page and mailed out over 300 copies of the draft to people who had attended the 1997 and 1998 public stakeholder meetings as well as people on the EPA workgroup. EPA received 79 letters or electronic responses to this draft: 34 from State government (representing 30 different States), 25 from local governments, 10 from trade associations, six from Federal government agencies, and four from other people/organizations. No comments were received from Tribal governments. EPA reviewed the comments and carefully considered their merit. The proposed GWR reflects many of the commentors' points and suggestions.

To inform and involve Tribal governments in the rulemaking process, EPA presented the GWR at the 16th Annual Consumer Conference of the National Indian Health Board, at the annual conference of the National Tribal Environmental Council, and at an Office of Ground Water and Drinking Water (OGWDW)/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 over 100 tribes were represented at the annual conference of the National Tribal Environmental Council. At both conferences, an OGWDW representative conducted two workshops on EPA's drinking water program and upcoming regulations, including the GWR.

Comments received from Tribal governments regarding the GWR focused on concerns and some opposition to mandatory disinfection for ground water systems. They also suggested that any waiver process be adequately characterized by guidance and simple to implement. The proposed

GWR was designed so that a majority of systems will not be required to disinfect. Systems will have the opportunity to correct significant deficiencies, find a new source, and in some cases monitor for fecal contamination. Disinfection is only required under the proposed GWR if these other measures do not work. However, some systems in coordination with the primacy agent or State, might choose disinfection over these other options because it may be the least costly alternative.

At the OGWDW/Inter Tribal Council of Arizona meeting, representatives from 15 tribes participated. In addition, over 500 tribes and Tribal organizations were sent the presentation materials and meeting summary. Because many tribes have ground water systems, participants expressed concerns over some elements of the rule. Specifically, they had concerns about how the primacy agent would determine significant deficiencies identified in a sanitary survey and how the sensitivity assessment would be conducted. Because no tribes currently have primacy, EPA is the primacy agent and will identify significant deficiencies as part of sanitary surveys and conduct the sensitivity assessments.

7.4 Paperwork Reduction Act

The information collected as a result of this rule will allow the State and EPA to evaluate PWS compliance with the rule. For the first three years after promulgation of this rule, the major information requirements pertain to start up costs for States to satisfy primacy requirements and systems to become familiar with the rule. Responses to the request for information are mandatory (Part 141). The information collected is not confidential.

EPA is required to estimate the burden on PWS for complying with the GWR. Burden means the total time, effort, or financial resources expended by persons to generate, maintain, retain, or disclose or provide information to or for a Federal agency. This includes the time needed to review instructions; develop, acquire, install, and utilize technology and systems for the purposes of collecting, validating, and verifying information, processing and maintaining information, and disclosing and providing information; adjust the existing ways to comply with any previously applicable instructions and requirements; train personnel to be able to respond to a collection of information; search data sources; complete and review the collection of information; and transmit or otherwise disclose the information.

Exhibit 7–9 presents EPA's estimates of the annual burden on PWS and States for reporting and record keeping from the first three years after promulgation of the preferred multi-barrier option. It should be noted that the majority of the monitoring, record keeping and reporting burden occurs beyond the three-year period of the estimate. The Information Collection Request prepared by EPA, includes a estimate for 10-year time frame to show the costs and burdens beyond the initial period covered by the ICR, to reflect the reality of full rule implementation.

**Exhibit 7–9. Summary of the Ground Water Rule
Total Respondents, Responses, Burden, and Costs for PWSs and States**

	Number Respondents Annually	Number Responses Annually	Total Annual Burden (hrs)	Total Annual Labor Cost	Total Annual Capital Cost	Total Annual O&M Cost
PWSs	52,331	99,821	263,238	$7,819,882	$1,376,302	$0
States and Territories	56	168	88,107	$2,332,979	$ 0	$ 0
Total	52,387	99,989	351,345	$10,152,861	$1,376,302	$0

7.5 Protecting Children From Environmental Health Risks and Safety Risks

Executive Order (EO) 13045 (62 *FR* 19885, April 23, 1997) applies to any rule initiated after April 21, 1997, or proposed after April 21, 1998, that (1) is determined to be "economically significant" as defined under E.O. 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 EPA.

As discussed in Chapter 5 of this RIA, in developing the risk and benefits analysis for the GWR, the effects on children, both in terms of unique risk and cost-of-illness estimates, were explicitly taken into consideration. This analysis suggests that the proposed rule provides a greater per capita health benefit to children than to adults, mostly due to the high cost-of-illness associated with viral illnesses avoided in young children. In other words, the analysis suggests that the viral and bacterial illnesses of concern to the GWR disproportionately effect children, and therefore, the benefits of the proposed rule accrue disproportionately to children.

As can be seen in Exhibit 7–10, the proposed Multi-Barrier option results in the second most number of cases of illness avoided–second only to the Across-the-Board Disinfection option. Given the extraordinary costs of the Across-the-Board Disinfection option, EPA believes that the proposed Multi-Barrier option is the most protective of children's health of all reasonably feasible alternatives.

Exhibit 7–10. Viral Illnesses and Deaths Avoided In Children Across Regulatory Alternatives

GWR Option	Sanitary Survey	Sanitary Survey and Triggered Monitoring	Multi-Barrier	Across-the-Board Disinfection
Number of Viral Illnesses Avoided per Year				
< 5 years old	2,292	13,044	15,058	21,125
5-16 years old	1,773	9,974	11,508	16,059
Number of Viral Deaths Avoided per Year				
< 5 years old	0	1	1	1
5-16 years old	0	1	1	2
Annual Cost (million $)				
3% discount rate	$72.7	$157.6	$182.7	$777.1
7% discount rate	$76.0	$168.5	$198.6	$866.0

With regard to sensitive sub-populations, EPA explicitly examined the effects of the proposed rule both on young children and immuno-compromised individuals. As discussed above, Exhibit 7–10, illustrates that the proposed Multi-Barrier option is the most protective of children's health of all reasonably feasible alternatives. Similarly, Exhibit 7–11, below shows that the proposed Multi-Barrier option results in the second most number of cases of illness avoided among immuno-compromised individuals–second only to the Across-the-Board Disinfection option. Given the extraordinary costs of the Across-the-Board Disinfection option, EPA believes that the proposed Multi-Barrier option is the most protective of immuno-compromised individuals' health of all the reasonably feasible alternatives.

Exhibit 7–11. Viral Illnesses Avoided in Immuno-Compromised Persons Across Regulatory Alternatives

GWR Option	Sanitary Survey	Sanitary Survey and Triggered Monitoring	Multi-Barrier	Across-the-Board Disinfection
Number of Viral Illnesses Avoided per Year				
< 5 years old	23	130	151	211
5-16 years old	18	100	115	161
> 16 Years Old	191	1,086	1,253	1,746
Number of Viral Deaths Avoided per Year				
< 5 years old	0.00	0.01	0.01	0.01
5-16 years old	0.00	0.00	0.00	0.01
> 16 Years Old	0.01	0.03	0.04	0.05
Annual Cost (million $)				
3% discount rate	$72.7	$157.6	$182.7	$777.1
7% discount rate	$76.0	$168.5	$198.6	$866.0

7.6 Environmental Justice

Executive Order 12898 establishes a Federal policy for incorporating environmental justice into Federal agency missions by directing agencies to identify and address disproportionately high and 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 has consulted with minority and low-income stakeholders.

The Environmental Justice Executive Order requires the Agency to consider environmental justice issues in the rulemaking and to consult with Environmental Justice (EJ) stakeholders. There are two aspects of the proposed GWR that relate specifically to this policy, the overall nature of the rule, and the convening of a stakeholder meeting specifically to address environmental justice issues.

As part of EPA's responsibilities to comply with Executive Order 12898, the Agency held a stakeholder meeting on March 12, 1998 to address various components of pending drinking water regulations; and how they may impact sensitive sub-populations, minority populations, and low-income populations. Topics discussed included treatment techniques, costs and benefits, data quality, health effects, and the regulatory process. Participants included national, State, Tribal, municipal, and individual stakeholders. EPA conducted the meetings by video conference call with participants in eleven cities. This meeting was a continuation of stakeholder meetings that started in 1995 to obtain input on the Agency's Drinking Water Programs. The major objectives for the March 12, 1998 meeting were:

- Solicit ideas from Environmental Justice stakeholders on known issues concerning current drinking water regulatory efforts;

- Identify key issues of concern to EJ stakeholders; and

- Receive suggestions from EJ stakeholders concerning ways to increase representation of Environmental Justice communities in EPA regulatory efforts.

In addition, EPA developed a plain-English guide specifically for this meeting to assist stakeholders in understanding the multiple and sometimes complex drinking water issues.

The GWR applies to all public water systems that use ground water as their source water, including community water systems, nontransient noncommunity water systems, and transient noncommunity water systems. Consequently, the health protection benefits provided by this proposed rule are equal across all of the income and minority groups served by these systems. Existing regulations such as the Surface Water Treatment Rule and Interim Enhanced Surface Water Treatment Rule provide similar health benefit protection to communities that use surface water or ground water under the influence of surface water. Therefore, EPA believes this rule will equally protect the health of all minority and low-income populations served by systems regulated under this rule from exposure to microbial contamination.

8. Summary of Costs and Benefits

8.1 Review of Regulatory Options, Costs and Benefits

The proposed Ground Water Rule (GWR) must specify the appropriate use of disinfection treatment and simultaneously addresses other components of ground water system operation and maintenance to assure public health protection. In this RIA, EPA has analyzed the cost and health benefit impacts associated with four regulatory options. Since the basic provisions for the four options build upon one another, the associated costs and benefits are also expected to increase from the less stringent to the more stringent options. Chapter 5 ("Benefits Analysis") described in detail the estimated national health benefits of the GWR regulatory options, while Chapter 6 ("Cost Analysis") described the projected national compliance cost estimates. This chapter presents a summary and comparison of the national benefits and costs for each of these four regulatory options.

8.1.1 Review of Regulatory Options

The four regulatory options that EPA evaluated for this proposed rulemaking capture a range of benefits and costs based on the number of PWSs estimated to be affected by the specific compliance requirements. Each option, for example, assumes that a different proportion of PWSs will be required to take action, depending on the requirement set forth under the rule option. In general, these four options may be characterized by the main regulatory requirements summarized in Exhibit 8–1 below.

Exhibit 8–1. GWR Regulatory Options and Main Requirements

Regulatory Compliance Requirement	GWR Option			
	Option: 1 Sanitary Survey Only	Option: 2 San. Survey & Triggered Monitoring	Option 3: Multi-Barrier Approach[1]	Option 4: Across-the-Board Disinfection
Sanitary survey	T	T	T	T
Triggered monitoring		T	T	
Hydrogeologic sensitivity assessment and routine monitoring			T	
All systems must install or upgrade and maintain treatment				T
[1] Preferred Option				

EPA has selected the Multi-Barrier Option as its preferred option. Based upon the information presented in this document, EPA believes that monetized net benefits may be maximized under the Multi-Barrier option, that this option provides additional benefits that EPA did not monetize, and that it is best achieves the rule's objective to reduce the risk of illness and death from microbial contamination in PWSs relying on ground water.

As shown in Exhibit 8–1 above, the regulatory requirements build incrementally upon one another for a more targeted approach to identify and correct any systems not in compliance. The exception to this trend is the Across-the-Board Disinfection option, which requires that all ground water systems achieve and demonstrate 4-log treatment (inactivation and/or removal). The components and differences between these regulatory scenarios are discussed in more detail in Chapter 3 (“Consideration of Regulatory Options”).

8.1.2 Review of National Cost Estimates

Exhibit 8–2 presents EPA’s estimates for the total national cost for the four GWR regulatory scenarios. Using a 3 percent discount rate, costs on an annualized basis range from $72.7 million for Option 1, Sanitary Survey only, to $777.1 million for Option 4, Across-the-Board Disinfection. Assuming a 7 percent discount rate, as shown in Exhibit 8-3, the range of total annualized national cost increases to $76.0 million annually under Option 1, Sanitary Survey only, to $866.0 million for Option 4, Across-the-Board Disinfection.

Exhibit 8–2. Summary of National Benefits and Costs (Using 3 Percent Discount Rate)

Regulatory Option	Millions ($)		
	Benefit	Cost	Net Benefit
Option 1: Sanitary Survey Only	$32.5	$72.7	($40.2)
Option 2: Sanitary Survey and Triggered Monitoring	$177.9	$157.6	$20.3
Option 3: Multi-Barrier Approach[1]	$205.0	$182.7	$22.3
Option 4: Across-the-Board Disinfection	$283.1	$777.1	($494.0)
[1] Preferred Option			

Exhibit 8–3. Summary of National Benefits and Costs (Using 7 Percent Discount Rate)

Regulatory Option	Millions ($)		
	Benefit	Cost	Net Benefit
Option 1: Sanitary Survey Only	$32.5	$76.0	($43.5)
Option 2: Sanitary Survey and Triggered Monitoring	$177.9	$168.5	$9.4
Option 3: Multi-Barrier Approach[1]	$205.0	$198.6	$6.4
Option 4: Across-the-Board Disinfection	$283.1	$866.0	($582.90)
[1] Preferred Option			

The four options considered in this proposed GWR reflect increasing levels of protection against outbreaks from microbial contamination employing a variety of control measures. The total annual cost of compliance steadily increases across Options 1, 2 and 3—the Sanitary Survey, Sanitary Survey and Triggered Monitoring, and Multi-Barrier options, respectively. The total annual cost of compliance for Option 4, Across-the-Board Disinfection ($866 million at 7 percent discount rate) is, however, over four times the cost of compliance for Option 3, Multi-Barrier approach ($198.6 million at a 7 percent discount rate). This trend is due largely to the requirement that all GWSs treat their water source under the Across-the-Board Disinfection option, regardless of the source water quality and potential for fecal contamination.

8.1.3 Review of National Benefits Estimates

The monetized health benefits associated with each of the four GWR options is also shown in Exhibit 8–2 and Exhibit 8–3. As noted above, these four rule options provide increasing levels of protection against microbial contamination, as reflected in the estimated health benefits. Annual national benefits range from $32.5 million for Option 1, Sanitary Survey only, to $283.1 million for Option 4, Across-the-Board Disinfection. The national benefits estimates do not show the four-fold increase that was observed in national costs between Option 3, the Multi-Barrier Approach, and Option 4, Across-the-Board Disinfection. The value of national benefits under these two regulatory options differ by approximately $78.1 million annually.

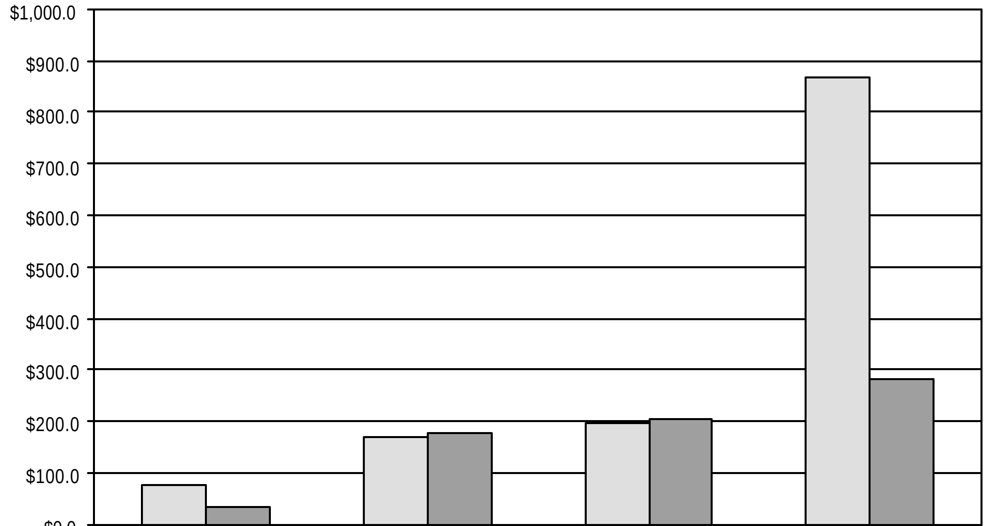
8.2 Comparison of Benefits and Costs

This section presents a comparison of total benefits and costs for each of the four GWR options. Three separate analyses are considered, including a direct comparison of aggregate national cost and benefits, the presentation of net benefits, and the results of a cost-effectiveness analysis of each regulatory option.

8.2.1 National Benefit-Cost Comparison

Exhibits 8–2 and 8–3 present monetized net benefits (i.e., the absolute difference between the total value of national costs and benefits for each rule option). Both Option 2, Sanitary Survey and Triggered Monitoring, and Option 3, Multi-Barrier Approach, show positive net benefits whether capital costs are annualized at 3 or 7 percent. Under both discount rate scenarios, both the Sanitary Survey option and the Across-the-Board Disinfection have negative net benefits (see also Exhibit 8–4).

Exhibit 8–4.
Comparison of National Costs and Benefits (7% Discount Rate)



	Sanitary Survey	Sanitary Survey and Triggered Monitoring	Multi-Barrier	Across-the-Board Disinfection
Costs (million $)	$76.0	$168.5	$198.6	$866.0
Benefits (million $)	$32.5	$177.9	$205.0	$283.1

Exhibit 8–5 and Exhibit 8–6 present the estimated monetized net benefits of the four rule options by systems size, under discount rates of 3 and 7 percent, respectively. As the system size category increases, the net benefits of each rule option increase. This reflects the fact that the health benefits of each option are a linear function of population, while the per capita cost of compliance drops, as system size increases, reflecting economies of scale in the production of clean drinking water. EPA also expects nonmonetized net benefits to increase as system sizes increase because a larger number of people would be affected by benefits such as decreased chronic illness, improved distribution systems, and greater confidence in public water supplies.

Exhibit 8–5. Net Benefits of Each Regulatory Option by System Size Category (Using 3 Percent Discount Rate (million$))

Option/Regulatory Scenario	$ Millions; By System Size								All Systems
	<100	100–500	501–1000	1K to 3.3K	3.3K to 10K	10K to 50K	50K to 100K	100K to 1M	
Option 1: Sanitary Survey Only	($22.4)	($11.6.)	($3.5)	($2.8)	$1.2	$0.1	$4.8	$3.7	($40.2)
Option 2: Sanitary Survey and Triggered Monitoring	($65.8)	($16.4)	$3.4	$14.8	$23.7	$14.1	$28.4	$27.7	$20.3
Option 3: Multi-Barrier Approach[1]	($70.6.)	($21.8)	$2.9	$15.9	$24.2	$17.2	$32.6	$31.7	$22.3
Option 4: Across-the-Board Disinfection	($185.8)	($167.9)	($54.7)	($63.4)	($40.3)	($12.3)	$5.8	$34.5	($494.0)
[1] Preferred Option									

Exhibit 8–6. Net Benefits of Each Regulatory Option by System Size Category (Using 7 Percent Discount Rate (million$))

Option/Regulatory Scenario	$Millions; By System Size								All Systems
	<100	100–500	501–1000	1K to 3.3K	3.3K to 10K	10K to 50K	50K to 100K	100K to 1M	
Option 1: Sanitary Survey Only	($23.6)	($12.2)	($3.8)	($3.1)	$1.0	($0.1)	$4.8	$3.7	($43.5)
Option 2: Sanitary Survey and Triggered Monitoring	($70.9)	($18.8)	$2.7	$14.0	$23.1	$13.6	$28.1	$27.6	$9.4
Option 3: Multi-Barrier Approach[1]	($77.8)	($25.7)	$1.9	$14.7	$23.2	$16.7	$32.2	$31.4	$6.4
Option 4: Across-the-Board Disinfection	($215.8)	($188.6)	($62.4)	($73.9)	($49.1)	($17.3)	$1.6	$32.8	($582.9)
[1] Preferred Option									

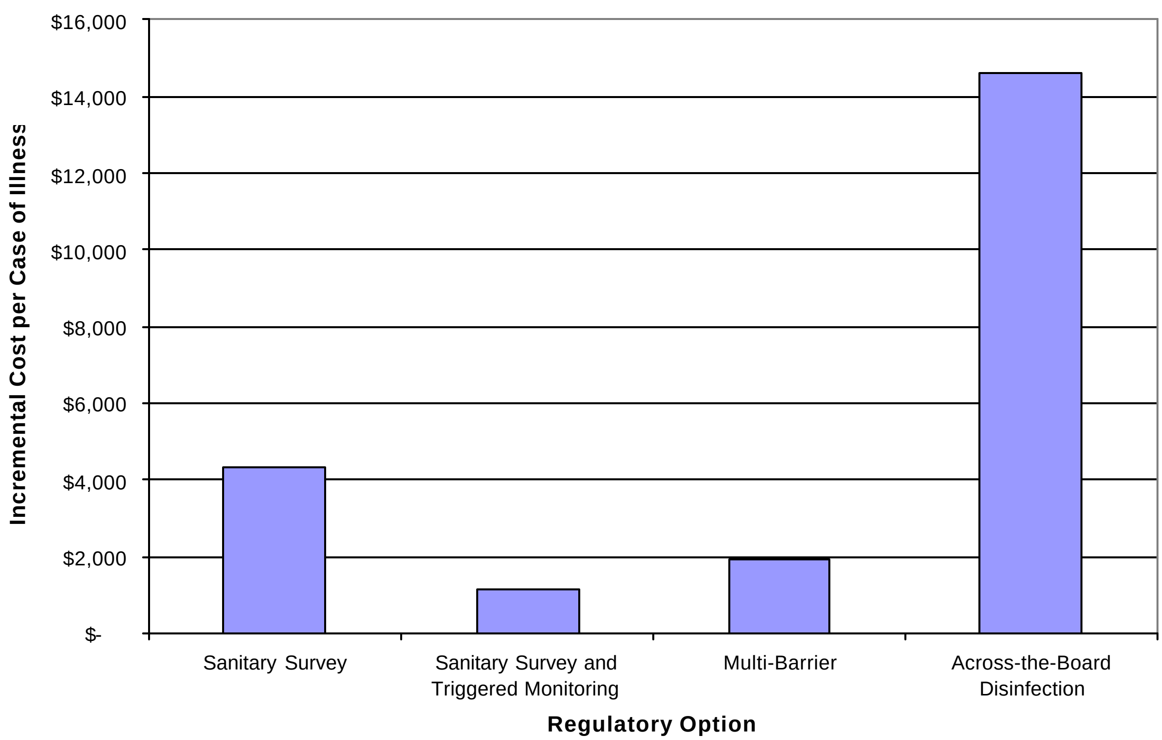
8.2.2 Cost-Effectiveness

Cost-effectiveness analysis is another commonly used measure of the economic efficiency. This analysis compares how well the regulatory options are meeting the intended regulatory objectives. For the proposed GWR, the cost-effectiveness can be measured as the cost per case of illness avoided.

Exhibit 8–7 shows the incremental cost per case avoided for each GWR option. Specifically, the bar graph in Exhibit 8–7 shows that the additional cases avoided under Option 4, Across-the-Board Disinfection, will cost approximately $12,000 more per case than under Option 3, Multi-Barrier Approach. The Sanitary Survey and Triggered Monitoring option achieves the lowest incremental cost per case of illness avoided at $1,123 per case while the Multi-Barrier option is only slightly larger at $1,954 per case.

8.3 Uncertainty in Benefit and Cost Estimates

Exhibit 8-7 Incremental Cost per Case Avoided Across GWR Options



In developing the GWR, EPA modeled the current baseline risk from fecal contamination in ground water, the reduction in risk that results from the four rule options, and the cost of each of these rule options. There is uncertainty in the baseline number of systems, the risk calculation, the cost estimates, and the interaction of other upcoming rules. Many of these uncertainties are discussed in more detail in previous sections of the RIA.

First, there is uncertainty about the baseline number of systems and population because of data limitations in SDWIS. For example, some systems use both ground and surface water, but because of other regulatory requirements, are labeled in SDWIS as surface water systems. Therefore, EPA does not have a reliable estimate of how many of these mixed systems exist. The SDWIS data on noncommunity water systems does not have a consistent reporting convention for population served. Some noncommunity systems may report the population served over the course of a year, while others may report the population served on an average day. Also, SDWIS does not require noncommunity systems to provide information on current disinfection practices and, in some cases, it may overestimate the population served. For example, a park may report the population served yearly instead of daily.

Second, the risk calculations concerning the baseline number of illnesses and the reduction of illnesses that result from the various rule options contain some uncertainty. For example, a nationally representative study of baseline microbial occurrence in ground water does not exist. EPA chose the AWWARF study to represent properly constructed wells described in Chapter 4, because it is the most geologically representative of the thirteen studies that were available. EPA also relied on data from the EPA/AWWARF study to represent improperly constructed wells because this study targeted wells vulnerable to contamination and wells tested monthly for a year. Additionally, EPA had to rely on CDC outbreak data to characterize benefits associated with treatment failures and distribution system contamination. The Agency also assumed that the occurrence of fecal contamination will remain constant throughout the rule. However, this might not be the case if increased development results in fecal contamination of a larger number of aquifers in areas served by ground water systems.

Also, EPA did not have dose-response data for all viruses and bacteria associated with previous ground water disease outbreaks. For viral illness, the Agency used echovirus and rotavirus as surrogates for all pathogenic viruses from fecal contamination that can be found in ground water. By using these two viruses, the Agency captured the effects of low-to-medium infectivity viruses that cause severe illness, and high infectivity viruses that cause more mild illness. Another source of uncertainty is the number of baseline bacterial illnesses caused by ground water contamination. The bacterial risk could not be modeled because of lack of occurrence and dose-response data. Estimates of bacterial illness were made based on a ratio of bacterial to viral outbreaks as documented by the CDC and applied to the viral risk estimate discussed above.

Third, some uncertainty exists regarding the costs of today's rule because of the diverse nature of possible significant deficiencies systems would need to address. In addition, the rule's flexibility leads to some uncertainty in the estimates of who will be affected by each rule component and how nonts and systems will respond to significant deficiencies. These uncertainties could either under or overestimate the costs of the rule.

Fourth, EPA intends to propose regulations for radon and arsenic in drinking water that will affect a number of ground water systems and their disinfection practices. EPA also intends to finalize the Stage 2 Disinfection Byproducts Rule by the statutory deadline of May 2002. It is extremely difficult to estimate the combined effects of these possible regulations on ground water systems because of various combinations of contaminants that some systems may need to address. However, it is possible for a system to choose treatment technologies that would deal with multiple problems. The combined total cost impact of these drinking water rules is uncertain; however, it would likely be less than the cost of the simple sum of the estimated individual rules.

Finally, there are costs and benefits that are not monetized in this RIA. For example, a review of the medical and epidemiological literature identified several potential chronic diseases resulting from illnesses caused by enteroviruses (e.g., heart disease, diabetes, post-viral fatigue syndrome, and pancreatitis)—the strongest evidence for a viral role appears to exist for the development of diabetes and myocarditis (inflammation of the muscular walls of the heart).

Because the causal relationship is not well established and the number of cases associated with drinking water is unknown, the Agency was not able to quantify benefits from the GWR on reducing these diseases. Nonetheless the total number of these conditions from all pathways in the United States is substantial; it is estimated that nearly 7 million people have one form of diabetes and approximately 4.1 million have chronic heart disease (including myocarditis and cardiomyopathy).

In addition, the RIA does not include the value o f reduced pain and suffering because the disutility of illness is not associated with a market cost.

There are also non-health benefits of the rule that could not be monetized, such as, the value of upgrades to distribution systems, increased efficiencies, and increased frequency/intensity of process surveillance.

Appendix A
Risk Assessment Inputs and Results

TABLE OF CONTENTS

LIST OF EXHIBITS

Included in this appendix are the inputs and results from the risk assessment performed for the Ground Water Rule (GWR) benefits determination. Inputs for the risk assessment are organized under Section A.1. Results of the risk assessment are organized under Section A.2 and include:

- Results of the GWR baseline analysis (current conditions), as well as results for each of the fou regulatory options modeled;

- For each set of the five outputs, two sets of tables, each of which presents results for the two types of modeled viral pathogens (Type A and Type B). Each table includes the mean annual morbidity (illness) and mortality (death) estimates for PWS ground water systems; the 10th and 90th percentile estimates are also included to characterize the uncertainty associated with each mean value. All numbers (mean and the 10th and 90th percentile values) are rounded to the nearest whole number. The mean number represents the “best” estimate of the number of illnesses and deaths (remaining and avoided) based on the input assumptions and calculations used in the Monte Carlo simulation analysis. Given the uncertainties quantified in the model, there is a 10% probability that the actual values are below the 10^{th} percentile and a 10% probability that they are above the 90^{th} percentile.

- The first set of tables in each section presents the results of calculations using daily, age-based consumption distributions incorporating US Department of Agriculture (USDA) 1994–1996 daily individual intake data for community water, all drinking water sources (“all sources, consumers only”). The “all sources, consumers only” results represent the upper bound estimat of annual illnesses and deaths for the baseline scenario and each regulatory option. The second set of tables presents results generated using the USDA daily consumption data for “community water supply, all respondents”. The “community water supply, all respondents” results represent the lower bound consumption for estimates of annual illnesses and deaths for each scenario.

A.1 Inputs to the Risk Assessment

Inputs to the GWR risk assessment are summarized in this section of the appendix.

A.1.1 Potentially-Exposed Populations, Including Sensitive Subgroups

Exhibit A–1 lists the numbers of persons in the potentially exposed populations served by undisinfected ground water systems. The populations are broken down by type and size of system. The fraction of the population in sensitive subgroups is shown in Exhibit A–2.

Exhibit A–1. Populations Served by Non-Disinfecting Ground Water Systems

Service Population Category	Estimated Population Served Undisinfected Ground Water[1]		
	Community Water Systems (CWS)	Nontransient Noncommunity (NTNC) Systems	Transient Noncommunity (TNC) Systems
< 100	471,214	364,978	2,616,086
101–500	1,005,419	1,283,450	3,401,284
501–1,000	852,017	998,666	1,167,404
1001–3,300	2,667,256	804,994	890,370
3,301–10,000	3,670,492	243,552	686,852
10,001–50,000	2,309,365	116,450	1,386,890
50,001–100,000	3,898,783	0	737,461
>100,000	3,472,410	0	1,475,474
Totals	18,346,956	3,812,090	12,361,821

[1]Source: GWR model calculation. Reference for total population served in each service population category is the Drinking Water Baseline Handbook, draft, First Edition (EPA 1999_).

Exhibit A–2. Fractions of General Population having Age-Based and Health-Based Sensitivity to Viral Pathogens in Ground Water

Age Group	Age Fraction of General Population	Sensitive Based on Age Only	Immunocompromised: AIDs Patients; Organ Transplant Patients; Non-Hospitalized Cancer Therapy Patients	Immunocompromised: Nursing Home (age-adjusted factor)[1]
Neonate (birth to 1 month)	0.005	0.99	0.01	—
Toddler (>1 month to 2 years)	0.0235	0.99	0.01	—
Young Child (>2 to 5 years)	0.0442	0.99	0.01	—
Child (>5 yrs. to 16 years)	0.1591	—	0.01	—
Adult (>16 to 65 years)	0.642	—	0.01	0.008[1]
Elderly (>65 years)	0.126	0.942	0.01	

[1] Assumes all nursing home patients are > 16 years old.

A.1.2 Viral Pathogen Occurrence and Concentration in Source Water

Virus occurrence and virus concentration assumptions for this exposure assessment are discussed together because both are based on occurrence data from the AWWARF study (Abbaszadegan et al., 1998), a survey of mainly properly constructed wells; and the EPA/AWWA study (Lieberman et al., 1995), a survey of known contaminated wells and therefore, assumed to be representative of poorly constructed wells. Viral occurrence estimates and supporting assumptions are summarized in Exhibit A–3. EPA estimates that among properly constructed drinking water source wells, 4.4 percent are contaminated with Type A virus and 4.8 percent are contaminated with Type B virus. Among poorly constructed wells, it is estimated that 5.5 percent are contaminated with Type A virus and 6.0 percent are contaminated with Type B virus. Contaminated, poorly-constructed wells are assumed to have a mean concentration of 29.41 ± 55.7 MPNIU/ 100 L, in comparison with a mean concentration of 0.356 ± 0.297 MPNIU/ 100L. in contaminated properly-constructed wells. These occurrence distributions were incorporated as lognormal distributions in the Monte Carlo simulation t reflect the variability in virus concentration among contaminated systems.

Exhibit A–3. Viral Occurrence and Concentration in Source Water

Well Quality	Virus Type	Percent of Wells Contaminated	Mean Virus Concentration when Contaminated (MPNIU100 L)[1]
Properly-Constructed Wells (83% of all GWSs)	Type A virus	4.4 percent[2]	0.356 ± 0.297[6,7]
	Type B virus	4.8 percent[3]	0.356 ± 0.297[7]
Poorly-Constructed Wells (17% of all GWSs)	Type A virus	5.5 percent[4]	29.41 ± 55.7[8,9]
	Type B virus	6.0 percent[5]	29.41 ± 55.7[9]

1 Most probable number of infectious units of virus.

2 AWWARF study: The RT-PCR methods detected the presence of rotavirus nucleic acids in 14.6 percent of wells tested to which the ratio of enterovirus cell-culture to RT-PCR positive wells (0.3) was applied.

3 AWWARF study: The AWWARF study found that 4.8 percent of wells tested were positive for the presence of enteroviruses using the Buffalo Green Monkey (BGM) cell culture assay.

4 EPA/AWWA study: Because there are no rotavirus data available from the EPA/AWWA study at this time, it is assumed that rotavirus (Type A virus) and echovirus (Type B virus) occur in poorly constructed wells in the same ratio as calculated for properly constructed wells (0.92).

5 EPA/AWWA study: Calculated by dividing the total number of positive BGM cell culture assays by the total number of assays performed.

6 Because there are no concentration data for rotavirus available from either study, it is assumed that the mean concentration of Type A virus in properly-constructed wells is the same as for Type B virus.

7 AWWARF study: Range of enterovirus (Type B virus) concentrations in cell-culture isolates was 0.123 to 1.86 MPNIU/100 L; data are fitted to a lognormal distribution from which the mean and standard deviation are calculated.

8 Because there are no concentration data for rotavirus available from either study, it is assumed that the mean concentration of Type A virus in poorly-constructed wells is the same as for Type B virus.

9 EPA/AWWA study: Range of enterovirus concentrations in cell-culture isolates was 0.9 to 212 MPNIU/100 L; data are fitted to a lognormal distribution from which the mean and standard deviation are calculated.

A.1.3 Pathogen Inactivation in Ground Water Systems and Resulting Baseline Tap Water Concentrations

Undisinfected Systems

The pathogen concentration in tap water from undisinfected systems is assumed to be the same as the pathogen concentration in source water.

Disinfecting Systems

Properly operating disinfecting systems are assumed to inactivate 99.99 percent (4 logs) of vira pathogens, and the concentration of pathogens in tap water from properly operating disinfecting systems is assumed to be 0.01 percent of the concentration in source water. The model does not include assumptions regarding pathogen inactivation during treatment failure or distribution system contamination events because of insufficient data on these events.

A.1.4 Drinking Water Consumption Factors

Daily Intake

Custom daily intake distributions were developed for this analysis using Grapher for Windows software. These distributions correspond to the age-bins for which morbidity data are available. The distributions incorporate age-based intake data reported in the *1994–1996 USDA, Continuing Survey of Food Intakes by Individuals* for "all sources, consumers only" and for "community water supply, all respondents" (cited in EPA 1999a). The USDA "all sources, consumers only" data set represents the upper bound and the "community water supply, all respondents" data set the lower bound of daily consumption values considered for this risk assessment. Shown below are the key characteristics of the two drinking water consumption distributions for the overall population (all ages) obtained by EPA from the CSFII data.

	"All Sources, Consumers Only" (L/day)	**Community Water Supply, All Respondents (L/day)**
Mean	1.241	0.927
1st %-tile	0.047	0
5th %-tile	0.184	0
10th %-tile	0.294	0.032
25th %-tile	0.584	0.264
50th %-tile	1.045	0.710

75th %-tile	1.640	1.313
	"All Sources, Consumers Only" (L/day)	**Community Water Supply, All Respondents (L/day)**
90th %-tile	2.345	2.016
95th %-tile	2.922	2.544
99th %-tile	4.808	4.242

Annual Exposure

For each type of ground water system (GWS) (i.e., CWS, NTNC, and TNC), the number of exposure days per year (i.e., the number of days in which tap water is consumed) is estimated. It is assumed that consumers in CWSs ingest drinking water from those sources 350 days/year while it is assumed that consumers in NTNC systems ingest drinking water from those sources 250 days/year, and that drinking water from TNC systems is consumed 15 days/year.

A.1.5 Hazard Identification Parameters

Hazard identification parameters included in the GWR model include: infectivity (the ability of microorganism to colonize the body of the host); morbidity (the probability of illness given infection); and mortality (the probability of death given illness). Pathogen hazard assumptions for Type A and B viruses when ingested in ground water are summarized in Exhibit A–4.

Epidemiological data on viral illness explicitly acquired via the ground water ingestion pathway are limited to a few CDC surveillance studies of waterborne disease outbreaks in groundwater systems. For this risk assessment, the assumed rates of morbidity and mortality for Type A and Type B viruses are based on national disease surveillance reports or on reported observations during viral epidemics. Typically these studies address several routes of transmission (i.e, waterborne, direct contact, and/or respiratory transmission).

For Type A viruses, the morbidity rate in children < 2 years old is estimated to be 0.88, based on epidemiological data from national studies summarized by Kapikian and Chanock (1996). Older children and adults are more likely to be asymptomatic or to experience mild symptoms when infected with Type A virus because of acquired immunity. The morbidity rate for Type A viral illness among persons > 2 years old is therefore assumed to be 0.1, a conservative estimate based on several community studies (Wenman et al., 1979; Foster et al., 1980). For Type B virus, the morbidity rate also varies by age and is based on a community-wide study by Hall (1980). The results of this study were consistent with reported morbidity rates from the New York Viral Watch (Kogon, 1969), a large, multi-year study of viral disease (CEOH 1998).

Secondary transmission of Type A and Type B viruses also has been reported. For Type A viruses, the review by Kapikian and Chanock (1996) suggests that young children regularly transmit Type A virus to other children and to their adult care givers by direct contact transmission; older children and adults are not assumed to transmit the virus by this secondary route. For the less infectiou Type B virus, a triangular distribution of the secondary morbidity rate for all age groups is based on epidemiological studies reviewed by Morens et al. (1991).

Mortality due to Type A and Type B viral illnesses is not well characterized. The Type A virus mortality rate assumed for this risk assessment is based on surveillance of a birth cohort of 3.9 millior U.S. children, followed for 5 years (Tucker et al. 1998). The observed mortality due to Type A viral illness in this cohort was 0.00073 percent, i.e., 20 deaths among 2.7 million cases of illness (CEOH, 1998). In the absence of adult Type A mortality data, this rate is assumed for all age groups. For Type B viruses, a mortality rate of 0.92 percent of infected children < 1 month old is assumed. This rate is based on studies of infected infants during epidemics of Type B illness in newborn nurseries (CEOH 1998). A mortality rate of 0.041 percent is assumed for all other persons based on calculations by Stedge et al. (1998) that 2 percent of Type B illnesses are severe and that 2 percent of those seriously ill will die as a result of illness.

A.1.6 Illnesses and Deaths in Undisinfected and Disinfected (4-log removal) Systems

The GWR model calculates annual numbers of illnesses and deaths due to source contaminatior in undisinfected systems. Exhibit A–5 summarizes the model calculations, which incorporate the mod assumptions regarding drinking water exposures to pathogens from contaminated sources and health hazards from Type A and Type B viral pathogens.

A.1.7 Additional Illnesses and Deaths Resulting from Treatment Failures and Distribution System Contamination

For every baseline waterborne illness in an undisinfected CWS, NTNC, or TNC ground water system with source contamination, it is estimated that there is an additional **0.43** illness in a ground water system experiencing source contamination with treatment failure. Also, for every baseline waterborne illness in an undisinfected CWS or NTNC ground water system with source contamination (TNC systems do not have distribution systems), an additional **0.32** illness is estimated due to distribution system contamination.

Exhibit A–4. Hazard Identification of Viral Pathogens for the GWR Risk Assessment

Pathogen hazards	Infectivity	Morbidity		Mortality
Definition	Infectivity is the ability of the pathogen to colonize the host; it is defined by dose-response relationship.	Primary morbidity is the probability of illness given infection; can vary in sensitive subgroups.	Secondary spread is the probability of illness given contact with a (primary) ill person.	Mortality is the probability of death as a result of illness.
Model	General model of dose-response (beta-Poisson): P (I) = 1– (1 + N/$) – " where: P (I)= probability of infection N = number of pathogenic viruses ingested ", $= pathogen-specific rate constants.[1]			
Type A virus	Highly infective virus; " = 0.26, $=0.42[2]	< 2 yrs old = 0.88[4]	< 2 yrs old = 0.55[4]	7.3 x 10-6 [6]
		> 2 yrs = 0.1[5]	> 2 yrs old = 0[4]	
Type B virus	Moderately infective virus; " = 0.374, $ =187[3]	< 5 yrs old = 0.5[7]	Triangular distribution (all age groups), from 0.11 to 0.55; mode = 0.35[8]	< 1 month = 0.0092[6,9]
		$ 5 to 16 years = 0.57[7]		$ 1 month = 0.00041[10]
		> 16 years = 0.33[7]		

1 Regli et al., 1991; 2 Ward et al., 1986; 3 Schiff et al., 1984; 4 Kapikian and Chanock, 1996; 5 Wenman et al., 1979 and Foster et al., 1980; 6 CEOH 1998; 7 Hall 1980; 8 Morens et al., 1991; 9 rate of mortality given infection; 10 Stedge, 1998.

Exhibit A–5. Summary of GWR Baseline Risk Calculations for Undisinfected and Disinfected (4-log removal) Systems

Health Effect	Calculation	Summary
Infection	Mean Individual Daily Probability of Infection	The model calculates the mean individual daily probability of infection using: the fraction of contaminated wells (virus hit rate); the potentially exposed population; variable distributions of virus concentration in undisinfected drinking water (same as source water concentration for untreated systems) and daily intake; and the rotavirus dose-response rate constants for Type A virus or the echovirus rate constants for Type B. The probability of infection given a dose of one of these pathogens: $P(I) = 1 - (1 + N/\$)^{-"}$ where: P(I) = probability of infection, N = numbers of pathogenic viruses ingested, and " and $ = pathogen-specific rate constants. The mean and standard deviation of the mean are calculated.
	Mean Annual Probability of Infection	The model calculates the annual probability that an individual in the population category will be infected at least once: $P(I_{Ann}) = 1-[1-P(I)]^{days}$ where: $P(I_{Ann})$ = the annual probability of infection, P (I) = the mean daily probability of infection. The cumulative geometric function incorporates the annual number of days of exposure (i.e., 350 days in CWSs, 250 days in NTNC systems, and 15 days in TNC systems). The mean and standard deviation of the mean are calculated for each age group and type and size of ground water system .
Morbidity	Annual Number of Illnesses	The annual number of illnesses is the annual number of infections multiplied by the fraction of infections causing disease (i.e., morbidity rate), calculated for each age group and type of system. This calculation incorporates a factor for secondary spread as appropriate. The model applies the secondary spread factor by age group as follows: secondary illnesses = (the age-specific number of primary illnesses) × (rate of secondary spread).
Mortality	Annual Number of Deaths	Deaths due to Type A virus in all age groups are calculated by multiplying the annual number of primary and secondary illnesses by the case fatality rate of 7.3 per million cases of illnesses. For Type B virus, deaths in the neonate (< 1 month) population are calculated by multiplying the annual number of primary and secondary infections by 0.92 percent. Deaths in all other age groups are calculated by multiplying the annual numbers of primary and secondary illnesses by the composite case fatality rate of 0.041 percent.

A.2. Results of the Risk Calculations

In addition to calculating risks from ingestion of ground water under baseline (i.e., current) conditions, this assessment performs risk calculations for four GWR options: (1) sanitary surveys only (2) sanitary surveys with triggered monitoring; (3) a multiple barrier approach; and (4) across the board disinfection treatment. For each option, the model is used to calculate annual numbers of illnesses and deaths in undisinfected ground water systems. The CDC ratios of outbreak-related illnesses due to treatment failure of disinfecting systems and distribution system contamination (Exhibit A–6) are used estimate additional illnesses from those types of contamination. Each GWR option is discussed briefly below.

A.2.1 Results of the Risk Calculations: Baseline

Estimated annual numbers of illness from ingestion of Type A Virus and Type B virus in public ground water systems are summarized in Exhibits A–6 through A–9. These exhibits present the calculated mean and the 10th and 90th percentile estimates of annual illness and deaths for Type A virus and Type B virus, respectively. Summing the estimates of illness for both types of viruses gives a combined mean estimate of approximately 168,000 illnesses each year for the model runs using the "All Sources, Consumers Only" daily intake distributions. The vast majority of these illnesses are attributable to the highly infective, but less lethal Type A viruses. The combined mean estimated number of deaths per year given the "All Sources, Consumers Only" daily intake distributions is 15, the majority of those being due to the more lethal but less infectious Type B viruses.

Exhibit A–6. Estimates of Baseline Type A Viral Illness and Death (“All Sources, Consumers Only” Age-Based Consumption Distributions)

	Illnesses per Year			Deaths per Year		
Cause/Source of Contamination	**10th percentile**	**Mean**	**90th percentile**	**10th percentile**	**Mean**	**90th percentile**
Source contamination in undisinfected ground water systems	77,794	**78,172**	78,562	1	**1**	1
Source contamination in ground water systems with failed disinfection	33,452	**33,614**	33,781	0	**0**	0
Contamination of distribution systems of ground water systems	21,615	**21,712**	21,812	0	**0**	0
Total	**132,879**	**133,498**	**134,133**	**1**	**1**	**1**

Exhibit A–7. Estimates of Baseline Type B Viral Illness and Death (“All Sources, Consumers Only” Age-Based Consumption Distributions)

	Illnesses per Year			Deaths per Year		
Cause/Source of Contamination	**10th percentile**	**Mean**	**90th percentile**	**10th percentile**	**Mean**	**90th percentile**
Source contamination in undisinfected ground water systems	19,019	**19,642**	20,253	8	**8**	8
Source contamination in ground water systems with failed disinfection	8,178	**8,446**	8,709	3	**4**	4
Contamination of distribution systems of ground water systems	5,869	**6,069**	6,265	2	**3**	3
Total	**33,062**	**34,157**	**35,227**	**14**	**14**	**15**

Exhibit A–8. Estimates of Baseline Type A Viral Illness and Death (“Community Water Supply, All Respondents” Age-Based Consumption Distributions)

	Illnesses per Year			Deaths per Year		
Cause/Source of Contamination	**10th percentile**	**Mean**	**90th percentile**	**10th percentile**	**Mean**	**90th percentile**
Source contamination in undisinfected ground water systems	65,422	65,878	66,324	0	**0**	0
Source contamination in ground water systems with failed disinfection	28,132	28,328	28,519	0	**0**	0
Contamination of distribution systems of ground water systems	18,220	18,360	18,497	0	**0**	0
Total	**111,777**	**112,566**	**113,329**	**1**	**1**	**1**

Exhibit A–9. Estimates of Baseline Type B Viral Illness and Death (“Community Water Supply, All Respondents” Age-Based Consumption Distributions)

	Illnesses per Year			Deaths per Year		
Cause/Source of Contamination	**10th percentile**	**Mean**	**90th percentile**	**10th percentile**	**Mean**	**90th percentile**
Source contamination in undisinfected ground water systems	14,622	**15,107**	15,587	6	**6**	6
Source contamination in ground water systems with failed disinfection	6,287	**6,496**	6,703	3	**3**	3
Contamination of distribution systems of ground water systems	4,516	**4,671**	4,825	2	**2**	2
Total	**25,425**	**26,273**	**27,112**	**11**	**11**	**11**

A.2.2 Results of the Risk Calculations: Option 1-- Sanitary Survey-Only

Exhibits A–10 through A–13 summarize the estimated annual numbers of illness from ingestion of Type A virus and Type B virus remaining after implementation of the GWR sanitary survey requirement. The difference between these estimates and those for the baseline is the expected reduction in death and illness that would result from implementation of sanitary surveys alone. Given the “All Sources, Consumers Only” consumption distributions, this option is estimated to reduce the mean number of illnesses by over 13,500 illnesses each year in comparison with the baseline. This option is also estimated to reduce the mean number of deaths resulting from waterborne illness by one a year.

Exhibit A–10. Estimates of Type A Viral Illness and Death after Option 1—Sanitary Survey Only ("All Sources, Consumers Only" Age-Based Consumption Distributions)

	Illnesses per Year			Deaths per Year		
Cause/Source of Contamination	**10th percentile**	**Mean**	**90th percentile**	**10th percentile**	**Mean**	**90th percentile**
Source contamination in undisinfected ground water systems	70,503	**71,600**	72,686	1	**1**	1
Source contamination in ground water systems with failed disinfection	28,451	**32,352**	36,168	0	**0**	0
Contamination of distribution systems of ground water systems	17,156	**18,989**	20,798	0	**0**	0
Total	**118,601**	**122,941**	**127,194**	**1**	**1**	**1**

Exhibit A–11. Estimates of Type B Viral Illness and Death after Option 1—Sanitary Survey Only ("All Sources, Consumers Only" Age-Based Consumption Distributions)

	Illnesses per Year			Deaths per Year		
Cause/Source of Contamination	**10th percentile**	**Mean**	**90th percentile**	**10th percentile**	**Mean**	**90th percentile**
Source contamination in undisinfected ground water systems	17,357	**17,977**	18,612	7	**8**	8
Source contamination in ground water systems with failed disinfection	6,898	**7,855**	8,816	3	**3**	4
Contamination of distribution systems of ground water systems	4,775	**5,311**	5,859	2	**2**	2
Total	**29,843**	**31,143**	**32,440**	**13**	**13**	**14**

Exhibit A–12. Estimates of Type A Viral Illness and Death after Option 1—Sanitary Survey Only (“Community Water Supply, All Respondents” Age-Based Consumption Distributions)

	Illnesses per Year			Deaths per Year		
Cause/Source of Contamination	**10th percentile**	**Mean**	**90th percentile**	**10th percentile**	**Mean**	**90th percentile**
Source contamination in undisinfected ground water systems	59,381	**60,321**	61,259	0	**0**	0
Source contamination in ground water systems with failed disinfection	24,009	**27,255**	30,507	0	**0**	0
Contamination of distribution systems of ground water systems	14,512	**16,057**	17,632	0	**0**	0
Total	**100,023**	**103,633**	**107,185**	**1**	**1**	**1**

Exhibit A–13. Estimates of Type B Viral Illness and Death after Option 1—Sanitary Survey Only (“Community Water Supply, All Respondents” Age-Based Consumption Distributions)

	Illnesses per Year			Deaths per Year		
Cause/Source of Contamination	**10th percentile**	**Mean**	**90th percentile**	**10th percentile**	**Mean**	**90th percentile**
Source contamination in undisinfected ground water systems	13,342	**13,819**	14,304	**6**	**6**	6
Source contamination in ground water systems with failed disinfection	5,312	**6,037**	6,780	**2**	**3**	3
Contamination of distribution systems of ground water systems	3,671	**4,086**	4,512	**2**	**2**	2
Total	**22,951**	**23,942**	**24,937**	**10**	**10**	**10**

A.2.3 Results of the Risk Calculations: <u>Option 2: Sanitary Survey and Triggered Monitoring</u>

Estimated annual illnesses from ingestion of Type A virus and Type B virus in public ground water systems given implementation of the Sanitary Survey and Triggered Monitoring Option are summarized in Exhibits A–14 through A–17. Given the "All Sources, Consumers Only" consumption distributions, this option is estimated to reduce the mean number of waterborne illnesses by over 83,000 illnesses annually, in comparison with the baseline. The Sanitary Survey and Triggered Monitoring Option is also estimated to reduce the mean number of deaths resulting from waterborne illness by about 8 per year, a greater than 50 percent reduction in the baseline.

Exhibit A–14. Estimates of Type A Viral Illness and Death after Option 2—Sanitary Survey and Triggered Monitoring ("All Sources, Consumers Only" Age-Based Consumption Distributions)

	Illnesses per Year			Deaths per Year		
Cause/Source of Contamination	**10th percentile**	**Mean**	**90th percentile**	**10th percentile**	**Mean**	**90th percentile**
Source contamination in undisinfected ground water systems	35,860	**42,066**	48,144	0	**0**	0
Source contamination in ground water systems with failed disinfection	1,314	**6,121**	10,999	0	**0**	0
Contamination of distribution systems of ground water systems	17,181	**19,013**	20,843	0	**0**	0
Total	**59,621**	**67,200**	**74,630**	**0**	**0**	**1**

Exhibit A–15. Estimates of Type B Viral Illness and Death after Option 2—Sanitary Survey and Triggered Monitoring ("All Sources, Consumers Only" Age-Based Consumption Distributions)

	Illnesses per Year			Deaths per Year		
Cause/Source of Contamination	**10th percentile**	**Mean**	**90th percentile**	**10th percentile**	**Mean**	**90th percentile**
Source contamination in undisinfected ground water systems	8,866	**10,465**	12,053	4	**4**	5
Source contamination in ground water systems with failed disinfection	270	**1,340**	2,397	0	**1**	1
Contamination of distribution systems of ground water systems	4,769	**5,311**	5,863	2	**2**	2
Total	**15,154**	**17,115**	**19,010**	**6**	**7**	**8**

Exhibit A–16. Estimates of Type A Viral Illness and Death after Option 2—Sanitary Survey and Triggered Monitoring ("Community Water Supply, All Respondents" Age-Based Consumption Distributions)

	Ilnesses per Year			Deaths per Year		
Cause/Source of Contamination	**10th percentile**	**Mean**	**90th percentile**	**10th percentile**	**Mean**	**90th percentile**
Source contamination in undisinfected ground water systems	30,146	**35,338**	40,584	0	**0**	0
Source contamination in ground water systems with failed disinfection	1,068	**5,147**	9,207	0	**0**	0
Contamination of distribution systems of ground water systems	14,497	**16,050**	17,597	0	**0**	0
Total	**49,970**	**56,535**	**62,818**	**0**	**0**	**0**

Exhibit A–17. Estimates of Type B Viral Illness and Death after Option 2—Sanitary Survey and Triggered Monitoring ("Community Water Supply, All Respondents" Age-Based Consumption Distributions)

	Illnesses per Year			Deaths per Year		
Cause/Source of Contamination	**10th percentile**	**Mean**	**90th percentile**	**10th percentile**	**Mean**	**90th percentile**
Source contamination in undisinfected ground water systems	6,821	**8,046**	9,285	3	**3**	4
Source contamination in ground water systems with failed disinfection	205	**1,027**	1840	0	**0**	1
Contamination of distribution systems of ground water systems	3,667	**4,086**	4,500	2	**2**	2
Total	**11,685**	**13,159**	**14,630**	**5**	**5**	**6**

A.2.4 Results of the Risk Calculations: Option 3—Multi-Barrier Approach

Estimated annual illnesses from ingestion of Type A virus and Type B virus in public ground water systems after implementation of the Multiple Barrier Option are summarized in Exhibits A–18 through A–21. Given "All Sources, Consumers Only" consumption distibutions, the Multiple Barrier Option is estimated to reduce the mean number of waterborne viral illnesses by over 96,000 illnesses each year in comparison with the baseline. This option is also estimated to reduce the mean number of deaths from waterborne illness by about nine each year.

Exhibit A–18. Estimates of Type A Viral Illness and Death after Option 3—Multi-Barrier Option ("All Sources, Consumers Only" Age-Based Consumption Distributions)

	Illnesses per Year			Deaths per Year		
Cause/Source of Contamination	**10th percentile**	**Mean**	**90th percentile**	**10th percentile**	**Mean**	**90th percentile**
Source contamination in undisinfected ground water systems	21,023	**31,161**	41,306	0	**0**	0
Source contamination in ground water systems with failed disinfection	1,410	**6,777**	12,241	0	**0**	0
Contamination of distribution systems of ground water systems	17,177	**19,015**	20,847	0	**0**	0
Total	**45,971**	**56,953**	**67,492**	**0**	**0**	**0**

Exhibit A–19. Estimates of Type B Viral Illness and Death after Option 3—Multi-Barrier Option ("All Sources, Consumers Only" Age-Based Consumption Distributions)

	Illnesses per Year			Deaths per Year		
Cause/Source of Contamination	**10th percentile**	**Mean**	**90th percentile**	**10th percentile**	**Mean**	**90th percentile**
Source contamination in undisinfected ground water systems	5,152	**7,677**	10,223	2	**3**	4
Source contamination in ground water systems with failed disinfection	301	**1,484**	2,631	0	**1**	1
Contamination of distribution systems of ground water systems	4,770	**5,301**	5,848	2	**2**	2
Total	**11,830**	**14,462**	**17,135**	**5**	**6**	**7**

Exhibit A–20. Estimates of Type A Viral Illness and Death after Option 3—Multi-Barrier Option ("Community Water Supply, All Respondents" Age-Based Consumption Distributions)

	Illnesses per Year			Deaths per Year		
Cause/Source of Contamination	**10th percentile**	**Mean**	**90th percentile**	**10th percentile**	**Mean**	**90th percentile**
Source contamination in undisinfected ground water systems	17,712	**26,189**	34,666	0	**0**	0
Source contamination in ground water systems with failed disinfection	1,139	**5,689**	10,173	0	**0**	0
Contamination of distribution systems of ground water systems	14,504	**16,065**	17,630	0	**0**	0
Total	**38,591**	**47,943**	**56,995**	**0**	**0**	**0**

Exhibit A–21. Estimates of Type B Viral Illness and Death after Option 3—Multi-Barrier Option ("Community Water Supply, All Respondents" Age-Based Consumption Distributions)

	Illnesses per Year			Deaths per Year		
Cause/Source of Contamination	**10th percentile**	**Mean**	**90th percentile**	**10th percentile**	**Mean**	**90th percentile**
Source contamination in undisinfected ground water systems	3,933	5,907	7,877	2	2	3
Source contamination in ground water systems with failed disinfection	231	1,117	1,989	0	0	1
Contamination of distribution systems of ground water systems	3,665	4,086	4,510	2	2	2
Total	**9,059**	**11,110**	**13,138**	**4**	**5**	**5**

A.2.5 Results of the Risk Calculations: Option 4--Across-the-Board Disinfection and Sanitary Survey

Estimated annual illnesses from ingestion of Type A virus and Type B virus in public ground water systems after implementation of the Across-the-Board Disinfection and Sanitary Survey Option are summarized in Exhibits A–22 through A–25. Although all systems would treat ground water under this option, a few, less frequent disinfection failure and distribution system contamination events each year would continue to cause a few residual illnesses and deaths in populations served by ground water systems. Given "All Sources, Consumers Only" consumption distributions, this option is estimated to reduce the mean number of waterborne viral illnesses by greater than 132,000 per year and the mean number of deaths by about 12 per year.

Exhibit A–22. Estimates of Type A Viral Illness and Death from Ingestion of Ground Water after Option 4—Across-the-Board Disinfection and Sanitary Survey ("All Sources, Consumers Only" Age-Based Consumption Distributions)

	Illnesses per Year			Deaths per Year		
Cause/Source of Contamination	**10th percentile**	**Mean**	**90th percentile**	**10th percentile**	**Mean**	**90th percentile**
Source contamination in undisinfected ground water systems	778	**790**	801	0	**0**	0
Source contamination in ground water systems with failed disinfection	1,769	**8,662**	15,655	0	**0**	0
Contamination of distribution systems of ground water systems	17,177	**19,015**	20,847	0	**0**	0
Total	**21,575**	**28,467**	**35,536**	**0**	**0**	**0**

Exhibit A–23. Estimates of Type B Viral Illness and Death from Ingestion of Ground Water after Option 4—Across the Board Disinfection and Sanitary Survey ("All Sources, Consumers Only" Age-Based Consumption Distributions)

	Illnesses per Year			Deaths per Year		
Cause/Source of Contamination	**10th percentile**	**Mean**	**90th percentile**	**10th percentile**	**Mean**	**90th percentile**
Source contamination in undisinfected ground water systems	12	**12**	13	0	**0**	0
Source contamination in ground water systems with failed disinfection	367	**1,797**	3,204	0	**1**	1
Contamination of distribution systems of ground water systems	4,770	**5,301**	5,848	2	**2**	2
Total	**5,631**	**7,111**	**8,570**	**2**	**3**	**4**

Exhibit A–24. Estimates of Type A Viral Illness and Death from Ingestion of Ground Water after Option 4—Across-the-Board Disinfection and Sanitary Survey ("Community Water Supply, All Respondents" Age-Based Consumption Distributions)

	Illnesses per Year			Deaths per Year		
Cause/Source of Contamination	**10th percentile**	**Mean**	**90th percentile**	**10th percentile**	**Mean**	**90th percentile**
Source contamination in undisinfected ground water systems	606	**615**	623	0	**0**	0
Source contamination in ground water systems with failed disinfection	1,452	**7,261**	13,081	0	**0**	0
Contamination of distribution systems of ground water systems	14,504	**16,065**	17,631	0	**0**	0
Total	**18,109**	**23,941**	**29,830**	**0**	**0**	**0**

Exhibit A–25. Estimates of Type B Viral Illness and Death from Ingestion of Ground Water after Option 4—Across-the-Board Disinfection ("Community Water Supply, All Respondents" Age-Based Consumption Distributions)

	Illnesses per Year			Deaths per Year		
Cause/Source of Contamination	**10th percentile**	**Mean**	**90th percentile**	**10th percentile**	**Mean**	**90th percentile**
Source contamination in undisinfected ground water systems	9	**9**	10	0	**0**	0
Source contamination in ground water systems with failed disinfection	279	**1,352**	2,395	0	**1**	1
Contamination of distribution systems of ground water systems	3,665	**4,086**	4,510	2	**2**	2
Total	**4,340**	**5,447**	**6,554**	**2**	**2**	**3**

Appendix B-1
Results from Benefits Valuation Using the Upper Bound Drinking Water Consumption Distribution

(All Sources, Consumers Only)

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LIST OF EXHIBITS

B.1 Introduction

Included in this appendix are the results from the Ground Water Rule (GWR) benefits valuation and include: 1) results of the valuation of the output of the risk modeling and 2) selected distribution analysis.

Results of the valuation exercise are organized under section B.1 and include:

- Results for each of the four regulatory scenarios;
- For each of the four sets of outputs,

One detailed summary table with cost details for health and immunocompromised populations, for Type A and B viral and bacterial morbidity and mortality impacts; and

A pie chart indicating the relative contribution of each factor to the total benefits.

Distribution analysis is included in Section B.3 and includes analysis by size, type, and, for the Multi-Barrier Approach, by age.

B.2 Monetization of Health Benefits

B.2.1 Option 1: Sanitary Survey Only

Exhibit B–1 below shows the range of potential health benefits under the Sanitary Survey Option given the uncertainty in the risk assessment results. Details of the mean, 10th percentile, and 90th percentile of the annual expected value of reduced morbidity and mortality for this regulatory option is provided according to the immune status of the affected victim population. The overall annual health benefits of the Sanitary Survey Option range from a low (10th percentile) of $8.8 million to a high (90th percentile) of $57.6 million, with a mean of $32.5 million.

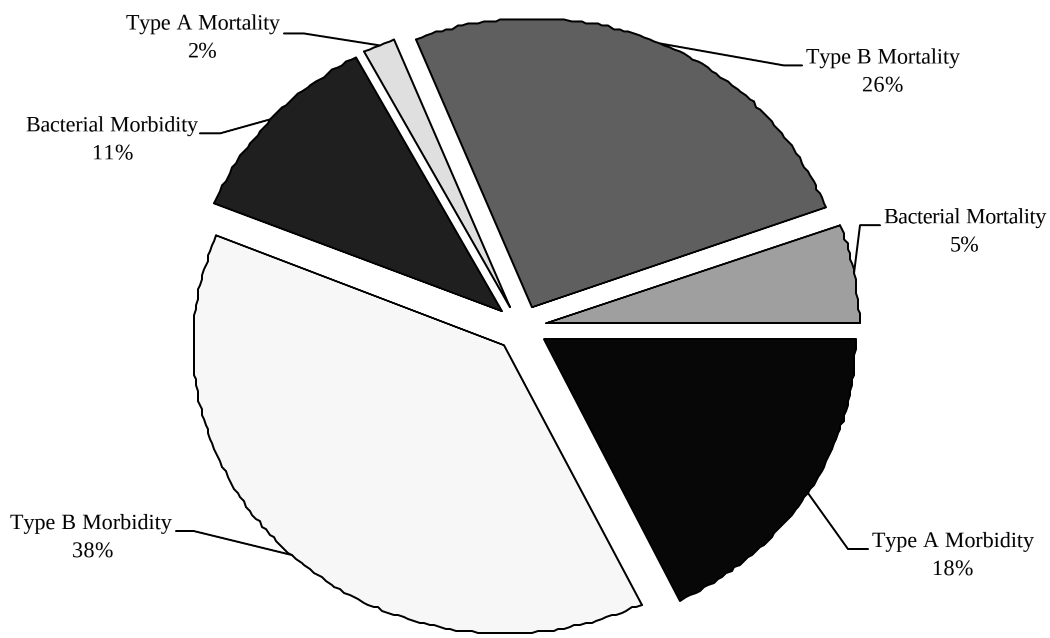
Exhibit B–1. Health Benefits from Sanitary Survey Option (million$)

Pathogen Type	Morbidity Benefits		Mortality Benefits	
	Healthy	Immuno-compromised	Healthy	Immuno-compromised
Type A virus				
10th percentile	$ 3.0	$ 0.5	$ 0.3	$ 0.0
mean	$ 4.9	$ 0.9	$ 0.5	$ 0.0
90th percentile	$ 7.1	$ 1.3	$ 0.8	$ 0.0
Type B virus				
10th percentile	$ 2.1	$ 0.1	$ 1.4	$ 0.0
mean	$ 12.0	$ 0.5	$ 8.3	$ 0.0
90th percentile	$ 22.4	$ 0.9	$ 15.5	$ 0.1
Viral Subtotal				
10th percentile	$ 5.0	$ 0.6	$ 1.7	$ 0.0
mean	$ 16.9	$ 1.4	$ 8.8	$ 0.1
90th percentile	$ 29.4	$ 2.2	$ 16.2	$ 0.2
Bacterial Subtotal				
10th percentile	$ 1.0	$ 0.1	$ 0.3	$ 0.0
mean	$ 3.4	$ 0.3	$ 1.8	$ 0.0
90th percentile	$ 5.9	$ 0.4	$ 3.2	$ 0.0
GWR Total				
10th percentile	$ 6.8		$ 2.0	
TOTAL (mean)	**$ 21.9**		**$ 10.6**	
90th percentile	$ 37.9		$ 19.7	

B.2.2 Option 1: Sanitary Survey Only

The percentage distribution of these mean health benefits by pathogen type is displayed in Exhibit B–2 below.

Exhibit B–2.
Health Effects for Sanitary Survey Option



Overall, the health benefits associated with the GWR under the Sanitary Survey Option are attributed to reductions of Type B viral illnesses (38 percent) and deaths (26 percent), compared to Type A health benefits (18 and 2 percent for Type A illness and death, respectively). Although there are significantly fewer cases of Type B illness and deaths, it is the more costly illness as discussed in Section B.2.3.

B.2.3 Option 2: Sanitary Survey and Triggered Monitoring

Exhibit B–3 presents the 10th percentile and mean, and 90th percentiles of the potential health benefits under the Sanitary Survey and Triggered Monitoring Option. The overall annual health benefits range from a low (10th percentile) of $147.4 million to a high (90th percentile) of $208.6 million with a mean of $177.9 million.

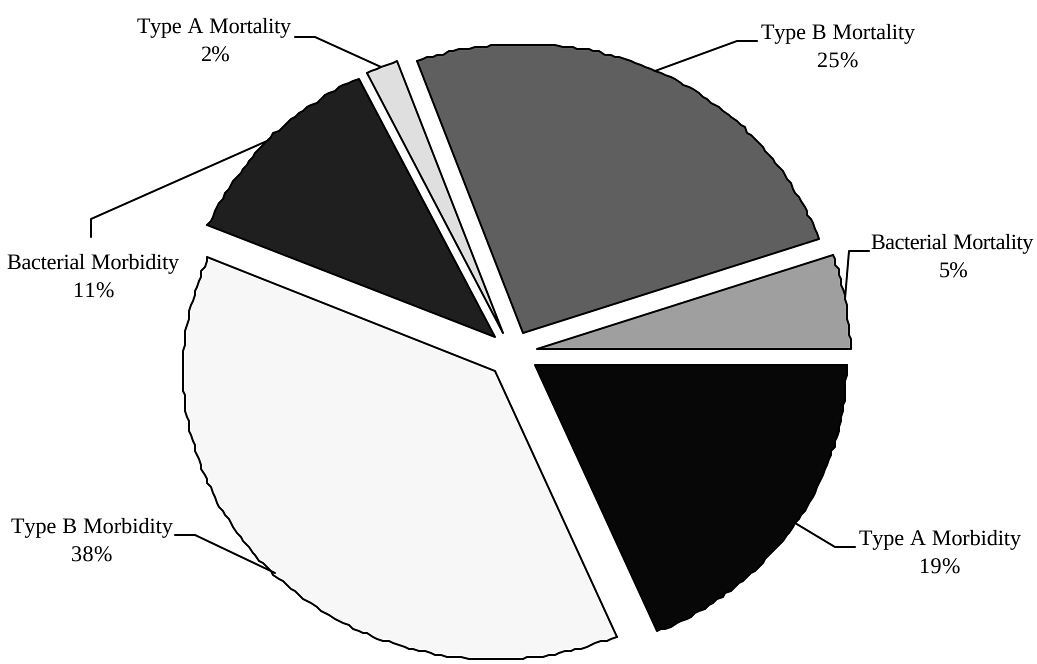
Exhibit B–3. Health Benefits from Sanitary Survey and Triggered Monitoring Option (million$)

Pathogen Type	Morbidity Benefits		Mortality Benefits	
	Healthy	Immuno-compromised	Healthy	Immuno-compromised
Type A virus				
10th percentile	$ 24.6	$ 4.4	$ 2.6	$ 0.0
mean	$ 27.9	$ 5.0	$ 3.0	$ 0.0
90th percentile	$ 31.3	$ 5.6	$ 3.3	$ 0.1
Type B virus				
10th percentile	$ 52.6	$ 2.2	$ 36.2	$ 0.1
mean	$ 64.7	$ 2.7	$ 44.6	$ 0.2
90th percentile	$ 76.9	$ 3.2	$ 53.1	$ 0.3
Viral Subtotal				
10th percentile	$ 77.2	$ 6.6	$ 38.8	$ 0.2
mean	$ 92.6	$ 7.7	$ 47.6	$ 0.3
90th percentile	$ 108.1	$ 8.8	$ 56.4	$ 0.4
Bacterial Subtotal				
10th percentile	$ 15.4	$ 1.3	$ 7.8	$ 0.0
mean	$ 18.5	$ 1.5	$ 9.5	$ 0.1
90th percentile	$ 21.6	$ 1.8	$ 11.3	$ 0.1
GWR Total				
10th percentile	$ 100.6		$ 46.8	
TOTAL (mean)	**$ 120.4**		**$ 57.5**	
90th percentile	$ 140.4		$ 68.2	

B.2.4 Option 2: Sanitary Survey and Triggered Monitoring

The percentage distribution of these mean health benefits by pathogen type is displayed in Exhibit B–4. As can be seen in this Sanitary Survey and Triggered Monitory Option, the greatest benefit results in a reduced Type B Morbidity (38 percent) followed by a reduction in Type B Mortality (25 percent).

Exhibit B–4. Health Effects of Sanitary Survey and Triggered Monitoring Option



B.2.5 Option 3: Multi-Barrier Approach

Exhibit B–5 presents the range of potential health benefits under the Multi-Barrier Approach given the uncertainty in the risk assessment results, including the mean, 10th percentile, and 90th percentile of the annual expected value of reduced morbidity and mortality for this regulatory option. The overall annual health benefits of the Multi-Barrier Approach range from a low (10th percentile) of $168.5 million to a high (90th percentile) of $241.9 million, with a mean of $205.0 million.

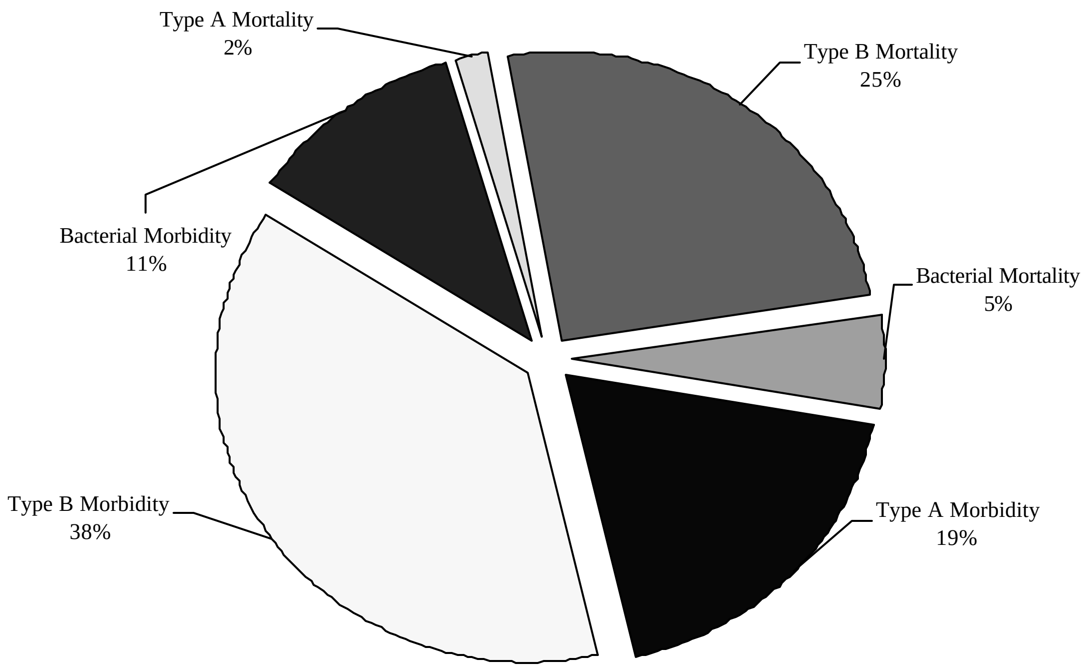
Exhibit B–5. Health Benefits from Multi-Barrier Approach (million$)

Pathogen Type	Morbidity Benefits		Mortality Benefits	
	Healthy	Immuno-compromised	Healthy	Immuno-compromised
Type A virus				
10th percentile	$ 27.5	$ 5.0	$ 2.9	$ 0.0
mean	$ 32.2	$ 5.8	$ 3.4	$ 0.1
90th percentile	$ 37.1	$ 6.7	$ 4.0	$ 0.1
Type B virus				
10th percentile	$ 60.5	$ 2.5	$ 41.7	$ 0.1
mean	$ 74.5	$ 3.1	$ 51.4	$ 0.3
90th percentile	$ 88.6	$ 3.7	$ 61.2	$ 0.4
Viral Subtotal				
10th percentile	$ 88.1	$ 7.5	$ 44.7	$ 0.2
mean	$ 106.8	$ 8.9	$ 54.9	$ 0.3
90th percentile	$ 125.6	$ 10.4	$ 65.1	$ 0.4
Bacterial Subtotal				
10th percentile	$ 17.6	$ 1.5	$ 8.9	$ 0.0
mean	$ 21.4	$ 1.8	$ 11.0	$ 0.1
90th percentile	$ 25.1	$ 2.1	$ 13.0	$ 0.1
GWR Total				
10th percentile	$ 114.7		$ 53.8	
TOTAL (mean)	**$ 138.8**		**$ 66.2**	
90th percentile	$ 163.2		$ 78.7	

B.2.6 Option 3: Multi-Barrier Approach

The percentage distribution of these mean health benefits by pathogen type is displayed in Exhibit B–6. As seen under the Sanitary Survey and Triggered Monitoring Option, the majority of the overall health benefits of the GWR under the Multi-Barrier Approach are attributed to reductions of Type A and B viral illnesses, 19 and 38 percent, respectively.

Exhibit B–6. Health Effects for Multi-Barrier Approach



B.2.7 Option 4: Across-the-Board Disinfection

Exhibit B–7 presents the mean, 10th and 90th percentiles of the potential health benefits under the Across-the-Board Disinfection Option. This regulatory alternative examines the effect of regulatic should all systems be required to implement treatment practices, assuming that the treatment reduced annual illnesses and deaths with greater than 99.9 percent effectiveness. Illnesses and deaths, however, were assumed to still occur given the possibility of treatment failure or distribution system contamination. Under the Across-the-Board Disinfection Option, the overall annual health benefits range from a low (10th percentile) of \$255.0 million to a high (90th percentile) of \$311.1 million, with mean of \$283.1 million.

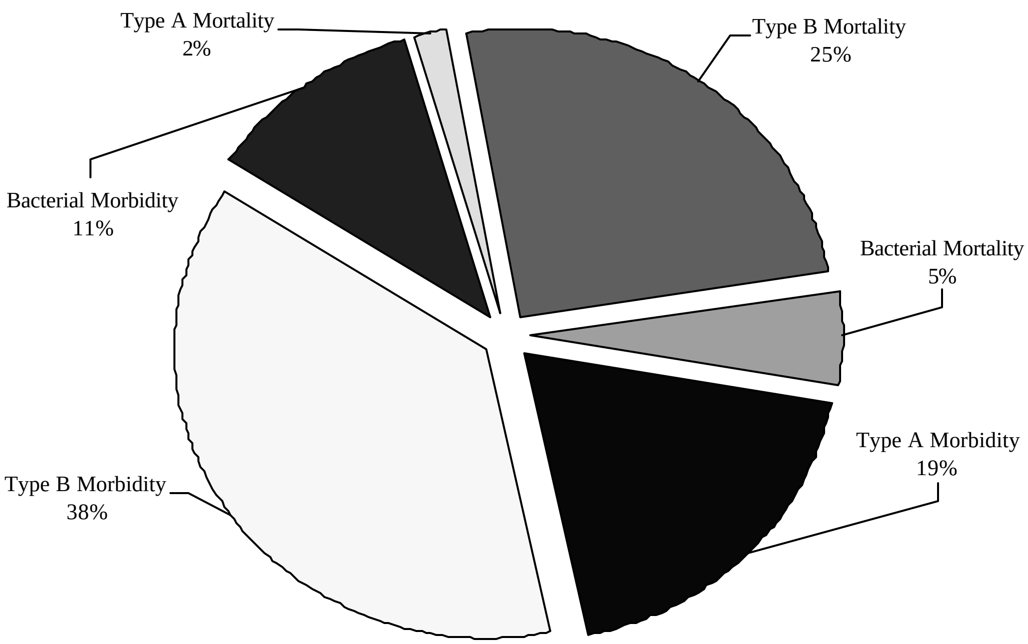
Exhibit B–7. Health Benefits from Across-the-Board Disinfection Option (million$)

Pathogen Type	Morbidity Benefits		Mortality Benefits	
	Healthy	Immuno-compromised	Healthy	Immuno-compromised
Type A virus				
10th percentile	$ 42.1	$ 7.6	$ 4.5	$ 0.1
mean	$ 45.2	$ 8.2	$ 4.8	$ 0.1
90th percentile	$ 48.3	$ 8.7	$ 5.2	$ 0.1
Type B virus				
10th percentile	$ 91.3	$ 3.8	$ 63.0	$ 0.2
mean	$ 102.4	$ 4.2	$ 70.7	$ 0.4
90th percentile	$ 113.5	$ 4.7	$ 78.4	$ 0.5
Viral Subtotal				
10th percentile	$ 133.4	$ 11.4	$ 67.4	$ 0.3
mean	$ 147.6	$ 12.4	$ 75.5	$ 0.4
90th percentile	$ 161.8	$ 13.4	$ 83.5	$ 0.5
Bacterial Subtotal				
10th percentile	$ 26.7	$ 2.3	$ 13.5	$ 0.1
mean	$ 29.5	$ 2.5	$ 15.1	$ 0.1
90th percentile	$ 32.4	$ 2.7	$ 16.7	$ 0.1
GWR Total				
10th percentile	$ 173.7		$ 81.3	
TOTAL (mean)	**$ 192.0**		**$ 91.1**	
90th percentile	$ 210.2		$ 100.9	

B.2.8 Option 4: Across-the-Board Disinfection

The distribution of the annual expected value of reducing morbidity and mortality is shown in Exhibit B–8. The pattern is identical to that previously seen in the Multi-Barrier Approach: 38 percent of the health benefits were attributable to reduced Type B morbidity, 19 percent to reduced Type A morbidity, 25 percent to reduced Type B mortality, 12 percent and 5 percent to reduced bacterial morbidity and mortality, respectively, and 2 percent to reduced Type A mortality

Exhibit B–8. Health Effects of Across-the-Board Disinfection Option



B.3 Distribution of Health Benefits

B.3.1 System Size

Exhibit B-9 presents the acute health benefits (i.e., reductions in morbidity and mortality), of the GWR options, by system size. As can be seen in this exhibit, the greatest overall health benefit results from the Across-the-Board Disinfection Option, and least with the Sanitary Survey Option.

B.3.2 System Type

Exhibit B–9. Acute Health Benefits of the GWR Regulatory Options, by System Size (million$)

MORBIDITY BENEFITS				
Size Category	Sanitary Survey	Sanitary Survey and Triggered Monitoring	Multi-Barrier	Across-the-Board Disinfection
<100	$ 0.6	$ 4.5	$ 5.2	$ 7.2
100-500	$ 1.7	$ 10.4	$ 11.9	$ 16.8
500-1K	$ 1.3	$ 7.7	$ 8.9	$ 12.5
1K-3.3K	$ 2.8	$ 15.0	$ 17.3	$ 24.0
3.3K-10K	$ 3.3	$ 17.5	$ 20.2	$ 27.8
10K-50K	$ 2.2	$ 11.4	$ 13.2	$ 18.1
50K-100K	$ 3.2	$ 17.6	$ 20.3	$ 27.9
100K-1M	$ 3.1	$ 16.2	$ 18.7	$ 25.7
Total	**$ 18.2**	**$ 100.3**	**$ 115.7**	**$ 160.0**
MORTALITY BENEFITS				
Size Category	Sanitary Survey	Sanitary Survey and Triggered Monitoring	Multi-Barrier	Across-the-Board Disinfection
<100	$ 0.3	$ 1.9	$ 2.2	$ 3.0
100-500	$ 0.8	$ 4.7	$ 5.4	$ 7.4
500-1K	$ 0.6	$ 3.6	$ 4.2	$ 5.7
1K-3.3K	$ 1.4	$ 7.2	$ 8.3	$ 11.5
3.3K-10K	$ 1.6	$ 8.5	$ 9.8	$ 13.5
10K-50K	$ 1.1	$ 5.5	$ 6.3	$ 8.7
50K-100K	$ 1.6	$ 8.6	$ 9.9	$ 13.6
100K-1M	$ 1.5	$ 7.8	$ 9.0	$ 12.4
Total	**$ 8.9**	**$ 47.9**	**$ 55.2**	**$ 75.9**
TOTAL BENEFITS				
Size Category	Sanitary Survey	Sanitary Survey and Triggered Monitoring	Multi-Barrier	Across-the-Board Disinfection
<100	$ 0.9	$ 6.4	$ 7.4	$ 10.2
100-500	$ 2.5	$ 15.1	$ 17.3	$ 24.2
500-1K	$ 2.0	$ 11.3	$ 13.0	$ 18.2
1K-3.3K	$ 4.1	$ 22.3	$ 25.7	$ 35.5
3.3K-10K	$ 4.9	$ 26.0	$ 30.0	$ 41.3
10K-50K	$ 3.2	$ 16.9	$ 19.5	$ 26.7
50K-100K	$ 4.8	$ 26.2	$ 30.2	$ 41.5
100K-1M	$ 4.6	$ 24.0	$ 27.7	$ 38.1
Total	**$ 27.1**	**$ 148.2**	**$ 170.8**	**$ 235.9**

Exhibit B–10 presents the acute health benefits of the four GWR regulatory options by system type. The least health benefits will result from implementing the Sanitary Survey Option.

Exhibit B–10. Acute Health Benefits of the GWR Regulatory Options, by System Type (million$)

VIRAL MORBIDITY BENEFITS				
Size Category	Sanitary Survey	Sanitary Survey and Triggered Monitoring	Multi-Barrier	Across-the-Board Disinfection
CWS	$ 15.7	$ 81.7	$ 94.3	$ 129.6
NTNC	$ 2.2	$ 12.9	$ 14.8	$ 21.5
TNC	$ 0.3	$ 5.7	$ 6.6	$ 8.9
Total	**$ 18.2**	**$ 100.3**	**$ 115.7**	**$ 160.0**
VIRAL MORTALITY BENEFITS				
Size Category	Sanitary Survey	Sanitary Survey and Triggered Monitoring	Multi-Barrier	Across-the-Board Disinfection
CWS	$ 7.7	$ 40.2	$ 46.3	$ 63.8
NTNC	$ 1.1	$ 6.1	$ 7.0	$ 9.6
TNC	$ 0.1	$ 1.6	$ 1.9	$ 2.5
Total	**$ 8.9**	**$ 47.9**	**$ 55.2**	**$ 75.9**
TOTAL BACTERIAL BENEFITS				
Size Category	Sanitary Survey	Sanitary Survey and Triggered Monitoring	Multi-Barrier	Across-the-Board Disinfection
CWS	$ 4.7	$ 24.4	$ 28.1	$ 38.7
NTNC	$ 0.7	$ 3.8	$ 4.3	$ 6.2
TNC	$ 0.1	$ 1.5	$ 1.7	$ 2.3
Total	**$ 5.4**	**$ 29.6**	**$ 34.2**	**$ 47.2**
TOTAL GWR BENEFITS				
Size Category	Sanitary Survey	Sanitary Survey and Triggered Monitoring	Multi-Barrier	Across-the-Board Disinfection
CWS	$ 28.1	$ 146.3	$ 168.8	$ 232.0
NTNC	$ 3.9	$ 22.8	$ 26.1	$ 37.3
TNC	$ 0.5	$ 8.8	$ 10.1	$ 13.7
Total	**$ 32.5**	**$ 177.9**	**$ 205.0**	**$ 283.1**

B.3.3 Multi-Barrier Morbidity Distribution by Age

The resulting viral-related health benefits resulting form implementation of the Multi-Barrier Approach is presented in Exhibit B–11. Overall, the reduced Type A virus morbidity will be $4.3 million for TNC systems.

Exhibit B–11. Viral Related Health Benefits from Reduced Morbidity by Illness, System Type, and Victim Age Multi-Barrier Approach (million$)

Age Group	TYPE A VIRUS			TYPE B VIRUS		
	CWS	NTNC	TNC	CWS	NTNC	TNC
Less than 5 y.o.	$ 9.6	$ 1.6	$ 1.4	$ 3.9	$ 0.6	$ 0.1
Between 5-16 y.o.	$ 1.6	$ 0.3	$ 0.2	$ 9.8	$ 1.4	$ 0.3
Over 16 y.o.	$ 17.6	$ 3.0	$ 2.7	$ 51.8	$ 7.8	$ 1.8
TOTAL	**$ 28.8**	**$ 4.9**	**$ 4.3**	**$ 65.5**	**$ 9.8**	**$ 2.3**

B.3.4 Multi-Barrier Mortality Distribution by Age

The Reduced Mortality benefits as a result of implementing the Multi-Barrier Approach are presented in Exhibit B–12. The greatest health benefit, $32.7 million, will occur with regard to the Type B virus and those more than 16 years old.

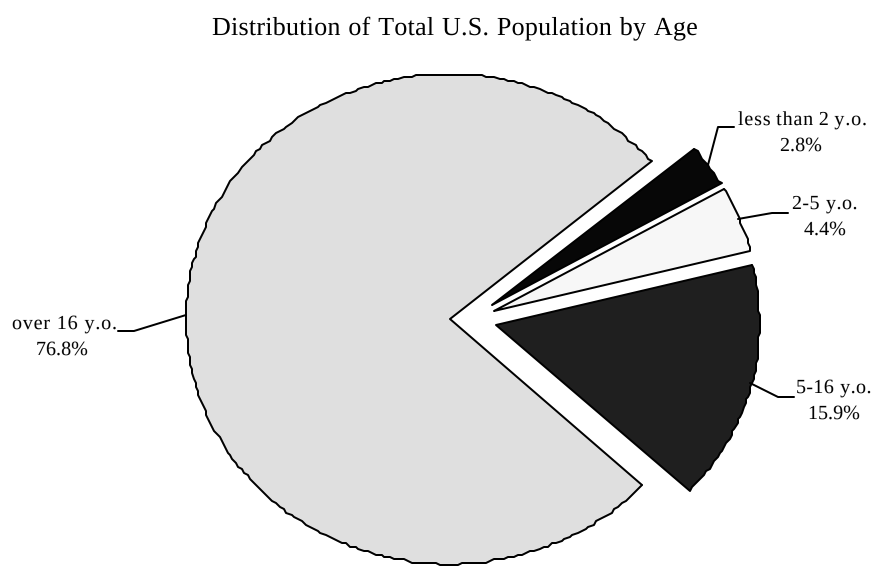
Exhibit B–12. Viral Related Health Benefits from Reduced Mortality by Illness, System Type, and Victim Age Multi-Barrier Approach (million$)

Age Group	TYPE A VIRUS			TYBE B VIRUS		
	CWS	NTNC	TNC	CWS	NTNC	TNC
Less than 5 y.o.	$ 0.5	$ 0.1	$ 0.1	$ 4.2	$ 0.6	$ 0.1
Between 5-16 y.o.	$ 0.3	$ 0.0	$ 0.0	$ 6.8	$ 1.0	$ 0.2
Over 16 y.o.	$ 1.9	$ 0.3	$ 0.3	$ 32.7	$ 4.9	$ 1.2
TOTAL	**$ 2.6**	**$ 0.5**	**$ 0.4**	**$ 43.7**	**$ 6.5**	**$ 1.5**

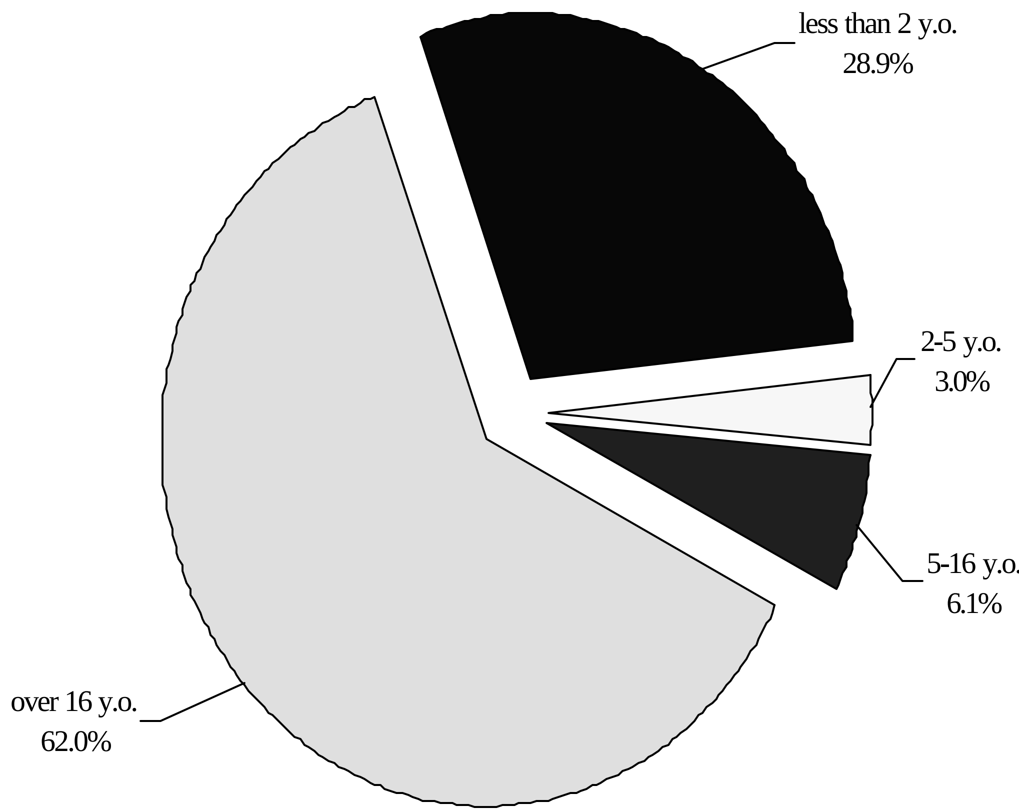
B.3.5 Multi-Barrier Age Type A Benefits Distribution by Age

Currently, the costs of Type A illness fall heavily on those under two years of age. Therefore, the benefit of reductions in Type A illness are disproportionately captured by those in this age group. As demonstrated in Exhibit B–13, children under two years of age make up only 2.8 percent of the U.S. population, while 28.9 percent of the reduction in Type A illness related costs are attributable to these young children.

Exhibit B–13. Comparison of Selected Age Categories in the U.S. Population to Their Relative Roles in Type A Morbidity and Mortality Health Benefits Multi-Barrier Approach



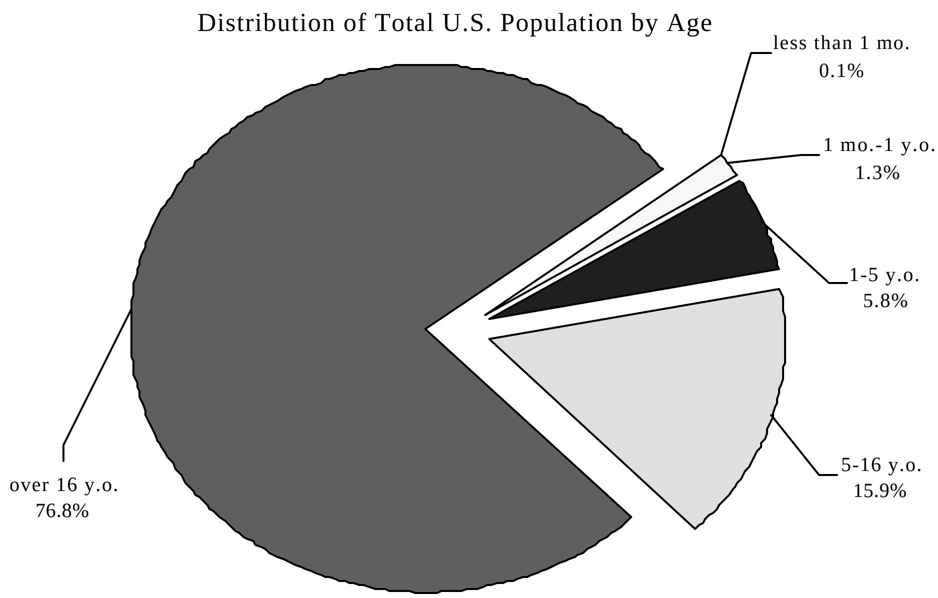
Distribution of Total Type A Health Benefits by Age



B.3.6 Multi-Barrier Age Type B Benefits Distribution by Age

As demonstrated in Exhibit B–14, a similar situation exists with Type B viruses, although to a lesser degree. Children under five years of age make up only 7.2 percent of the U.S. population, while 7.4 percent of the reduction in Type B illness related costs are attributable to these children.

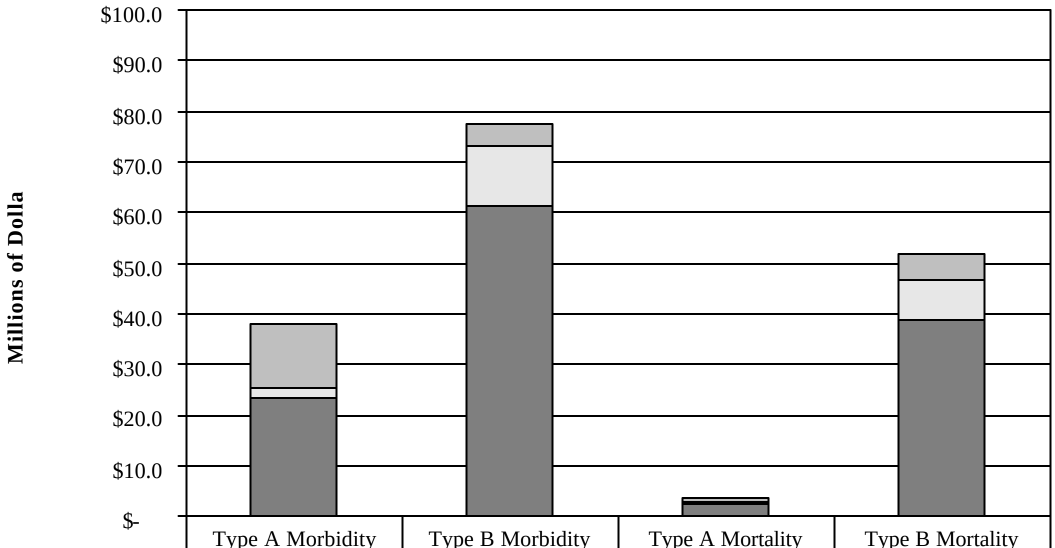
Exhibit B–14. Comparison of Selected Age Categories in the U.S. Population to Their Relative Roles in Type B Morbidity and Mortality Health Benefits Multi-Barrier Approach



B.3.7 Multi-Barrier Age Benefits Distribution by Age

Exhibit B–15 brings all of the virus and age-related information together to illustrate the breakdown of health benefits associated with the Multi-Barrier Approach. Two important points are made in this chart. As discussed earlier, the majority of health benefits are derived from reductions in Type A and Type B virus morbidity. Also, across virus type, because over 76 percent of the population is over 16 years of age, most of the benefit of reducing exposure to both Type A and Type B viruses is captured by people in this age group.

Exhibit B–15. Total GWR Morbidity and Mortality Health Benefits by Illness Type, and Victim Age Multi-Barrier Approach



	Type A Morbidity	Type B Morbidity	Type A Mortality	Type B Mortality
less than 5 y.o.	$12.6	$4.6	$0.6	$4.9
5-16 y.o.	$2.1	$11.5	$0.4	$8.0
over 16 y.o.	$23.3	$61.4	$2.5	$38.8

Appendix B-2
Results from Benefits Valuation Using the Lower Bound Drinking Water Consumption Distribution
(Community Water Supply, All Respondents)

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LIST OF EXHIBITS

B.1 Introduction

Included in this appendix are the results from the Ground Water Rule (GWR) benefits valuation and include: 1) results of the valuation of the output of the risk modeling and 2) selected distribution analysis.

Results of the valuation exercise are organized under section B.1 and include:

- Results for each of the four regulatory scenarios;

- For each of the four sets of outputs,

One detailed summary table with cost details for health and immunocompromised populations, for Type A and B viral and bacterial morbidity and mortality impacts; and

A pie chart indicating the relative contribution of each factor to the total benefits.

Distribution analysis is included in Section B.3 and includes analysis by size, type, and, for the Multi-Barrier Approach, by age.

B.2 Monetization of Health Benefits

B.2.1 Option 1: Sanitary Survey Only

Exhibit B–1 below shows the range of potential health benefits under the Sanitary Survey Option given the uncertainty in the risk assessment results. Details of the mean, 10th percentile, and 90th percentile of the annual expected value of reduced morbidity and mortality for this regulatory option is provided according to the immune status of the affected victim population. The overall annua health benefits of the Sanitary Survey Option range from a low (10th percentile) of $7.2 million to a hig (90th percentile) of $45.0 million, with a mean of $25.6 million.

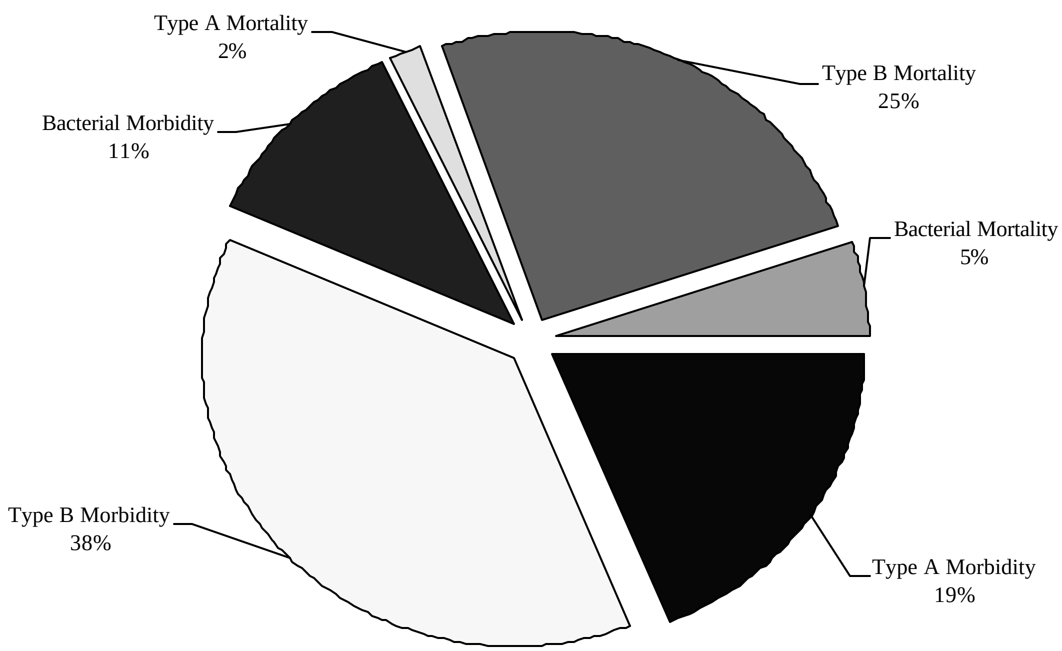
Exhibit B–1. Health Benefits from Sanitary Survey Option (million$)

Pathogen Type	Morbidity Benefits		Mortality Benefits	
	Healthy	Immuno-compromised	Healthy	Immuno-compromised
Type A virus				
10th percentile	$ 2.5	$ 0.5	$ 0.3	$ 0.0
mean	$ 4.1	$ 0.7	$ 0.4	$ 0.0
90th percentile	$ 5.9	$ 1.1	$ 0.6	$ 0.0
Type B virus				
10th percentile	$ 1.6	$ 0.1	$ 1.1	$ 0.0
mean	$ 9.3	$ 0.4	$ 6.4	$ 0.0
90th percentile	$ 17.2	$ 0.7	$ 11.9	$ 0.1
Viral Subtotal				
10th percentile	$ 4.1	$ 0.5	$ 1.3	$ 0.0
mean	$ 13.4	$ 1.1	$ 6.8	$ 0.0
90th percentile	$ 23.1	$ 1.8	$ 12.5	$ 0.1
Bacterial Subtotal				
10th percentile	$ 0.8	$ 0.1	$ 0.3	$ 0.0
mean	$ 2.7	$ 0.2	$ 1.4	$ 0.0
90th percentile	$ 4.6	$ 0.4	$ 2.5	$ 0.0
GWR Total				
10th percentile	$ 5.6		$ 1.6	
TOTAL (mean)	**$ 17.4**		**$ 8.2**	
90th percentile	$ 29.9		$ 15.1	

B.2.2 Option 1: Sanitary Survey Only

The percentage distribution of these mean health benefits by pathogen type is displayed in Exhibit B–2 below.

Exhibit B–2.
Health Effects for Sanitary Survey Option



Overall, the health benefits associated with the GWR under the Sanitary Survey Option are attributed to reductions of Type B viral illnesses (38 percent) and deaths (25 percent), compared to Type A health benefits (nineteen and two percent for Type A illness and death, respectively). Although there are significantly fewer cases of Type B illness and deaths, it is the more costly illness as discuss in Section B.2.3.

B.2.3 Option 2: Sanitary Survey and Triggered Monitoring

Exhibit B–3 presents the 10th percentile and mean, and 90th percentiles of the potential health benefits under the Sanitary Survey and Triggered Monitoring Option. The overall annual health benefits range from a low (10th percentile) of $115.9 million to a high (90th percentile) of $163.4 million with a mean of $139.6 million.

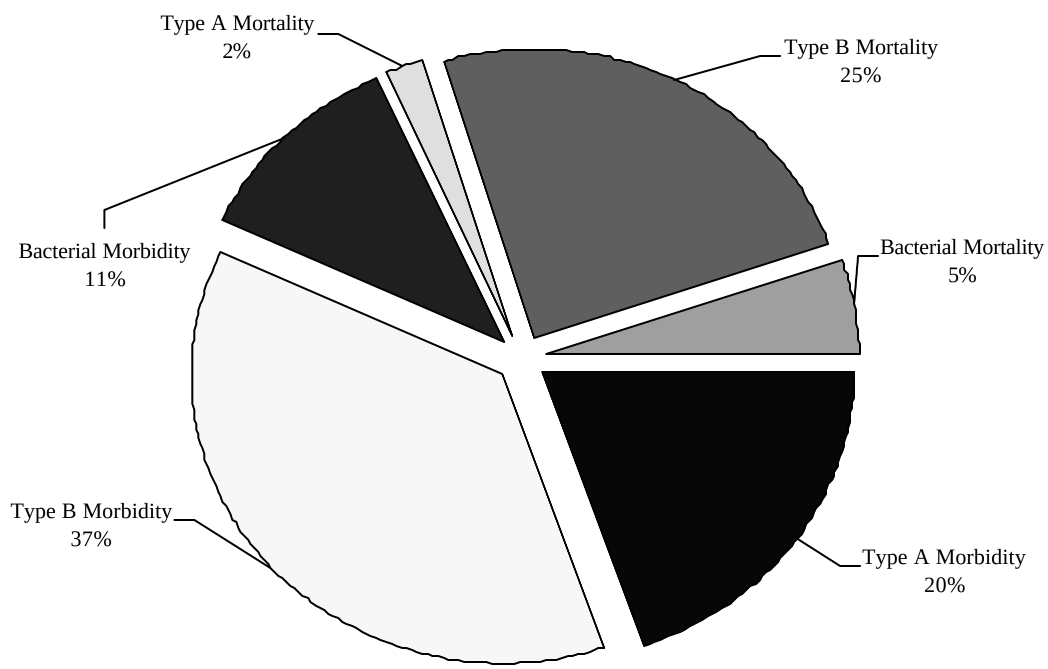
Exhibit B–3. Health Benefits from Sanitary Survey and Triggered Monitoring Option (million$)

Pathogen Type	Morbidity Benefits		Mortality Benefits	
	Healthy	Immuno-compromised	Healthy	Immuno-compromised
Type A virus				
10th percentile	$ 20.7	$ 3.8	$ 2.2	$ 0.0
mean	$ 23.4	$ 4.3	$ 2.5	$ 0.0
90th percentile	$ 26.2	$ 4.8	$ 2.8	$ 0.0
Type B virus				
10th percentile	$ 40.4	$ 1.7	$ 27.7	$ 0.1
mean	$ 49.7	$ 2.1	$ 34.1	$ 0.2
90th percentile	$ 59.1	$ 2.4	$ 40.6	$ 0.3
Viral Subtotal				
10th percentile	$ 61.1	$ 5.4	$ 29.9	$ 0.1
mean	$ 73.2	$ 6.3	$ 36.6	$ 0.2
90th percentile	$ 85.3	$ 7.2	$ 43.4	$ 0.3
Bacterial Subtotal				
10th percentile	$ 12.2	$ 1.1	$ 6.0	$ 0.0
mean	$ 14.6	$ 1.3	$ 7.3	$ 0.0
90th percentile	$ 17.1	$ 1.4	$ 8.7	$ 0.1
GWR Total				
10th percentile	$ 79.9		$ 36.0	
TOTAL (mean)	**$ 95.4**		**$ 44.2**	
90th percentile	$ 111.0		$ 52.4	

B.2.4 Option 2: Sanitary Survey and Triggered Monitoring

The percentage distribution of these mean health benefits by pathogen type is displayed in Exhibit B–4. As can be seen in this Sanitary Survey and Triggered Monitory Option, the greatest benefit results in a reduced Type B Morbidity (37 percent) followed by a reduction in Type B Mortality (25 percent).

Exhibit B–4. Health Effects of Sanitary Survey and Triggered Monitoring Option



B.2.5 Option 3: Multi-Barrier Approach

Exhibit B–5 presents the range of potential health benefits under the Multi-Barrier Approach given the uncertainty in the risk assessment results, including the mean, 10^{th} percentile, and 90^{th} percentile of the annual expected value of reduced morbidity and mortality for this regulatory option. The overall annual health benefits of the Multi-Barrier Approach range from a low (10^{th} percentile) of $132.7 million to a high (90^{th} percentile) of $189.4 million, with a mean of $161.0 million.

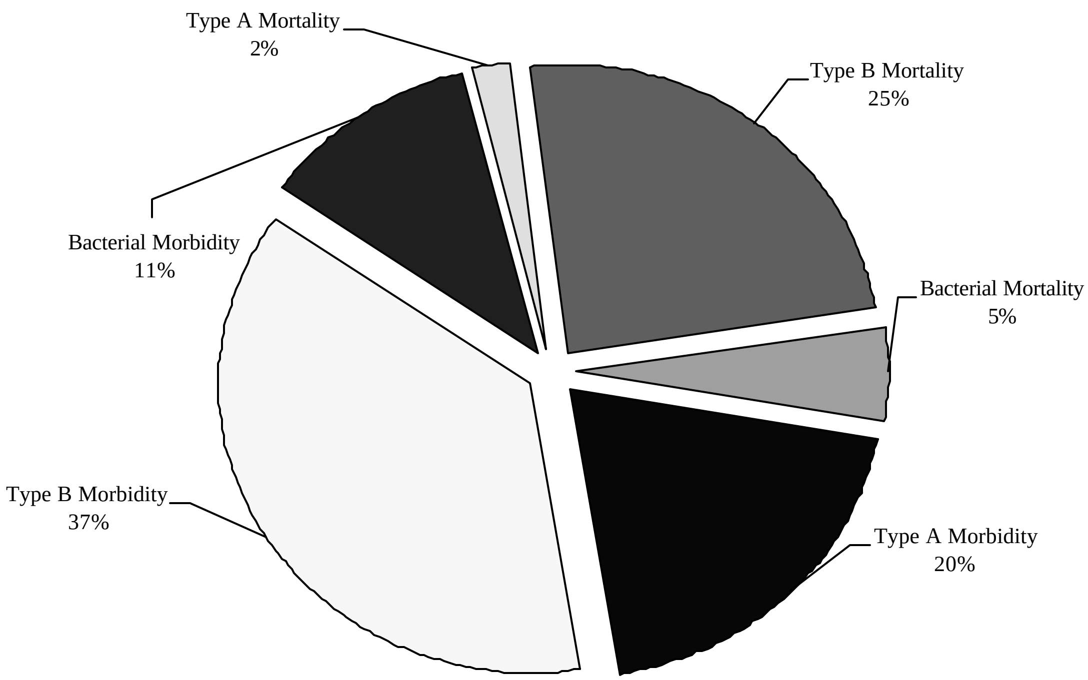
Exhibit B–5. Health Benefits from Multi-Barrier Approach (million$)

Pathogen Type	Morbidity Benefits		Mortality Benefits	
	Healthy	Immuno-compromised	Healthy	Immuno-compromised
Type A virus				
10th percentile	$ 23.2	$ 4.2	$ 2.5	$ 0.0
mean	$ 27.1	$ 4.9	$ 2.9	$ 0.0
90th percentile	$ 31.1	$ 5.6	$ 3.3	$ 0.1
Type B virus				
10th percentile	$ 46.6	$ 1.9	$ 32.0	$ 0.1
mean	$ 57.4	$ 2.4	$ 39.4	$ 0.2
90th percentile	$ 68.0	$ 2.8	$ 46.7	$ 0.3
Viral Subtotal				
10th percentile	$ 69.8	$ 6.1	$ 34.4	$ 0.1
mean	$ 84.4	$ 7.3	$ 42.3	$ 0.2
90th percentile	$ 99.0	$ 8.5	$ 50.0	$ 0.3
Bacterial Subtotal				
10th percentile	$ 14.0	$ 1.2	$ 6.9	$ 0.0
mean	$ 16.9	$ 1.5	$ 8.5	$ 0.0
90th percentile	$ 19.8	$ 1.7	$ 10.0	$ 0.1
GWR Total				
10th percentile	$ 91.2		$ 41.5	
TOTAL (mean)	**$ 110.0**		**$ 51.0**	
90th percentile	$ 129.0		$ 60.4	

B.2.6 Option 3: Multi-Barrier Approach

The percentage distribution of these mean health benefits by pathogen type is displayed in Exhibit B–6. As seen under the Sanitary Survey and Triggered Monitoring Option, the majority of the overall health benefits of the GWR under the Multi-Barrier Approach are attributed to reductions of Type A and B viral illnesses, 20 and 37 percent, respectively.

Exhibit B–6. Health Effects for Multi-Barrier Approach



B.2.7 Option 4: Across-the-Board Disinfection

Exhibit B–7 presents the mean, 10th and 90th percentiles of the potential health benefits under the Across-the-Board Disinfection Option. This regulatory alternative examines the effect of regulatic should all systems be required to implement treatment practices, assuming that the treatment reduced annual illnesses and deaths with greater than 99.9 percent effectiveness. Illnesses and deaths, however, were assumed to still occur given the possibility of treatment failure or distribution system contamination. Under the Across-the-Board Disinfection Option, the overall annual health benefits range from a low (10th percentile) of $201.1 million to a high (90th percentile) of $244.4 million, with mean of $222.7 million.

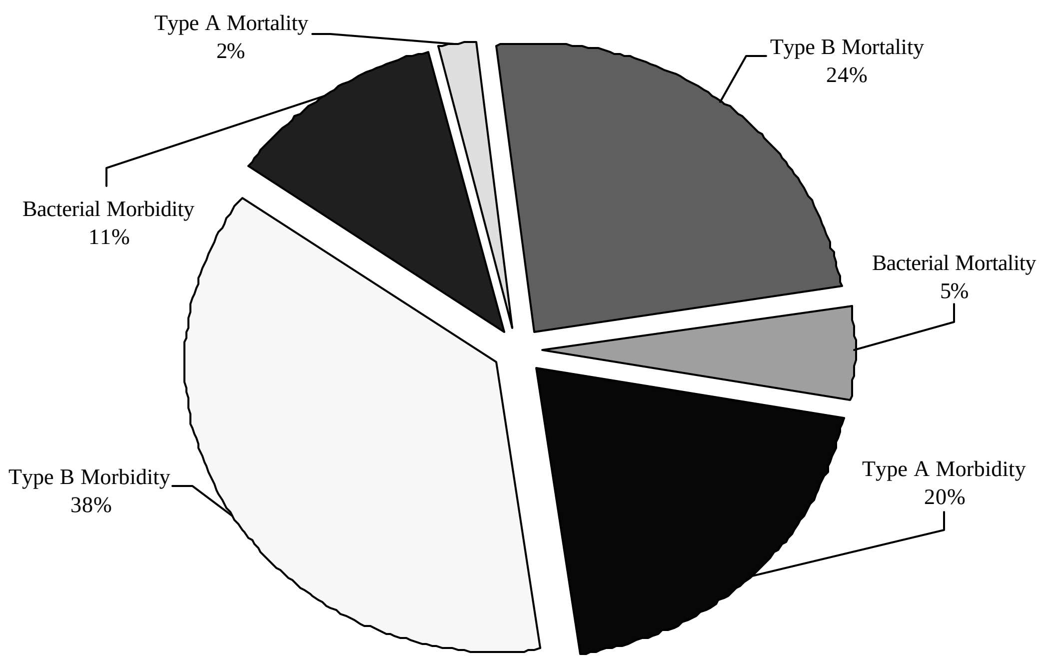
Exhibit B–7. Health Benefits from Across-the-Board Disinfection Option (million$)

Pathogen Type	Morbidity Benefits		Mortality Benefits	
	Healthy	Immuno-compromised	Healthy	Immuno-compromised
Type A virus				
10th percentile	$ 35.4	$ 6.4	$ 3.8	$ 0.1
mean	$ 37.9	$ 6.9	$ 4.1	$ 0.1
90th percentile	$ 40.5	$ 7.4	$ 4.3	$ 0.1
Type B virus				
10th percentile	$ 70.5	$ 2.9	$ 48.3	$ 0.2
mean	$ 78.9	$ 3.3	$ 54.2	$ 0.3
90th percentile	$ 87.4	$ 3.6	$ 60.0	$ 0.4
Viral Subtotal				
10th percentile	$ 105.9	$ 9.3	$ 52.1	$ 0.2
mean	$ 116.9	$ 10.2	$ 58.2	$ 0.3
90th percentile	$ 127.9	$ 11.0	$ 64.4	$ 0.4
Bacterial Subtotal				
10th percentile	$ 21.2	$ 1.9	$ 10.4	$ 0.0
mean	$ 23.4	$ 2.0	$ 11.6	$ 0.1
90th percentile	$ 25.6	$ 2.2	$ 12.9	$ 0.1
GWR Total				
10th percentile	$ 138.3		$ 62.8	
TOTAL (mean)	**$ 152.4**		**$ 70.3**	
90th percentile	$ 166.7		$ 77.7	

B.2.8 Option 4: Across-the-Board Disinfection

The distribution of the annual expected value of reducing morbidity and mortality is shown in Exhibit B–8. The pattern is similar to that previously seen in the Multi-Barrier Approach: 38 percent of the health benefits were attributable to reduced Type B morbidity, 20 percent to reduced Type A morbidity, 24 percent to reduced Type B mortality, eleven percent and five percent to reduced bacterial morbidity and mortality, respectively, and two percent to reduced Type A mortality.

Exhibit B–8. Health Effects of Across-the-Board Disinfection Option



B.3 Distribution of Health Benefits

B.3.1 System Size

Exhibit B–9 presents the acute health benefits (i.e., reductions in morbidity and mortality), of the GWR options, by system size. As can be seen on this exhibit, the greatest overall health benefit results from the Across-the-Board Disinfection Option and least with the Sanitary Survey Option.

Exhibit B–9. Acute Health Benefits of the GWR Regulatory Options, by System Size (million$)

MORBIDITY BENEFITS				
Size Category	Sanitary Survey	Sanitary Survey and Triggered Monitoring	Multi-Barrier	Across-the-Board Disinfection
<100	$ 0.5	$ 3.6	$ 4.1	$ 5.7
100-500	$ 1.3	$ 8.2	$ 9.5	$ 13.3
500-1K	$ 1.1	$ 6.1	$ 7.0	$ 9.9
1K-3.3K	$ 2.2	$ 11.9	$ 13.7	$ 19.1
3.3K-10K	$ 2.6	$ 13.9	$ 16.0	$ 22.1
10K-50K	$ 1.7	$ 9.0	$ 10.4	$ 14.3
50K-100K	$ 2.6	$ 14.0	$ 16.1	$ 22.2
100K-1M	$ 2.4	$ 12.8	$ 14.9	$ 20.4
Total	**$ 14.5**	**$ 79.5**	**$ 91.7**	**$ 127.0**
MORTALITY BENEFITS				
Size Category	Sanitary Survey	Sanitary Survey and Triggered Monitoring	Multi-Barrier	Across-the-Board Disinfection
<100	$ 0.2	$ 1.5	$ 1.7	$ 2.3
100-500	$ 0.6	$ 3.6	$ 4.1	$ 5.7
500-1K	$ 0.5	$ 2.8	$ 3.2	$ 4.4
1K-3.3K	$ 1.0	$ 5.6	$ 6.4	$ 8.9
3.3K-10K	$ 1.2	$ 6.6	$ 7.6	$ 10.4
10K-50K	$ 0.8	$ 4.2	$ 4.9	$ 6.7
50K-100K	$ 1.2	$ 6.6	$ 7.6	$ 10.5
100K-1M	$ 1.2	$ 6.0	$ 7.0	$ 9.6
Total	**$ 6.8**	**$ 36.8**	**$ 42.5**	**$ 58.6**
TOTAL BENEFITS				
Size Category	Sanitary Survey	Sanitary Survey and Triggered Monitoring	Multi-Barrier	Across-the-Board Disinfection
<100	$ 0.7	$ 5.1	$ 5.8	$ 8.0
100-500	$ 2.0	$ 11.8	$ 13.6	$ 19.0
500-1K	$ 1.6	$ 8.9	$ 10.2	$ 14.3
1K-3.3K	$ 3.3	$ 17.5	$ 20.2	$ 28.0
3.3K-10K	$ 3.9	$ 20.4	$ 23.6	$ 32.5
10K-50K	$ 2.5	$ 13.2	$ 15.3	$ 21.0
50K-100K	$ 3.8	$ 20.6	$ 23.7	$ 32.7
100K-1M	$ 3.6	$ 18.9	$ 21.8	$ 30.0
Total	**$ 21.3**	**$ 116.3**	**$ 134.2**	**$ 185.6**

B.3.2 System Type

Exhibit B–10 presents the acute health benefits of the four GWR regulatory options by system type. The least health benefits will result from implementing the Sanitary Survey Option.

Exhibit B–10. Acute Health Benefits of the GWR Regulatory Options, by System Type (million$)

VIRAL MORBIDITY BENEFITS				
Size Category	Sanitary Survey	Sanitary Survey and Triggered Monitoring	Multi-Barrier	Across-the-Board Disinfection
CWS	$ 12.5	$ 64.8	$ 74.9	$ 102.9
NTNC	$ 1.8	$ 10.2	$ 11.7	$ 17.1
TNC	$ 0.2	$ 4.5	$ 5.2	$ 7.0
Total	**$ 14.5**	**$ 79.5**	**$ 91.7**	**$ 127.0**
VIRAL MORTALITY BENEFITS				
Size Category	Sanitary Survey	Sanitary Survey and Triggered Monitoring	Multi-Barrier	Across-the-Board Disinfection
CWS	$ 6.0	$ 30.9	$ 35.7	$ 49.2
NTNC	$ 0.8	$ 4.7	$ 5.4	$ 7.4
TNC	$ 0.1	$ 1.3	$ 1.4	$ 1.9
Total	**$ 6.8**	**$ 36.8**	**$ 42.5**	**$ 58.6**
TOTAL BACTERIAL BENEFITS				
Size Category	Sanitary Survey	Sanitary Survey and Triggered Monitoring	Multi-Barrier	Across-the-Board Disinfection
CWS	$ 3.7	$ 19.1	$ 22.1	$ 30.4
NTNC	$ 0.5	$ 3.0	$ 3.4	$ 4.9
TNC	$ 0.1	$ 1.2	$ 1.3	$ 1.8
Total	**$ 4.3**	**$ 23.3**	**$ 26.8**	**$ 37.1**
TOTAL GWR BENEFITS				
Size Category	Sanitary Survey	Sanitary Survey and Triggered Monitoring	Multi-Barrier	Across-the-Board Disinfection
CWS	$ 22.1	$ 114.8	$ 132.7	$ 182.6
NTNC	$ 3.1	$ 17.8	$ 20.4	$ 29.4
TNC	$ 0.4	$ 7.0	$ 7.9	$ 10.7
Total	**$ 25.6**	**$ 139.6**	**$ 161.0**	**$ 222.7**

B.3.3 Multi-Barrier Morbidity Distribution by Age

The resulting viral-related health benefits resulting form implementation of the Multi-Barrier Approach is presented in Exhibit B–11. Overall, the reduced Type A virus morbidity will be $3.5 million for TNC systems.

Exhibit B–11. Viral Related Health Benefits from Reduced Morbidity by Illness, System Type, and Victim Age Multi-Barrier Approach (million$)

Age Group	TYPE A VIRUS			TYPE B VIRUS		
	CWS	NTNC	TNC	CWS	NTNC	TNC
Less than 5 y.o.	$ 8.0	$ 1.4	$ 1.1	$ 2.9	$ 0.4	$ 0.1
Between 5-16 y.o.	$ 1.4	$ 0.2	$ 0.2	$ 7.5	$ 1.1	$ 0.2
Over 16 y.o.	$ 15.0	$ 2.6	$ 2.2	$ 40.1	$ 6.0	$ 1.4
TOTAL	**$ 24.3**	**$ 4.2**	**$ 3.5**	**$ 50.5**	**$ 7.5**	**$ 1.7**

B.3.4 Multi-Barrier Mortality Distribution by Age

The Reduced Mortality benefits as a result of implementing the Multi-Barrier Approach are presented in Exhibit B–12. The greatest health benefit, $25.3 million, will occur with regard to the Type B virus and those more than 16 years old.

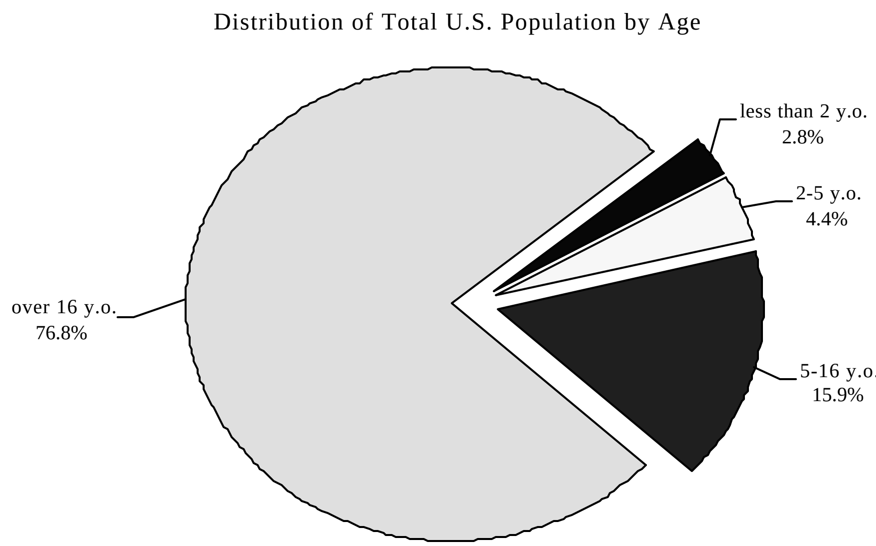
Exhibit B–12. Viral Related Health Benefits from Reduced Mortality by Illness, System Type, and Victim Age Multi-Barrier Approach (million$)

Age Group	TYPE A VIRUS			TYBE B VIRUS		
	CWS	NTNC	TNC	CWS	NTNC	TNC
Less than 5 y.o.	$ 0.4	$ 0.1	$ 0.1	$ 3.0	$ 0.4	$ 0.1
Between 5-16 y.o.	$ 0.2	$ 0.0	$ 0.0	$ 5.2	$ 0.8	$ 0.2
Over 16 y.o.	$ 1.6	$ 0.3	$ 0.2	$ 25.3	$ 3.8	$ 0.9
TOTAL	**$ 2.2**	**$ 0.4**	**$ 0.3**	**$ 33.5**	**$ 5.0**	**$ 1.1**

B.3.5 Multi-Barrier Age Type A Benefits Distribution by Age

Currently, the costs of Type A illness fall heavily on those under two years of age. Therefore, the benefit of reductions in Type A illness are disproportionately captured by those in this age group. As demonstrated in Exhibit B–13, children under two years of age make up only 2.8 percent of the U.S. population, while 28.4 percent of the reduction in Type A illness related costs are attributable to these young children.

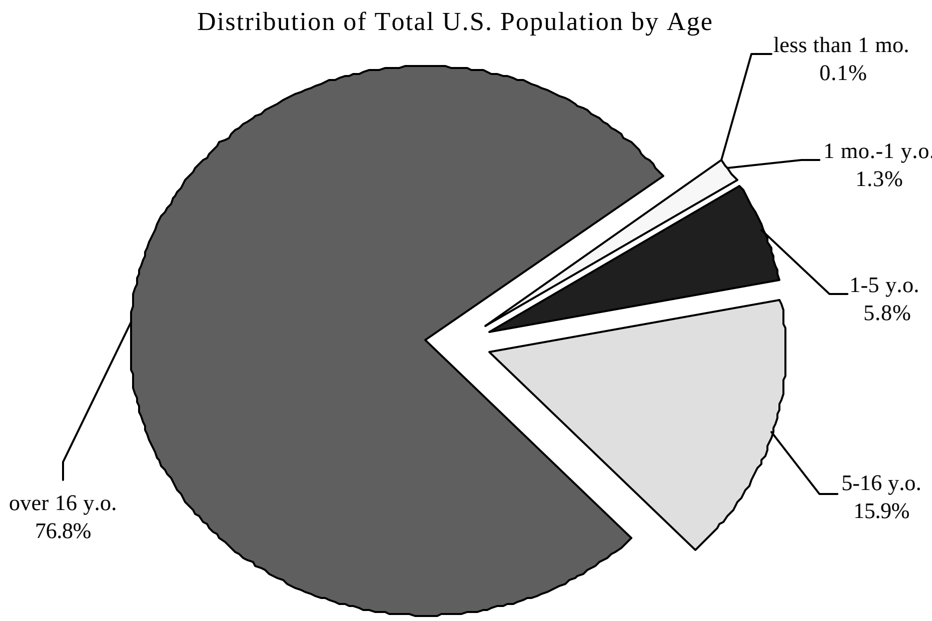
Exhibit B–13. Comparison of Selected Age Categories in the U.S. Population to Their Relative Roles in Type A Morbidity and Mortality Health Benefits Multi-Barrier Approach

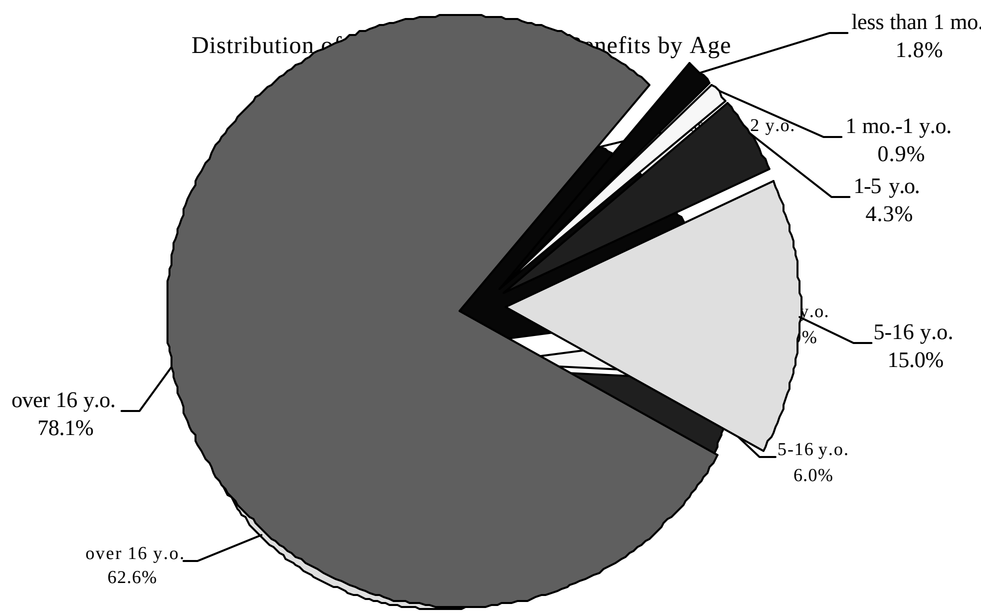


B.3.6 Multi-Barrier Age Type B Benefits Distribution by Age

As demonstrated in Exhibit B–14, a similar situation exists with Type B viruses, although to a lesser degree. Children under five years of age make up only 7.2 percent of the U.S. population, while 7.0 percent of the reduction in Type B illness related costs are attributable to these children.

Exhibit B–14. Comparison of Selected Age Categories in the U.S. Population to Their Relative Roles in Type B Morbidity and Mortality Health Benefits Multi-Barrier Approach

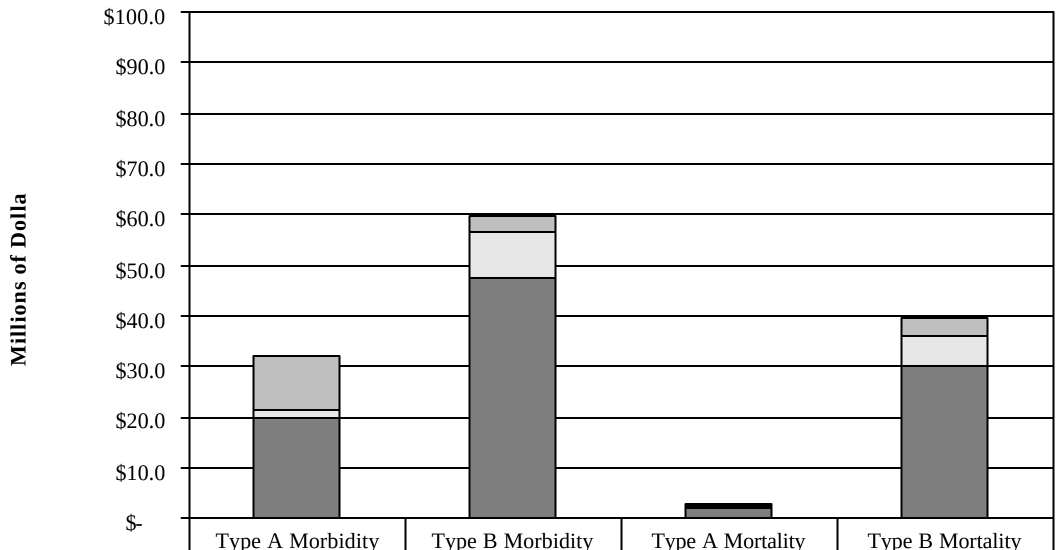




B.3.7 Multi-Barrier Age Benefits Distribution by Age

Exhibit B–15 brings all of the virus and age-related information together to illustrate the breakdown of health benefits associated with the Multi-Barrier Approach. Two important points are made in this chart. As discussed earlier, the majority of health benefits are derived from reductions in Type A and Type B virus morbidity. Also, across virus type, because over 76 percent of the population is over 16 years of age, most of the benefit (74 percent) of reducing exposure to both Type A and Type B viruses is captured by people in this age group.

Exhibit B–15. Total GWR Morbidity and Mortality Health Benefits by Illness Type, and Victim Age Multi-Barrier Approach



	Type A Morbidity	Type B Morbidity	Type A Mortality	Type B Mortality
less than 5 y.o.	$10.4	$3.4	$0.5	$3.5
5-16 y.o.	$1.8	$8.8	$0.3	$6.1
over 16 y.o.	$19.8	$47.5	$2.1	$30.0

Appendix C
Inputs to Cost Model

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LIST OF EXHIBITS

C.1 Introduction

This Appendix presents the background national cost estimates for the proposed Ground Water Rule (GWR). It provides a description of unit costs and underlying assumptions used to prepare the cost estimates, and the methodology used to compile these assumptions to estimate the cost of the four proposed GWR options. Additional details may be found in this Technical Background Document on Cost Modeling for the GWR RIA.

The proposed GWR and other rule options incorporate of rule components that identify and/or correct conditions that permit fecal contamination to reach ground water system consumer's taps. Several of these components are included in more than one of the GWR options. The different rule options include several components, as presented in Exhibit C–1.

Exhibit C–1. Components for Risk-Based Regulatory Options

Rule Scenario Components	Option 1: Sanitary Survey Only	Option 2: San. Survey and Triggered Monitoring	Option 3: Multi Barrier Approach	Option 4: Across-the-Board Disinfection
Monitoring and Assessment				
Sanitary Survey	U	U	U	U
Triggered Monitoring		U	U	
Sensitivity Assessment			U	
Routine Monitoring			U	
Response and Compliance Monitoring (Treatment Assurance)				
Significant Defects	U	U	U	U
Corrective Action		U	U	U
Compliance Monitoring		U	U	

Section C.2 presents the unit costs and costing assumptions that EPA has made for each of the rule components. In addition to the components shown in the exhibit, unit cost and costing assumption are also provided for *administrative costs,* costs expected to be incurred by both the States and the regulated entities. Section C.3 presents additional non-monetary cost model inputs

C.2 Unit Costs and Cost Assumptions

This section presents a summary of EPA's assumptions used to prepare estimates of the national costs of the proposed GWR and other regulatory options. It contains a description of the estimates of unit costs (the cost that would be incurred by each State, individual treatment facility or system) and the predicted actions that systems and States will make to comply with the proposed GWR.

Only summary unit costs are presented in this document, more detailed descriptions of the assumptions and methodologies used to develop these cost estimates are presented in the *Cost and Technology Document for the Ground Water Rule* (US EPA, 1999a).

C.2.1 Administrative Costs

States will incur administrative costs upon implementation of the GWR. These administrative costs are not directly required by specific provisions of GWR options, but are necessary for States to ensure the provisions of the GWR are properly carried out. States will need to allocate time for their staff to establish and then maintain the programs necessary to comply with the GWR.

C.2.1.1 Unit Costs

Resources are estimated in terms of full-time equivalents (FTEs). EPA has assumed a cost of $64,480 for one FTE, including overhead and fringe. Time requirements for a variety of State agency activities and responses are estimated for this RIA.

Exhibit C–2 lists activities required for the State to start the program following promulgation o the GWR. Start-up activities include developing and adopting State regulations that meet the Federal GWR requirements. States must also train their staff and the water system's staff on the new requirements, and modify their data management systems to track any new information that must be reported by systems to the State. For the GWR options that include monitoring with a laboratory method not currently required by the State, the State must devote a portion of its staff time to certifyin laboratories for the new method.

Exhibit C–2. Estimated State Resources Required for GWR Administration (One Time Start-up Activities)

Administrative Activity	Estimated State Resources (FTE)	Estimated Cost
Public Notification	0.1	$6,500
Regulation Adoption and Program Development	0.5	$32,200
Upgrade Data Management Systems	1.3	$83,800
Initial Lab Certification and Training	0.39	$25,100
System Training and Technical Assistance	1.0	$64,500
Staff Training	0.23	$14,800

Exhibit C–3 lists the annual resources that a State will require to continue implementation of th GWR. On an annual basis, States must coordinate with their particular EPA Region to be certain the State is consistent with Federal requirements. States must also continue to train State and drinking water system staffs, maintain laboratories certifications and report system compliance information to t Safe Drinking Water Information System (SDWIS).

Exhibit C–3. Estimated State Resources Required for GWR Administration (Annual Activities)

Administrative Activity	Estimated State Resources (FTE)	Estimated Cost
Coordination with EPA	0.5	$32,200
Lab Certification	0.5	$32,200
On-Going Technical Assistance	0.5	$32,200
SDWIS Reporting	0.5	$32,200
Clerical	0.2	$12,900
Supervision	0.22	$14,200
Staff Training	0.05	$3,200

In addition to the administrative costs of developing and maintaining a program for GWR compliance, States will be required to spend time responding to ground water sources that are found to be fecally contaminated. EPA's estimates of the average time required for a single source testing positive for the presence of a fecal indicator are presented in Exhibit C–4.

Exhibit C–4. Estimated State Resources Required to Respond to Source Water Contamination

Activity	State Resources for Small (<10,000) Ground Water System (hours)	State Resources for Large (>10,000) Ground Water System (hours)
Review Plans and Specification	16	32
Violation Letter	4	4
Data Entry	4	4

C.2.2 Sanitary Survey

In addition to the increase in scope of the sanitary survey, the GWR options also increase the frequency that the surveys will be performed. Federal regulations under 40 CFR §141.121 permit reduction in total coliform sampling for ground water systems serving less than 1,000 in certain cases. To qualify, a community system must have had a sanitary survey that found the system to be free of defects in the past five years. Noncommunity ground water systems that have had a sanitary survey within the first 10 years of rule implementation also qualify.

Based upon these requirements and a review of State regulations, EPA has estimated that on average, States currently conduct sanitary surveys of community ground water systems once every five years and noncommunity ground water systems once every 10 years. The frequency of sanitary surveys under the proposed GWR and options is once every three years for community ground water systems (with the possible reduction to five years) and once every five years for noncommunity systems.

C.2.2.1 Unit Costs

Most States already require sanitary surveys, therefore, EPA has estimated the incremental increase in cost for performing and preparing a sanitary survey which addresses those components specific to the GWR. Exhibit C–5 presents the cost estimates for State inspectors to perform sanitary surveys and for system operators to provide the information to meet current sanitary survey requirements and to meet the requirements of the options for the proposed GWR. These incremental costs range from as low as $30 per survey for systems serving under 100 individuals to $700 per survey per system for the largest systems.

Exhibit C–5. Estimated Costs to State for Sanitary Surveys (1998$)

Cost for	Service Population Category							
	<100	101–500	501–1,000	1,001–3,300	3,301–10,000	10,001–50,000	50,001–100,000	>100,000
Under current requirements	$190	$190	$250	$280	$370	$530	$1,050	$2,200
With proposed GWR requirements	$220	$250	$370	$430	$590	$870	$1,500	$2,900

In addition to State costs, ground water systems will incur additional costs to meet the requirements of the GWR for sanitary surveys. These incremental costs range from as low as $30 per survey for systems serving under 100 individuals to as much as $700 per survey per system for the largest systems. These costs are presented in Exhibit C–6.

Exhibit C–6. Estimated Costs to Systems for Sanitary Surveys (1998$)

Cost for	Service Population Category							
	<100	101–500	501–1,000	1,001–3,300	3,301–10,000	10,001–50,000	50,001–100,000	>100,000
Under current requirements	$80	$80	$140	$170	$220	$310	$670	$1,460
With proposed GWR requirements	$110	$140	$220	$280	$360	$560	$980	$1,900

C.2.2.2 Costing Assumptions

EPA assumes that sanitary surveys will be conducted by the State (or primacy agent) on all noncommunity ground water systems within five years of promulgation of the Rule. For community ground water systems, EPA has assumed that all of the community ground water systems that achieve a 4 log inactivation or removal of virus will conduct sanitary surveys conducted every five years, and the remaining community ground water systems will conduct sanitary surveys once every three years.

Within the cost analysis model, it is necessary to calculate the incremental difference in current sanitary surveys versus the proposed sanitary survey. For both the public water system (PWS) and the State, a current average annual sanitary survey cost is calculated by multiplying the baseline cost per survey by the number of surveys the PWS would undergo over the 20-year period of analysis without the GWR (two for nontransient noncommunity [NTNC] and transient noncommunity [TNC] systems and four for community water systems [CWSs]), and then dividing by 20.

As shown in Exhibit C–7, EPA estimates that between 11 and 13 percent of the systems surveyed will be found to have significant defects that will require correction. This estimate is based upon data from a survey of best management practices in community ground water systems conducted by the Association of State Drinking Water Administrators (ASDWA, 1997). ASDWA's questionnaire asked the survey respondents if the system has any uncorrected significant defects. Over 800 survey responses were received from community ground water systems in three different Total Coliform Rule

(TCR) compliance categories that included (1) systems with no TCR MCL violations in the past two years, (2) systems with at least one non-acute TCR-MCL violations within the past two years, and (3) systems with at least one acute TCR-MCL violation in the past two years. EPA weighted the responses from systems in each TCR compliance category to develop the estimates of the national percentage of systems with a significant defect. Because no other data was available, EPA has assumed that the percentage of noncommunity ground water systems with significant deficiencies is proportional to the number obtained by the ASDWA survey for CWSs.

Exhibit C–7. Percentage of Significant Defects

System Type	Service Population Category							
	<100	101–500	501–1,000	1,001–3,300	3,301–10,000	10,001–50,000	50,001–100,000	>100,000
CWS	13%	12%	12%	12%	13%	13%	12%	12%
TNC	12%	12%	12%	12%	12%	11%	12%	11%
NTNC	12%	12%	12%	12%	12%	—	—	—

C.2.3 Corrective Action for Significant Defects

The primary purpose of conducting sanitary surveys is to identify significant defects in PWSs for correction. Currently, there are Federal Regulations that provide primacy agencies with the authority to require that systems correct significant defects. Under the proposed GWR and other options, a sanitary survey includes, but is not limited to:

> a defect in design, operation, or maintenance, or a failure or malfunction of the sources, treatment, storage, or distribution system that the State determines to be causing, or has the potential for causing the introduction of contamination into the water delivered to consumers.

States would be required to define what constitutes a significant deficiency as part of their primacy package.

All of the GWR options require the primacy agent to notify systems of significant deficiencies and require the systems to correct the significant defect within 90 days of notification. Systems that cannot correct the significant defect within 90 days would be required to submit a schedule to the State or primacy agent for their review and approval. Systems in consultation with the State may correct the significant deficiency, switch to an alternate source of water, or disinfect their source to 4 log inactivation. States or primacy agencies would be required to confirm that a system has corrected its significant deficiency either by receipt of notification from the system or by conducting an on-site inspection.

C.2.3.1 Unit Costs

The costs for correction of significant deficiencies depend almost entirely upon the nature of the deficiency. Because States have the authority to define significant deficiencies under the proposed GWR and options, EPA must predict the types of deficiencies that will be found and corrected as a result of the rule. EPA consulted with experts from within the Agency and from States to develop a list of deficiencies that are likely to be identified in sanitary surveys of ground water systems (EPA, 1996 a). The list indicated three general areas in which defects may be found: the source, the treatment system, and the distribution system. From this list, EPA developed a representative list of corrective actions from each of these general areas. The representative corrective actions are listed below.

Correction of Significant Deficiencies at the Source

- replacing a sanitary well seal,
- rehabilitating an existing well, and
- drilling a new well

Correction of Significant Deficiencies in Treatment Systems

- adjusting disinfection chemical feed rate
- increasing contact time prior to first customer

Correction of Significant Deficiencies in Distributions System

- install backflow prevention device
- replace/repair storage tank cover
- install security measures at storage tank site
- install a redundant booster pump

Exhibit C–8 presents the costs for correcting significant deficiencies. All costs are one-time expenditures that occur in the year the significant deficiency is found and corrected, except for adjusting the treatment chemical feed rate, which is an ongoing operating cost incurred in each year of operation.

Exhibit C–8. Estimated Costs for Correction of Significant Sanitary Defects (1998$)

Cost for	Service Population Category							
	<100	101–500	501– 1,000	1,001– 3,300	3,301– 10,000	10,001– 50,000	50,001– 100,000	>100,000
Replacing a Sanitary Well Seal (per well)	$3,300	$3,300	$3,300	$3,300	$3,300	$3,300	$3,300	$3,300
Rehabilitating an Existing Well (per well)	$10,700	$10,700	$10,700	$10,700	$10,700	$10,700	$10,700	$10,700
Replace/Repair Cover on Storage Tank(per tank)	$2,700	$6,000	$45,000	$62,000	$138,000	$159,000	$159,000	$159,000
Install Security Measures at Tank Site (per tank)	$9,100	$9,100	$9,100	$9,100	$12,500	$12,500	$12,500	$12,500
Install Backflow Prevention Device (per connection)	$2,100	$2,100	$2,100	$2,200	$2,200	$3,000	$4,700	$4,700
Install a Redundant Booster Pump (per pump)	$5,800	$7,400	$9,400	$11,000	$13,000	$14,900	$21,300	$27,600

C.2.3.2 Compliance Forecast

The corrections of significant defects that will be undertaken by ground water systems depend upon the defects defined as significant by States, and the conditions at the facilities. Both of these factors are unknown. To provide a reasonable estimate of the bounds of the uncertainty, with respect to the types of defects that will have to be corrected, EPA has developed estimates of a low cost scenario and a high cost scenario for correction of significant defects. The low cost scenario assumes a greater percentage of the systems with significant defects will have defects which are less expensive to correct (e.g., more systems will have to replace their sanitary well seal than will have to perform a complete rehabilitation of their well) in comparison to the high cost scenario. The percentages of systems with significant defects that were assumed to perform the representative correction in the high cost and low cost scenarios are listed in Exhibit C–9.

Exhibit C–9. Estimated Distribution of Corrective Actions Among Systems With a Significant Deficiency

	Low Cost Scenario	High Cost Scenario
Replacing a Sanitary Well Seal	50%	35%
Rehabilitating an Existing Well	35%	50%
Replace/Repair Cover on Storage Tank	2%	5%
Install Security Measures at Tank Site	5%	2%
Install Backflow Prevention Device	5%	3%
Install a Redundant Booster Pump	3%	5%

Each of the regulatory options requires each PWS to correct any significant defect found during a sanitary survey. The assignment of any significant deficiency is done as a two-step process within the cost analysis model, and is done independently for each sanitary survey over the 20-year period of analysis:

- First, a PWS is designated as having or not having the potential to have one or more significant defects, resulting from a single sanitary survey based on a probability estimate.

- Second, each PWS that is predicted to have a significant defect, in a single sanitary survey, may be assigned one or more of the six potential significant defects according to a probability distribution. In order to determine the sensitivity of the cost estimates to these probabilities, two scenarios are considered. Under the first scenario, PWSs are assigned to low cost significant defects with greater probability (known as the Low SD scenario), while in the second scenario, PWSs are assigned to high cost significant defects with greater probability (known as the High SD scenario).

This process is repeated for each sanitary survey the PWS undertakes over the 20-year period of analysis.

Since the timing of the sanitary surveys are not known, an average annual PWS cost of correcting significant defects is calculated by summing the cost of correcting all significant defects over the 20-year period of analysis and then dividing by 20. The average annual PWS cost of correcting significant defects includes the cost of developing engineering plans for submission to the State.[1]

In addition to the PWS's cost of correcting each significant defect, the State incurs a cost in reviewing the PWS's engineering plans. The State resources for plan review per corrected significant defect is shown in Exhibit C–4. Since the timing of the sanitary

[1] It is assumed that 97.1 percent of the average annual PWS cost of correcting significant defects is for the actual correction of the defects, while 2.9 percent is for plan development and submission to the State for review and approval.

surveys are not known, the average annual State cost of reviewing the PWS's engineering plans is calculated by multiplying the unit cost for plan review by the number of significant defects corrected over the 20-year period of analysis and then dividing by 20.

C.2.4 Hydrogeologic Sensitivity Assessment

The hydrogeologic sensitivity assessment is a component of the multiple-barrier option for the GWR. The hydrogeologic sensitivity assessment is performed by States, or another primacy agent, on each ground water source to determine if the source is sensitive to microbial contamination and therefore, requires monitoring to insure there is no fecal contamination.

C.2.4.1 Unit Costs

Costs for the hydrogeologic sensitivity assessment include compiling existing data reviewing that data in order to determine the sensitivity of an aquifer. EPA has estimated the time for States to locate existing hydrogeologic data, such as a well construction record or for a State assessor to inspect and review this data. EPA has assumed that the hydrogeologic sensitivity assessment will be performed, based on existing data. EPA has also assumed that the sensitivity assessment will be performed on-site, however this is not a requirement under the GWR multiple barrier option. Cost estimates for States to perform hydrogeologic assessment are presented in Exhibit C–10.

Exhibit C–10. Estimated Costs for States and Systems to Perform Hydrogeologic Sensitivity Assessments (1998$)

Cost for	Service Population Category							
	<100	101–500	501–1,000	1,001–3,300	3,301–10,000	10,001–50,000	50,001–100,000	>100,000
State cost for performing hydrogeologic sensitivity assessment (per system)	$62	$124	$186	$248	$310	$620	$1,178	$3,224

C.2.4.2 Costing Assumptions

EPA assumes that hydrogeologic sensitivity assessments will be performed on all ground water sources that are not providing 4 log inactivation or removal of virus. EPA estimates that 15 percent of the systems that are assessed will be determined to be sensitive. This estimate is based upon data collected for the AWWA Study (Abbaszadegan et al., 1998; 1999). As part of this study, system operators were asked to review well construction information and provide detailed information about the hydrogeologic setting in which their well was located. Of the survey respondents that were able to provide this information, 15 percent indicated that their wells were located in unconfined aquifers that were karst, fractured bedrock, or unknown geology. EPA also assumed that wells in unconfined conditions with unknown hydrogeology will be classified as sensitive hydrogeology (i.e., sensitive to fecal contamination).

C.2.5 Triggered Source Water Monitoring

Triggered source water monitoring is a component of two regulatory options. Triggered monitoring requires collection and analysis of samples at the sources of the ground water systems following the detection of total coliform (TC) in one or more samples collected for compliance with the Total Coliform Rule. States have the option of requiring the triggered source water samples to be tested for the presence of one of three fecal indicators; fecal coliform/*E. coli*, enterococci, or male specific coliphage. If a system detects the fecal indicator at its source, then the system must take a corrective action to either eliminate the contamination, obtain a new uncontaminated source, or install treatment to achieve a 4 log removal or inactivation of virus.

C.2.5.1 Unit Costs

For the purpose of the cost analysis, EPA has assumed that States will select *E. coli* as the indicator of contamination for analysis. States, systems, and laboratories have much greater familiarity with this method in comparison to the other available methods. Fecal coliform/*E. coli* analysis is already required under the Total Coliform Rule. EPA has estimated that the cost for triggered monitoring is $53 per sample. This cost assumes a $25 cost for performing laboratory analysis. This is based upon common commercial laboratory costs and one hour of the system operators time (at an estimated cost of $28 per hour) to collect the sample, arrange for delivery to the laboratory, and to review the results of the analysis. EPA has assumed that all wells are equipped with existing taps for sampling prior to the application of any treatment chemicals. Therefore, no additional costs are assumed for installation of a tap or re-piping of wells to permit sampling.

C.2.5.2 Costing Assumptions

Two compliance estimates are necessary to develop cost estimates associated with triggered monitoring; the frequency with which systems will have to perform triggered monitoring and the number of systems that are expected to test positive for the fecal indicator.

EPA estimated the probability of a ground water system’s total coliform sample testing positive as a part of its regulatory impact analysis for the Total Coliform Rule (EPA, 1989). These estimates varied based upon the size of the system. EPA believes that these probabilities are a reasonable estimate of current conditions. EPA calculated the frequency of total coliform positives per year per system by multiplying the number of TC samples required per year by the probability of a TC positive. The results are the estimated number of triggered monitoring samples per year, presented in Exhibit C–11. The option allows States to waive the triggered monitoring requirements if a PWS demonstrates that the total coliform contamination is not source water related. This analysis assumes that the probability of a PWS receiving this waiver for a single entry point is 10 percent. Also, a one-time repeat sampling waiver exists for both triggered monitoring and routine monitoring. Once a PWS finds a single positive sample, they may take five repeat samples, and if all five repeat samples are negative, the source water is considered not to be contaminated. For the purposes of this analysis, it is assumed that all PWSs that have a positive source water sample will make use of this one-time sampling waiver.

Exhibit C–11. Estimated Number of Triggered Source Water Samples Per Year

System Type	Service Population Category							
	<100	101–500	501–1,000	1,001–3,300	3,301–10,000	10,001–50,000	50,001–100,000	>100,000
CWS	0–3	0–3	0–3	0–3	0–4	1–4	4–7	7–22
TNC	0–3	0–3	0–3	0–3	0–3	—	—	—
NTNC	0–3	0–3	0–3	0–3	0–3	—	—	—

Since it is assumed that all contaminated entry points will be discovered in the first year, the entry points with no source water positive samples, or those with a single positive sample and five negative follow-up samples in the first year, will continue to undertake triggered monitoring sampling for the remainder of the analysis period. The number of samples they will take each year is assigned using a uniform distribution based on the number of expected total coliform violations they might have per year (see Exhibit C–11). It is assumed that 8.83 percent[2] of these entry points will have a single source water positive sample, and will take five repeat samples. None of these will have a positive repeat sample.

EPA has estimated the number of systems that will test positive in triggered monitoring by reviewing indicator occurrence data. The AWWARF study (Abbazadegan et al., 1998; 1999) found enteroccocci bacteria in nine percent of the wells sampled. Wells selected for the study were representative of hydrogeologic conditions for public water supply wells in the United States, and most wells in the study were only sampled once. EPA has determined that the enterococci occurrence from the AWWARF study provides the best estimate of the percentage of wells that will be found to test positive for the presence of a fecal indicator in triggered source water sampling, and therefore, has assumed that nine percent of the systems tested will be found to contain fecal contamination.

C.2.6 Routine Source Water Monitoring

Routine source water monitoring is a component of the multiple barrier option for the GWR. Routine source water monitoring involves monthly sampling of those ground

[2] (Probability of not having a single positive result in year 1)/(Probability of not having a repeat positive result in year one) x (Probability of having a single positive result in year one) = (Probability (having a single positive result in years 2–20). ((1–0.09)/(1–0.09*0.8))*0.09 = 0.883.

water sources that are determined to be at high risk for the presence of fecal contamination. The hydrogeologic sensitivity assessment is used to determine which wells are at high risk of contamination. High risk wells would be sampled each month and tested for the presence of fecal contamination using one of three possible indicators; *E. coli*, *Enteroccci*, or male specific coliphage. The State will select the fecal indicator. Ground water systems with wells that test positive for the presence of a fecal indicator will be required to take action to correct the contamination (See Section C.2.7), unless the system is able to obtain a one-time waiver from the State. A waiver could be granted by the State if the system collects five repeat samples from the well testing positive within 24 hours and the system does not detect the fecal indicator in any of five samples. This waiver can only be granted once per source.

States may reduce the frequency of monitoring for high risk ground water sources after one year of monitoring if there are no samples that test positive. States may also waive source water monitoring altogether after the first year if the State determines that fecal contamination of the well is highly unlikely.

C.2.6.1 Unit Costs

As with triggered monitoring, EPA has assumed that States will select *E. coli* as the indicator of contamination for analysis. States, systems, and laboratories have much greater familiarity with this method in comparison to the other available methods. Fecal coliform/*E. coli* are analysis already required under the Total Coliform Rule. EPA has estimated that the cost for triggered monitoring is $53 per sample. This cost assumes a $25 cost for performing laboratory analysis. This is based upon common commercial laboratory costs and one hour of the system operators' time (at an estimated cost of $28 per hour) to collect the sample, arrange for delivery to the laboratory, and to review the results of the analysis. EPA has assumed that all wells are equipped with existing taps for sampling prior to the application of any treatment chemicals. Therefore, no additional costs are assumed for installation of a tap or re-piping of wells to permit sampling.

C.2.6.2 Costing Assumptions

EPA has estimated that 15 percent of the sources for ground water systems will be determined to be sensitive and, therefore subject to routine monitoring. EPA has determined that the EPA/AWWARF study data (Lieberman et al., 1994; 1999) provides the best estimate of results which can be expected from routine monitoring. This study sampled 30 wells that were determined to be vulnerable to contamination based upon criteria that included hydrogeologic sensitivity. Each of the wells was sampled monthly over the course of one year for a variety of fecal indicators including *E. coli*. Fifty percent (15/30) of the wells in the EPA/AWWARF study tested positive for the presence of *E. coli*. However, three of the 15 wells with positive samples only tested positive in one of twelve samples. Using this data, EPA has estimated that 50 percent of the ground water sources that are required to perform routine monitoring will detect the fecal indicator. Because of the high costs associated with corrective actions, EPA has assumed that all systems with a routine source water positive sample will resample within 24 hours of detecting the fecal contamination. EPA has estimated that 20 percent of the systems that perform the repeat sampling will not find fecal indicators in any of the repeat samples and will receive waivers from the State.

It is assumed that all contaminated entry points will be discovered in the first year, the entry points with no source water positive samples, or those with a single positive sample and five negative follow-up samples in the first year, will continue to undertake routine sampling
once a quarter for the remainder of the period of analysis. It is assumed that 41.67 percent[3] of these entry points will have a single source water positive sample, and will take five repeat samples. None of these should have a positive repeat sample.

C.2.7 Corrective Action for Fecal Contamination

Detection of fecal indicators in the source of undisinfected ground water systems requires corrective action under the two GWR options. Corrective action includes eliminating the contamination from the source, obtaining an alternative source of water, or providing disinfection treatment that achieves 4 log inactivation or removal of viruses.

C.2.7.1 Unit Costs

The costs of the corrective actions vary based upon the corrective action selected by the system after consultation with the State and based upon the size of the system. EPA has assumed that a variety of corrective actions could be implemented by ground water systems that detect fecal contamination within their source waters. The corrective actions include;

<u>Eliminate Contamination</u>

- Rehabilitate an existing well
- Remove/relocate existing source of contamination (septic tank)
- Construct a new well
- Purchase water from a nearby system

[3] (Probability of not having a single positive result in year 1)/(Probability of not having a repeat positive result in year one) x (Probability of having a single positive result in year one) = (Probability of having a single positive result in years 2–20). ((1–0.5)/(1–0.5*0.8))*0.5 = 0.4167.

Disinfect Source Water to Achieve a 4 log Inactivation/Removal of Virus

- Install and operate chlorine gas disinfection
- Install and operate hypochlorination
- Install and operate chloramination
- Install and operate chlorine dioxide disinfection
- Install and operate mixed oxidants disinfection
- Install and operate ozonation
- Install and operate reverse osmosis filtration
- Install and operate ultraviolet disinfection

Costs for each of the corrective actions that eliminate the cause of contamination or obtain water from an alternative source are presented in Exhibits C–12. Costs have been developed for each of the non-treatment corrective actions for a range of sizes of systems. For all of the non-treatment corrective actions, except purchasing water, all costs consist of capital costs incurred during the first year in which the corrective action is undertaken. Purchasing water includes both a capital cost for constructing a pipeline to connect the system to the new supply and the net increased cost which the system will pay to purchase water from the system. The cost presented subtracts the system's cost of producing its own water that the system no longer has to incur from the estimated purchase price. Depending on the corrective actions, there may up to three different cost estimates: capital cost (the cost of constructing/installing the equipment), replacement cost (cost of replacing significant components of the system after several years of operation), and operation and maintenance costs (annual cost of operating equipment and performing routine maintenance).

Exhibit C–12. Estimated Costs for Eliminating Cause of Contamination or Obtaining Alternate Water Source (1998$)

	Service Population Category							
Cost for	**<100**	**101–500**	**501– 1,000**	**1,001– 3,300**	**3,301– 10,000**	**10,001– 50,000**	**50,001– 100,000**	**>100,000**
Rehabilitating an existing well (Capital cost)	$8,700	$10,700	$10,700	$10,700	$10,700	$10,700	$10,700	$10,700
Relocating an existing source of contamination (Capital cost)	$15,100	$15,100	$15,100	$15,100	$15,100	$15,100	$15,100	$15,100
Constructing a new well (Capital cost)	$12,000	$26,900	$26,900	$26,900	$26,900	$26,900	$26,900	$26,900
Constructing a pipeline to enable Purchasing water (Capital Cost)	$156,500	$156,500	$179,400	$179,400	$219,200	$219,200	$319,600	$353,300
Net cost of purchasing water ($ /1,000 gal)	$1.03	$1.08	$0.58	$1.32	$1.92	$1.24	$1.28	$0.84

Costs for disinfecting ground water in order to achieve a 4 log inactivation of virus are presented in Exhibit C–13. Costs are presented by average daily and design flow instead of by system population served. Exhibit C–13 presents capital costs and annual operation and maintenance costs for all treatment types, and presents year 10 replacement cost for most treatment technologies. Year 10 replacement costs are estimated for the systems that will require replacement of a significant component half way through the design life of the system.

C.2.7.2 Compliance Forecast

Selection of the most appropriate corrective action will be made by the system with the assistance/review of the State. EPA developed estimates of corrective actions that ground water systems with fecal contamination would undertake to eliminate or treat their contamination. These estimates considered the current implementation of treatment types, the cost of the corrective action, and the need for systems to comply with provisions of the Disinfection Byproducts Rule (DBPR). The portion of systems that will choose treatment versus non-treatment corrective actions is assumed proportional to the percentage of systems in each service

Exhibit C–13. Estimated Costs for Disinfection Treatments (1998$)

	Average Daily Flow/Design Flow (MGD)							
Cost for	**0.007 / 0.03**	**0.026 / 0.10**	**0.09 / 0.30**	**0.21 / 0.75**	**0.82 /2.2**	**3.25 / 7.8**	**11.2 / 23.5**	**45 /81**
Chlorine gas feed capital cost	$65,000	$65,000	$59,000	$63,000	$79,000	$140,000	$300,000	$630,000
Chlorine gas feed replacement cost year 10	$11,200	$11,200	$17,000	$18,600	$23,200	$41,000	$101,000	$230,000
Chlorine gas feed annual O&M cost	$3,600	$3,700	$8,900	$10,300	$12,600	$20,200	$45,800	$143,000
Hypochlorite feed capital cost	$7,000	$7,000	$45,000	$45,000	$45,000	N/A	N/A	N/A
Hypochlorite feed replacement cost year 10	$2,800	$2,800	$6,700	$6,700	$6,700	N/A	N/A	N/A
Hypochlorite annual O&M cost	$4,000	$5,000	$6,000	$10,000	$27,000	N/A	N/A	N/A
Chloramination system capital cost	$124,000	$124,000	$124,000	$124,000	$127,000	$202,000	$406,000	$838,000
Chloramination system replacement cost year 10	$22,500	$22,500	$22,500	$22,500	$23,100	$35,200	$115,700	$244,800
Chloramination annual O&M cost	$7,100	$7,200	$7,300	$7,700	$10,000	$23,100	$54,800	$165,000
Chlorine Dioxide System Capital Cost	$94,000	$149,000	$169,000	$189,000	$233,000	$387,000	$806,000	$1,637,000

Exhibit C–13. Estimated Costs for Disinfection Treatments (1998$)

Cost for	Average Daily Flow/Design Flow (MGD)							
	0.007 / 0.03	0.026 / 0.10	0.09 / 0.30	0.21 / 0.75	0.82 /2.2	3.25 / 7.8	11.2 / 23.5	45 /81
Chlorine Dioxide System replacement cost year 10	$21,000	$68,000	$79,000	$88,000	$130,000	$170,000	$340,000	$630,000
Chlorine Dioxide annual O&M Cost	$4,000	$9,700	$10,900	$12,800	$18,700	$36,800	$89,500	$308,000
Mixed Oxidant capital cost	$155,000	$442,000	$944,000	N/A	$1,254,000	$1,604,000	$2,279,000	$2,256,000
Mixed Oxidant replacement costs year 10	$69,000	$220,000	$490,000	N/A	$640,000	$830,000	$1,200,000	$2,000,000
Mixed Oxidants annual O&M costs	$3,800	$17,400	$35,900	N/A	$56,400	$185,700	$592,300	$2,255,600
Ozonation Capital Cost	$79,000	$110,000	$277,000	$336,000	$569,000	$1,470,000	$3,290,000	$6,550,000
Ozonation Annual O&M cost	$3,000	$3,800	$12,200	$14,100	$19,100	$43,200	$99,000	$336,000
Reverse Osmosis Capital Cost	$170,000	$360,000	$970,000	$2,100,000	$4,800,000	$14,600,000	$36,500,000	$117,000,000
Reverse Osmosis Annual O&M Cost	$15,000	$31,000	$66,000	$130,000	$430,000	$1,420,000	$4,600,000	$18,000,000
Ultraviolet Disinfection Capital Cost	$14,000	$31,000	$85,000	$140,000	$358,000	N/A	N/A	N/A
Ultraviolet Disinfection Annual O&M Cost	$800	$2,000	$5,500	$9,400	$34,000	N/A	N/A	N/A

1 Cost for ultraviolet disinfection are calculated at slightly different flow rates than indicated in the table.

population category that currently perform disinfection treatment. Because of the uncertainty inherent in projecting the number of systems that would undertake each corrective action, EPA assumed varying percentages of the non-treatment corrective actions to provide and upper and lower cost bounds. Estimates of the corrective actions that will be undertaken by systems with source water contamination are presented in Exhibit C–14.

Each entry point that is predicted to undertake a corrective action is assigned one of 13 potential corrective actions according to a probability distribution. In order to determine the sensitivity of the cost estimates to these probabilities, two scenarios were considered. Under the first scenario, entry points were assigned to low cost corrective actions with greater probability (known as the Low CA scenario), while in the second scenario, entry points were assigned to high cost corrective actions with greater probability (known as the High CA scenario).

Exhibit C–14. Estimated Selection of Corrective Action by Systems with Source Water Contamination

Corrective Action	Service Population Category							
	<100	101–500	501– 1,000	1,001– 3,300	3,301– 10,000	10,001– 50,000	50,001– 100,000	>100,000
Rehabilitating an existing well	25–30%	10–15%	8–12%	8–12%	7–10%	6–8%	21–25%	8–10%
Constructing an New Well	10–15%	6–12%	3–6%	5–6%	3–5%	2–4%	8–11%	4–6%
Purchasing water	1–3%	1–3%	1 –3 %	1–3%	1–3%	0%	0%	0%
Eliminating Source of contamination	11–13%	5–8%	7 – 8 %	7–8%	5–6%	3%	9–10%	2%
Chlorine Gas Disinfection	0%	0%	0%	0%	31%	77%	51%	78%
Hypochlorination	41%	63%	69%	69%	41%	5%	0%	0%
Chloramination	0%	1%	0%	0%	1%	1%	3%	3%
Chlorine Dioxide Disinfection	1%	1%	1%	1%	1%	1%	1%	1%
Mixed Oxidants	0%	0%	1%	1%	1%	0%	0%	0%
Ozonation	1%	1%	1%	1%	1%	1%	1%	1%
Reverse Osmosis	0%	1%	1%	1%	1%	1%	1%	0%
Ultraviolet Disinfection	3%	3%	3%	3%	3%	1%	1%	1%

After each entry point, that will undertake a corrective action, is assigned to a type of corrective action, the capital and operations & maintenance (O&M) costs for these corrective actions are calculated. Since it is assumed that all corrective actions occur in year one, all corrective actions require a capital expenditure in year one. Some also require a replacement capital expenditure in year 10. For all technologies with an O&M cost component, equal O&M expenditures are assumed to occur each year. Depending on the unit cost equations for the respective corrective action, the capital and O&M costs are either fixed parameters or a simple function of the entry point's design flow or average daily flow.

It is assumed that the capital cost of each corrective action includes the PWS's cost of developing engineering plans for submission to the State.[4] In addition to the PWS's cost of corrective action, the State incurs a cost in reviewing the PWS's engineering plans. The cost of plan review per corrective action is shown in Exhibit C–1. Finally, the State is required to perform an on-site investigation if a PWS chooses to meet the corrective action requirement by rehabilitating a well or removing a known source of contamination.

C.2.8 Non-Quantifiable Costs

[4] It is assumed that 97.1 percent of the capital cost is for the actual corrective action, while 2.9 percent is for plan development and submission to the State for review and approval.

Although EPA has estimated the cost of all the rule's components on drinking water systems and States, there are some costs that the Agency did not quantify. These non-quantifiable costs result from uncertainties surrounding rule assumptions and from modeling assumptions. For example, EPA did not estimate a cost for systems to acquire land if they needed to build a treatment facility or drill a new well. This was not costed because many systems will be able to construct new wells or treatment facilities on land already owned by the utility. In addition, if the cost of land was prohibitive, a system may chose another lower cost alternative such as connecting to another source. A cost for systems choosing this alternative is quantified in our analysis.

C.3 Non-monetary Inputs to Cost Model

Exhibit C–15. Non Community System Flows

Service Area Type	Avg. Flow gpd/ person	Population Served by TNC Systems	Average Flow for all TNC Systems	Population Served by NTNC Systems	Average Flow for all NTNC Systems
Day Care Centers	15	10,213	153,195	61,653	924,795
Highway Rest Areas	5	516,369	2,581,845	6,105	30,525
Hotels/Motels	65	558,443	36,298,795	46,680	3,034,200
Interstate Carriers	5	11,257	56,285	35,221	176,105
Medical Facilities	100	208,623	20,862,300	144,061	14,406,100
Mobile Home Parks	100	66,797	6,679,700	19,236	1,923,600
Restaurants	8.5	2,255,959	19,175,652	154,528	1,313,488
Schools	25	150,365	3,759,125	3,015,155	75,378,875
Service Stations	10	326,644	3,266,440	12,177	121,770
Summer Camps	42.5	765,742	32,544,035	6,711	285,218
Water Wholesalers	100	791,429	79,142,900	46,075	4,607,500
Agricultural Prod/Services	100	22,770	2,277,000	27,968	2,796,800
Airparks	4	67,116	268,464	6,060	24,240
Bowling Centers	3	23,170	69,510	0	0
Construction Activities	3	0	0	5,247	15,741
Churches	10	1,301,552	13,015,520	11,500	115,000
Campgrounds/RV Parks	45	639,160	28,762,200	19,680	885,600
Fire Departments	100	12,578	1,257,800	4,018	401,800
Federal Parks	10	93,665	936,650	780	7,800
Forest Service	5	37,600	188,000	4,494	22,470
Golf and Country Clubs	25	254,016	6,350,400	11,716	292,900
Landfills	25	0	0	3,432	85,800
Libraries	15	3,330	49,950	0	0
Mines	25	0	0	13,447	336,175
Misc. Amusement Parks	20	88,038	1,760,760	66,462	1,329,240
Military Bases	100	2,900	290,000	37,525	3,752,500
Migrant Labor Camps	50	27,900	1,395,000	2,079	103,950
Misc. Recreation Areas	5	337,152	1,685,760	22,533	112,665
Museums	10	35,280	352,800	0	0
Nursing Homes	100	0	0	13,910	1,391,000
Office Parks	15	197,600	2,964,000	129,542	1,943,130
Prisons	120	0	0	121,940	14,632,800
Race Tracks	5	58,000	290,000	0	0
Retailers (excluding food)	10	184,128	1,841,280	120,775	1,207,750
Retailers (food)	18.5	142,988	2,645,278	45,724	845,894
State Parks	7.5	842,518	6,318,885	13,712	102,840
Utilities	25	6,025	150,625	84,621	2,115,525
Zoological Gardens	25	3,300	82,500	0	0

Exhibit C–15. Non Community System Flows

Service Area Type	Avg. Flow gpd/ person	Population Served by TNC Systems	Average Flow for all TNC Systems	Population Served by NTNC Systems	Average Flow for all NTNC Systems
Mfg. (food)	35	158,301	5,540,535	285,910	10,006,850
Mfg. (Mach & Comp. Equip.)	25	0	0	40,000	1,000,000
Mfg. (Elec. Equip. & Comps)	25	0	0	2,133	53,325
Mfg. (Chemicals)	25	0	0	12,384	309,600
Mfg. (Furniture & Fixtures)	25	2,750	68,750	1,472	36,800
Mfg. (Misc. Manufacturing)	25	8,991	224,775	275,146	6,878,650
Mfg. (Fab. Metal Products)	25	3,300	82,500	43,804	1,095,100
Mfg. (Paper & Allied Prods)	25	0	0	38,560	964,000
Mfg. (Petroleum Refining)	25	0	0	35,855	896,375
Mfg. (Primary Metals)	25	0	0	26,278	656,950
Mfg. (Printing)	25	0	0	4,000	100,000
Mfg. (Rub. & Misc. Plastics)	25	0	0	2,000	50,000
Mfg. (Stone, Clay, Glass, etc)	25	2,775	69,375	29,146	728,650
Mfg. (Tobacco Products)	25	0	0	1,500	37,500
Mfg. (Transportation Equip.)	25	0	0	1,080	27,000
Mfg. (Textiles)	25	0	0	34,590	864,750
Mfg. (Lumber & Wood Prods)	25	2,775	69,375	15,300	382,500
Unknowns	25	5,500	137,500	16,856	421,400
Mixed Knowns		214,345		92,797	0
TOTALS	30	10,441,364	283,665,464	5,319,657	159,233,246
Source: Geometries and Characteristics of Public Water Systems, US EPA, 1999.					

C.4 References

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Appendix D
Results of Cost Analysis

LIST OF EXHIBITS

This appendix contains exhibits summarizing the detailed results of running the GWR cost mode for each of the four regulatory options:

- Option 1: Sanitary Survey Only
- Option 2: Sanitary Survey and Triggered Monitoring
- Option 3: Multiple Barrier Approach
- Option 4: Across-the-Board Disinfection

For each option, this appendix presents three exhibits, covering the following topics:

Total National Compliance Costs

Costs, within this table, are reported as they impact two affected entities:

- Systems
- States

Using four scenarios:

- **Low** Corrective Action Costs and **Low** Significant Defect Scenario
- **Low** Corrective Action Costs and **High** Significant Defect Scenario
- **High** Corrective Action Costs and **Low** Significant Defect Scenario
- **High** Corrective Action Costs and **High** Significant Defect Scenario

Reported in two forms:

- Annualized Costs
- Present Value

Employing two discount rates (3 percent and 7 percent).

National Compliance Costs of the GWR by Public Water System Size

Costs, within this table, are reported as they impact two affected entities:

- Systems
- States

Using four scenarios:

- **Low** Corrective Action Costs and **Low** Significant Defect Scenario
- **Low** Corrective Action Costs and **High** Significant Defect Scenario
- **High** Corrective Action Costs and **Low** Significant Defect Scenario
- **High** Corrective Action Costs and **High** Significant Defect Scenario

With costs broken out by the following system sizes:
- less than 100 persons,
- 101–500 persons,
- 501–1,000 persons,
- 1,001–3,000 persons,
- 3,001–10,000 persons,
- 10,001–50,000 persons,
- 50,001–100,000 persons,
- 100,001–1,000,000 persons, and

Reported in Annualized Costs

Employing two discount rates (3 percent and 7 percent).

National Compliance Costs of the GWR by Public Water System Type

Costs, within this table, are reported as they impact two affected entities:
- Systems
- States

Using four scenarios:
- **<u>Low</u>** Corrective Action Costs and **<u>Low</u>** Significant Defect Scenario
- **<u>Low</u>** Corrective Action Costs and **<u>High</u>** Significant Defect Scenario
- **<u>High</u>** Corrective Action Costs and **<u>Low</u>** Significant Defect Scenario
- **<u>High</u>** Corrective Action Costs and **<u>High</u>** Significant Defect Scenario

With costs broken out by the following system types:
- Community Water Systems
- Nontransient, Noncommunity Water Systems
- Transient/Noncommunity Water Systems

Reported in Annualized Costs
- Employing two discount rates (3 percent and 7 percent).

Exhibit D–1. Total Costs for Option 1: Sanitary Survey Only ($million)

TOTAL NATIONAL COSTS	DISCOUNT RATE	
	3%	7%
Annual System Costs:		
Annual Cost (Low CA/Low SD)	$53.7	$56.2
Annual Cost (Low CA/High SD)	$56.8	$59.5
Annual Cost (High CA/Low SD)	$53.7	$56.2
Annual Cost (High CA/High SD)	$56.8	$59.5
Annual State Costs:		
Annual Cost (Low CA/Low SD)	$17.6	$18.2
Annual Cost (Low CA/High SD)	$17.5	$18.1
Annual Cost (High CA/Low SD)	$17.6	$18.2
Annual Cost (High CA/High SD)	$17.5	$18.1
Present Value of System Costs:		
PV Cost (Low CA/Low SD)	$798.3	$595.6
PV Cost (Low CA/High SD)	$845.5	$630.5
PV Cost (High CA/Low SD)	$798.3	$595.6
PV Cost (High CA/High SD)	$845.5	$630.5
Present Value of State Costs:		
PV Cost (Low CA/Low SD)	$261.2	$192.9
PV Cost (Low CA/High SD)	$259.6	$191.7
PV Cost (High CA/Low SD)	$261.2	$192.9
PV Cost (High CA/High SD)	$259.6	$191.7

Notes:
Low CA = Low Cost Corrective Action Scenario
High CA = High Cost Corrective Action Scenario
Low SD = Low Cost Significant Defect Scenario
High SD = High Cost Significant Defect Scenario

Exhibit D–2. Total Costs by PWS Size for Option 1: Sanitary Survey Only

	DISCOUNT RATE	SYSTEM SIZE CATEGORIES <100	101-500	501-1,000	1,001-3,300	3,301-10,000
Low Corrective Action / Low Significant Defect	3%					
System Costs (Annual)		$18.1	$11.4	$5.4	$7.9	$5.0
State Costs (Annual)		$4.1	$1.9	$0.6	$0.6	$0.3
Total Costs (Annual)		$22.3	$13.3	$6.0	$8.5	$5.3
High Corrective Action / Low Significant Defect	3%					
System Costs (Annual)		$18.1	$11.4	$5.4	$7.9	$5.0
State Costs (Annual)		$4.1	$1.9	$0.6	$0.6	$0.3
Total Costs (Annual)		$22.3	$13.3	$6.0	$8.5	$5.3
Low Corrective Action / High Significant Defect	3%					
System Costs (Annual)		$20.6	$13.9	$5.3	$6.4	$3.9
State Costs (Annual)		$4.0	$1.9	$0.6	$0.6	$0.3
Total Costs (Annual)		$24.6	$15.8	$5.8	$7.0	$4.2
High Corrective Action / High Significant Defect	3%					
System Costs (Annual)		$20.6	$13.9	$5.3	$6.4	$3.9
State Costs (Annual)		$4.0	$1.9	$0.6	$0.6	$0.3
Total Costs (Annual)		$24.6	$15.8	$5.8	$7.0	$4.2
Low Corrective Action / Low Significant Defect	7%					
System Costs (Annual)		$19.1	$12.0	$5.6	$8.2	$5.2
State Costs (Annual)		$4.3	$2.0	$0.6	$0.6	$0.3
Total Costs (Annual)		$23.4	$14.0	$6.2	$8.8	$5.5
High Corrective Action / Low Significant Defect	7%					
System Costs (Annual)		$19.1	$12.0	$5.6	$8.2	$5.2
State Costs (Annual)		$4.3	$2.0	$0.6	$0.6	$0.3
Total Costs (Annual)		$23.4	$14.0	$6.2	$8.8	$5.5
Low Corrective Action / High Significant Defect	7%					
System Costs (Annual)		$21.7	$14.5	$5.5	$6.7	$4.1
State Costs (Annual)		$4.2	$2.0	$0.6	$0.6	$0.3
Total Costs (Annual)		$25.9	$16.5	$6.1	$7.3	$4.4
High Corrective Action / High Significant Defect	7%					
System Costs (Annual)		$21.7	$14.5	$5.5	$6.7	$4.1
State Costs (Annual)		$4.2	$2.0	$0.6	$0.6	$0.3
Total Costs (Annual)		$25.9	$16.5	$6.1	$7.3	$4.4

Exhibit D–2. Total Costs by PWS Size for Option 1: Sanitary Survey Only *(continued)*

		SYSTEM SIZE CATEGORIES			
	DISCOUNT RATE	10,001-50,000	50,001-100,000	100,001-1,000,000	TOTAL
Low Corrective Action / Low Significant Defect	3%				
System Costs (Annual)		$3.6	$0.8	$1.4	$53.7
State Costs (Annual)		$0.2	$0.0	$0.0	$17.6
Total Costs (Annual)		$3.8	$0.8	$1.4	$71.2
High Corrective Action / Low Significant Defect	3%				
System Costs (Annual)		$3.6	$0.8	$1.4	$53.7
State Costs (Annual)		$0.2	$0.0	$0.0	$17.6
Total Costs (Annual)		$3.8	$0.8	$1.4	$71.2
Low Corrective Action / High Significant Defect	3%				
System Costs (Annual)		$3.6	$1.1	$2.0	$56.8
State Costs (Annual)		$0.2	$0.0	$0.0	$17.5
Total Costs (Annual)		$3.8	$1.1	$2.1	$74.3
High Corrective Action / High Significant Defect	3%				
System Costs (Annual)		$3.6	$1.1	$2.0	$56.8
State Costs (Annual)		$0.2	$0.0	$0.0	$17.5
Total Costs (Annual)		$3.8	$1.1	$2.1	$74.3
Low Corrective Action / Low Significant Defect	7%				
System Costs (Annual)		$3.8	$0.8	$1.5	$56.2
State Costs (Annual)		$0.2	$0.1	$0.0	$18.2
Total Costs (Annual)		$4.0	$0.9	$1.5	$74.4
High Corrective Action / Low Significant Defect	7%				
System Costs (Annual)		$3.8	$0.8	$1.5	$56.2
State Costs (Annual)		$0.2	$0.1	$0.0	$18.2
Total Costs (Annual)		$4.0	$0.9	$1.5	$74.4
Low Corrective Action / High Significant Defect	7%				
System Costs (Annual)		$3.7	$1.1	$2.1	$59.5
State Costs (Annual)		$0.2	$0.1	$0.0	$18.1
Total Costs (Annual)		$4.0	$1.2	$2.2	$77.6
High Corrective Action / High Significant Defect	7%				
System Costs (Annual)		$3.7	$1.1	$2.1	$59.5
State Costs (Annual)		$0.2	$0.1	$0.0	$18.1
Total Costs (Annual)		$4.0	$1.2	$2.2	$77.6

Exhibit D–3. Total Costs by PWS Type for Option 1: Sanitary Survey Only

	DISCOUNT RATE	SYSTEM TYPE Community Water Systems	Non-Transient/Non-Community Water Systems	Transient/Non-Community Water Systems	TOTAL
Low Corrective Action / Low Significant Defect	3%				
System Costs (Annual)		$32.9	$3.8	$16.9	$53.7
State Costs (Annual)		$2.9	$0.9	$4.0	$17.6
Total Costs (Annual)		$35.8	$4.7	$21.0	$71.2
High Corrective Action / Low Significant Defect	3%				
System Costs (Annual)		$32.9	$3.8	$16.9	$53.7
State Costs (Annual)		$2.9	$0.9	$4.0	$17.6
Total Costs (Annual)		$35.8	$4.7	$21.0	$71.2
Low Corrective Action / High Significant Defect	3%				
System Costs (Annual)		$33.1	$4.5	$19.2	$56.8
State Costs (Annual)		$2.8	$0.9	$4.0	$17.5
Total Costs (Annual)		$35.9	$5.4	$23.1	$74.3
High Corrective Action / High Significant Defect	3%				
System Costs (Annual)		$33.1	$4.5	$19.2	$56.8
State Costs (Annual)		$2.8	$0.9	$4.0	$17.5
Total Costs (Annual)		$35.9	$5.4	$23.1	$74.3
Low Corrective Action / Low Significant Defect	7%				
System Costs (Annual)		$34.3	$4.0	$17.9	$56.2
State Costs (Annual)		$3.0	$0.9	$4.2	$18.2
Total Costs (Annual)		$37.3	$5.0	$22.1	$74.4
High Corrective Action / Low Significant Defect	7%				
System Costs (Annual)		$34.3	$4.0	$17.9	$56.2
State Costs (Annual)		$3.0	$0.9	$4.2	$18.2
Total Costs (Annual)		$37.3	$5.0	$22.1	$74.4
Low Corrective Action / High Significant Defect	7%				
System Costs (Annual)		$34.5	$4.8	$20.2	$59.5
State Costs (Annual)		$2.9	$0.9	$4.1	$18.1
Total Costs (Annual)		$37.5	$5.7	$24.3	$77.6
High Corrective Action / High Significant Defect	7%				
System Costs (Annual)		$34.5	$4.8	$20.2	$59.5
State Costs (Annual)		$2.9	$0.9	$4.1	$18.1
Total Costs (Annual)		$37.47	$5.71	$24.32	$77.61

Exhibit D–4. Total Costs for Option 2: Sanitary Survey and Triggered Monitoring

TOTAL NATIONAL COSTS	DISCOUNT RATE	
	3%	7%
Annual System Costs:		
Annual Cost (Low CA/Low SD)	$133.9	$143.2
Annual Cost (Low CA/High SD)	$140.0	$149.5
Annual Cost (High CA/Low SD)	$137.4	$148.0
Annual Cost (High CA/High SD)	$143.5	$154.3
Annual State Costs:		
Annual Cost (Low CA/Low SD)	$18.9	$19.8
Annual Cost (Low CA/High SD)	$18.8	$19.7
Annual Cost (High CA/Low SD)	$18.9	$19.8
Annual Cost (High CA/High SD)	$18.8	$19.7
Present Value of System Costs:		
PV Cost (Low CA/Low SD)	$1,992.8	$1,517.5
PV Cost (Low CA/High SD)	$2,083.0	$1,584.3
PV Cost (High CA/Low SD)	$2,044.3	$1,567.4
PV Cost (High CA/High SD)	$2,134.6	$1,634.1
Present Value of State Costs:		
PV Cost (Low CA/Low SD)	$280.8	$209.5
PV Cost (Low CA/High SD)	$280.3	$209.1
PV Cost (High CA/Low SD)	$280.8	$209.5
PV Cost (High CA/High SD)	$280.3	$209.1

Notes:
Low CA = Low Cost Corrective Action Scenario
High CA = High Cost Corrective Action Scenario
Low SD = Low Cost Significant Defect Scenario
High SD = High Cost Significant Defect Scenario

Exhibit D–5. Total Costs by PWS Size Option 2: Sanitary Survey and Triggered Monitoring

	DISCOUNT RATE	SYSTEM SIZE CATEGORIES <100	101-500	501-1,000	1,001-3,300	3,301-10,000
Low Corrective Action / Low Significant Defect	3%					
System Costs (Annual)		$66.6	$31.4	$8.4	$10.2	$6.9
State Costs (Annual)		$4.6	$2.3	$0.7	$0.7	$0.4
Total Costs (Annual)		$71.2	$33.7	$9.1	$10.9	$7.2
High Corrective Action / Low Significant Defect	3%					
System Costs (Annual)		$68.6	$31.7	$9.9	$11.3	$6.9
State Costs (Annual)		$4.6	$2.3	$0.7	$0.7	$0.4
Total Costs (Annual)		$73.2	$34.0	$10.6	$12.0	$7.3
Low Corrective Action / High Significant Defect	3%					
System Costs (Annual)		$69.2	$32.7	$9.1	$11.0	$7.4
State Costs (Annual)		$4.6	$2.3	$0.7	$0.7	$0.4
Total Costs (Annual)		$73.8	$34.9	$9.8	$11.7	$7.7
High Corrective Action / High Significant Defect	3%					
System Costs (Annual)		$71.2	$33.0	$10.6	$12.1	$7.4
State Costs (Annual)		$4.6	$2.3	$0.7	$0.7	$0.4
Total Costs (Annual)		$75.7	$35.3	$11.3	$12.9	$7.8
Low Corrective Action / Low Significant Defect	7%					
System Costs (Annual)		$70.9	$33.5	$9.0	$10.9	$7.4
State Costs (Annual)		$4.9	$2.4	$0.7	$0.8	$0.4
Total Costs (Annual)		$75.9	$36.0	$9.8	$11.7	$7.8
High Corrective Action / Low Significant Defect	7%					
System Costs (Annual)		$73.8	$34.1	$10.7	$12.2	$7.5
State Costs (Annual)		$4.9	$2.4	$0.7	$0.8	$0.4
Total Costs (Annual)		$78.7	$36.5	$11.4	$12.9	$7.9
Low Corrective Action / High Significant Defect	7%					
System Costs (Annual)		$73.6	$34.9	$9.7	$11.8	$7.9
State Costs (Annual)		$4.9	$2.4	$0.7	$0.8	$0.4
Total Costs (Annual)		$78.5	$37.3	$10.4	$12.5	$8.3
High Corrective Action / High Significant Defect	7%					
System Costs (Annual)		$76.4	$35.4	$11.4	$13.0	$8.0
State Costs (Annual)		$4.9	$2.4	$0.7	$0.8	$0.4
Total Costs (Annual)		$81.3	$37.8	$12.1	$13.8	$8.4

Exhibit D–5. Total Costs by PWS Size Option 2: Sanitary Survey and Triggered Monitoring *(continued)*

	DISCOUNT RATE	SYSTEM SIZE CATEGORIES 10,001-50,000	50,001-100,000	100,001-1,000,000	TOTAL
Low Corrective Action / Low Significant Defect	3%				
System Costs (Annual)		$5.7	$3.7	$1.0	$133.9
State Costs (Annual)		$0.3	$0.1	$0.0	$18.9
Total Costs (Annual)		$6.1	$3.7	$1.1	$152.8
High Corrective Action / Low Significant Defect	3%				
System Costs (Annual)		$5.6	$2.3	$1.0	$137.4
State Costs (Annual)		$0.3	$0.1	$0.0	$18.9
Total Costs (Annual)		$5.9	$2.3	$1.1	$156.3
Low Corrective Action / High Significant Defect	3%				
System Costs (Annual)		$6.0	$3.7	$1.1	$140.0
State Costs (Annual)		$0.3	$0.1	$0.0	$18.8
Total Costs (Annual)		$6.3	$3.8	$1.1	$158.9
High Corrective Action / High Significant Defect	3%				
System Costs (Annual)		$5.8	$2.3	$1.1	$143.5
State Costs (Annual)		$0.3	$0.1	$0.0	$18.8
Total Costs (Annual)		$6.1	$2.4	$1.1	$162.3
Low Corrective Action / Low Significant Defect	7%				
System Costs (Annual)		$6.2	$4.0	$1.1	$143.2
State Costs (Annual)		$0.3	$0.1	$0.0	$19.8
Total Costs (Annual)		$6.6	$4.0	$1.2	$163.0
High Corrective Action / Low Significant Defect	7%				
System Costs (Annual)		$6.1	$2.5	$1.2	$148.0
State Costs (Annual)		$0.3	$0.1	$0.0	$19.8
Total Costs (Annual)		$6.4	$2.5	$1.2	$167.7
Low Corrective Action / High Significant Defect	7%				
System Costs (Annual)		$6.5	$4.0	$1.2	$149.5
State Costs (Annual)		$0.3	$0.1	$0.0	$19.7
Total Costs (Annual)		$6.8	$4.1	$1.2	$169.3
High Corrective Action / High Significant Defect	7%				
System Costs (Annual)		$6.3	$2.5	$1.2	$154.3
State Costs (Annual)		$0.3	$0.1	$0.0	$19.7
Total Costs (Annual)		$6.6	$2.6	$1.2	$174.0

Exhibit D–6. Total Costs by PWS Type Option 2: Sanitary Survey and Triggered Monitoring

	DISCOUNT RATE	SYSTEM TYPE Community Water Systems	Non-Transient/Non-Community Water Systems	Transient/Non-Community Water Systems	TOTAL
Low Corrective Action / Low Significant Defect	3%				
System Costs (Annual)		$50.6	$13.3	$70.0	$133.9
State Costs (Annual)		$3.6	$1.0	$4.5	$18.9
Total Costs (Annual)		$54.2	$14.4	$74.5	$152.8
High Corrective Action / Low Significant Defect	3%				
System Costs (Annual)		$52.3	$13.1	$72.0	$137.4
State Costs (Annual)		$3.6	$1.0	$4.5	$18.9
Total Costs (Annual)		$55.9	$14.1	$76.5	$156.3
Low Corrective Action / High Significant Defect	3%				
System Costs (Annual)		$53.5	$14.0	$72.5	$140.0
State Costs (Annual)		$3.6	$1.0	$4.5	$18.8
Total Costs (Annual)		$57.1	$15.1	$76.9	$158.9
High Corrective Action / High Significant Defect	3%				
System Costs (Annual)		$55.2	$13.8	$74.4	$143.5
State Costs (Annual)		$3.6	$1.0	$4.5	$18.8
Total Costs (Annual)		$58.8	$14.8	$78.9	$162.3
Low Corrective Action / Low Significant Defect	7%				
System Costs (Annual)		$54.1	$14.4	$74.8	$143.2
State Costs (Annual)		$3.8	$1.1	$4.8	$19.8
Total Costs (Annual)		$57.9	$15.4	$79.6	$163.0
High Corrective Action / Low Significant Defect	7%				
System Costs (Annual)		$56.1	$14.2	$77.6	$148.0
State Costs (Annual)		$3.8	$1.1	$4.8	$19.8
Total Costs (Annual)		$59.9	$15.3	$82.5	$167.7
Low Corrective Action / High Significant Defect	7%				
System Costs (Annual)		$57.2	$15.1	$77.3	$149.5
State Costs (Annual)		$3.8	$1.1	$4.8	$19.7
Total Costs (Annual)		$60.9	$16.2	$82.1	$169.3
High Corrective Action / High Significant Defect	7%				
System Costs (Annual)		$59.2	$14.9	$80.2	$154.3
State Costs (Annual)		$3.8	$1.1	$4.8	$19.7
Total Costs (Annual)		$62.9	$16.0	$85.0	$174.0

Exhibit D–7. Total Costs for Option 3: Multiple Barrier Approach

TOTAL NATIONAL COSTS	DISCOUNT RATE	
	3%	7%
Annual System Costs:		
Annual Cost (Low CA/Low SD)	$156.4	$169.6
Annual Cost (Low CA/High SD)	$162.7	$176.1
Annual Cost (High CA/Low SD)	$161.6	$176.8
Annual Cost (High CA/High SD)	$167.9	$183.4
Annual State Costs:		
Annual Cost (Low CA/Low SD)	$20.6	$22.1
Annual Cost (Low CA/High SD)	$20.6	$22.1
Annual Cost (High CA/Low SD)	$20.6	$22.1
Annual Cost (High CA/High SD)	$20.6	$22.1
Present Value of System Costs:		
PV Cost (Low CA/Low SD)	$2,327.3	$1,796.3
PV Cost (Low CA/High SD)	$2,421.0	$1,865.6
PV Cost (High CA/Low SD)	$2,403.8	$1,873.3
PV Cost (High CA/High SD)	$2,497.5	$1,942.7
Present Value of State Costs:		
PV Cost (Low CA/Low SD)	$306.0	$234.4
PV Cost (Low CA/High SD)	$306.0	$234.4
PV Cost (High CA/Low SD)	$306.0	$234.4
PV Cost (High CA/High SD)	$306.0	$234.4

Notes:
Low CA = Low Cost Corrective Action Scenario
High CA = High Cost Corrective Action Scenario
Low SD = Low Cost Significant Defect Scenario
High SD = High Cost Significant Defect Scenario

Exhibit D–8. Total Costs by PWS Size for Option 3: Multiple Barrier Approach

		SYSTEM SIZE CATEGORIES				
	DISCOUNT RATE	<100	101-500	501-1,000	1,001-3,300	3,301-10,000
Low Corrective Action / Low Significant Defect	3%					
System Costs (Annual)		$70.8	$39.1	$12.1	$13.5	$10.2
State Costs (Annual)		$5.6	$2.7	$0.8	$0.8	$0.4
Total Costs (Annual)		$76.4	$41.8	$12.8	$14.3	$10.6
High Corrective Action / Low Significant Defect	3%					
System Costs (Annual)		$74.3	$39.2	$11.2	$13.8	$12.2
State Costs (Annual)		$5.6	$2.7	$0.8	$0.8	$0.4
Total Costs (Annual)		$80.0	$41.9	$12.0	$14.6	$12.6
Low Corrective Action / High Significant Defect	3%					
System Costs (Annual)		$73.4	$40.7	$12.7	$14.3	$10.6
State Costs (Annual)		$5.6	$2.7	$0.8	$0.8	$0.4
Total Costs (Annual)		$79.0	$43.4	$13.5	$15.1	$11.0
High Corrective Action / High Significant Defect	3%					
System Costs (Annual)		$76.9	$40.8	$11.9	$14.6	$12.6
State Costs (Annual)		$5.6	$2.7	$0.8	$0.8	$0.4
Total Costs (Annual)		$82.5	$43.5	$12.6	$15.4	$13.0
Low Corrective Action / Low Significant Defect	7%					
System Costs (Annual)		$76.5	$42.4	$13.0	$14.7	$11.1
State Costs (Annual)		$6.3	$3.0	$0.9	$0.9	$0.4
Total Costs (Annual)		$82.9	$45.4	$13.9	$15.5	$11.5
High Corrective Action / Low Significant Defect	7%					
System Costs (Annual)		$81.6	$42.9	$12.2	$15.0	$13.3
State Costs (Annual)		$6.3	$3.0	$0.9	$0.9	$0.4
Total Costs (Annual)		$87.9	$45.9	$13.1	$15.9	$13.7
Low Corrective Action / High Significant Defect	7%					
System Costs (Annual)		$79.2	$44.1	$13.7	$15.5	$11.5
State Costs (Annual)		$6.3	$3.0	$0.9	$0.9	$0.4
Total Costs (Annual)		$85.5	$47.1	$14.5	$16.3	$12.0
High Corrective Action / High Significant Defect	7%					
System Costs (Annual)		$84.2	$44.6	$12.9	$15.8	$13.7
State Costs (Annual)		$6.3	$3.0	$0.9	$0.9	$0.4
Total Costs (Annual)		$90.6	$47.6	$13.7	$16.7	$14.2

Exhibit D–8. Total Costs by PWS Size for Option 3: Multiple Barrier Approach *(continued)*

	DISCOUNT RATE	SYSTEM SIZE CATEGORIES 10,001-50,000	50,001-100,000	100,001-1,000,000	TOTAL
Low Corrective Action / Low Significant Defect	3%				
System Costs (Annual)		$5.3	$3.9	$1.6	$156.4
State Costs (Annual)		$0.3	$0.1	$0.1	$20.6
Total Costs (Annual)		$5.7	$3.9	$1.6	$177.0
High Corrective Action / Low Significant Defect	3%				
System Costs (Annual)		$5.9	$3.3	$1.5	$161.6
State Costs (Annual)		$0.3	$0.1	$0.1	$20.6
Total Costs (Annual)		$6.3	$3.4	$1.6	$182.1
Low Corrective Action / High Significant Defect	3%				
System Costs (Annual)		$5.6	$3.9	$1.6	$162.7
State Costs (Annual)		$0.3	$0.1	$0.1	$20.6
Total Costs (Annual)		$5.9	$4.0	$1.7	$183.3
High Corrective Action / High Significant Defect	3%				
System Costs (Annual)		$6.2	$3.4	$1.6	$167.9
State Costs (Annual)		$0.3	$0.1	$0.1	$20.6
Total Costs (Annual)		$6.5	$3.4	$1.6	$188.4
Low Corrective Action / Low Significant Defect	7%				
System Costs (Annual)		$5.8	$4.2	$1.8	$169.6
State Costs (Annual)		$0.4	$0.1	$0.1	$22.1
Total Costs (Annual)		$6.2	$4.3	$1.8	$191.7
High Corrective Action / Low Significant Defect	7%				
System Costs (Annual)		$6.5	$3.6	$1.7	$176.8
State Costs (Annual)		$0.4	$0.1	$0.1	$22.1
Total Costs (Annual)		$6.8	$3.7	$1.8	$199.0
Low Corrective Action / High Significant Defect	7%				
System Costs (Annual)		$6.1	$4.3	$1.8	$176.1
State Costs (Annual)		$0.4	$0.1	$0.1	$22.1
Total Costs (Annual)		$6.5	$4.3	$1.9	$198.2
High Corrective Action / High Significant Defect	7%				
System Costs (Annual)		$6.8	$3.7	$1.7	$183.4
State Costs (Annual)		$0.4	$0.1	$0.1	$22.1
Total Costs (Annual)		$7.1	$3.7	$1.8	$205.5

Exhibit D–9. Total Costs by PWS Type for Option 3: Multiple Barrier Approach

	DISCOUNT RATE	SYSTEM TYPE Community Water Systems	Non-Transient/Non-Community Water Systems	Transient/Non-Community Water Systems	TOTAL
Low Corrective Action / Low Significant Defect	3%				
System Costs (Annual)		$60.6	$15.6	$80.2	$156.4
State Costs (Annual)		$3.9	$1.2	$5.6	$20.6
Total Costs (Annual)		$64.6	$16.8	$85.8	$177.0
High Corrective Action / Low Significant Defect	3%				
System Costs (Annual)		$62.1	$15.8	$83.6	$161.6
State Costs (Annual)		$3.9	$1.2	$5.6	$20.6
Total Costs (Annual)		$66.0	$17.1	$89.3	$182.1
Low Corrective Action / High Significant Defect	3%				
System Costs (Annual)		$63.7	$16.3	$82.7	$162.7
State Costs (Annual)		$3.9	$1.2	$5.6	$20.6
Total Costs (Annual)		$67.7	$17.6	$88.3	$183.3
High Corrective Action / High Significant Defect	3%				
System Costs (Annual)		$65.2	$16.6	$86.1	$167.9
State Costs (Annual)		$3.9	$1.2	$5.6	$20.6
Total Costs (Annual)		$69.1	$17.8	$91.8	$188.4
Low Corrective Action / Low Significant Defect	7%				
System Costs (Annual)		$65.6	$17.0	$87.0	$169.6
State Costs (Annual)		$4.2	$1.4	$6.4	$22.1
Total Costs (Annual)		$69.8	$18.4	$93.4	$191.7
High Corrective Action / Low Significant Defect	7%				
System Costs (Annual)		$67.2	$17.4	$92.2	$176.8
State Costs (Annual)		$4.2	$1.4	$6.4	$22.1
Total Costs (Annual)		$71.5	$18.8	$98.6	$199.0
Low Corrective Action / High Significant Defect	7%				
System Costs (Annual)		$68.8	$17.8	$89.6	$176.1
State Costs (Annual)		$4.2	$1.4	$6.4	$22.1
Total Costs (Annual)		$73.0	$19.1	$96.0	$198.2
High Corrective Action / High Significant Defect	7%				
System Costs (Annual)		$70.4	$18.1	$94.8	$183.4
State Costs (Annual)		$4.2	$1.4	$6.4	$22.1
Total Costs (Annual)		$74.7	$19.5	$101.2	$205.5

Exhibit D–10. Total Costs for Option 4: Across-the-Board Disinfection

TOTAL NATIONAL COSTS	DISCOUNT RATE 3%	DISCOUNT RATE 7%
Annual System Costs:		
Annual Cost (Low CA/Low SD)	$718.7	$794.1
Annual Cost (Low CA/High SD)	$723.9	$799.6
Annual Cost (High CA/Low SD)	$779.8	$875.3
Annual Cost (High CA/High SD)	$785.0	$880.7
Annual State Costs:		
Annual Cost (Low CA/Low SD)	$25.2	$28.6
Annual Cost (Low CA/High SD)	$25.2	$28.6
Annual Cost (High CA/Low SD)	$25.2	$28.6
Annual Cost (High CA/High SD)	$25.2	$28.6
Present Value of System Costs:		
PV Cost (Low CA/Low SD)	$10,691.7	$8,412.9
PV Cost (Low CA/High SD)	$10,769.9	$8,470.7
PV Cost (High CA/Low SD)	$11,601.0	$9,272.7
PV Cost (High CA/High SD)	$11,679.2	$9,330.5
Present Value of State Costs:		
PV Cost (Low CA/Low SD)	$375.5	$303.2
PV Cost (Low CA/High SD)	$375.0	$302.9
PV Cost (High CA/Low SD)	$375.5	$303.2
PV Cost (High CA/High SD)	$375.0	$302.9

Notes:
Low CA = Low Cost Corrective Action Scenario
High CA = High Cost Corrective Action Scenario
Low SD = Low Cost Significant Defect Scenario
High SD = High Cost Significant Defect Scenario

Exhibit D–11. Total Costs by PWS Size for Option 4: Across-the-Board Disinfection

	DISCOUNT RATE	SYSTEM SIZE CATEGORIES <100	101-500	501-1,000	1,001-3,300	3,301-10,000
Low Corrective Action / Low Significant Defect	3%					
System Costs (Annual)		$169.8	$186.8	$74.1	$103.4	$84.7
State Costs (Annual)		$9.0	$4.0	$0.9	$0.8	$0.4
Total Costs (Annual)		$178.8	$190.8	$75.0	$104.2	$85.0
High Corrective Action / Low Significant Defect	3%					
System Costs (Annual)		$206.1	$198.2	$76.6	$106.6	$93.9
State Costs (Annual)		$9.0	$4.0	$0.9	$0.8	$0.4
Total Costs (Annual)		$215.1	$202.2	$77.5	$107.4	$94.3
Low Corrective Action / High Significant Defect	3%					
System Costs (Annual)		$172.0	$187.8	$74.8	$104.0	$85.1
State Costs (Annual)		$9.0	$4.0	$0.9	$0.8	$0.4
Total Costs (Annual)		$181.0	$191.8	$75.7	$104.8	$85.5
High Corrective Action / High Significant Defect	3%					
System Costs (Annual)		$208.2	$199.3	$77.3	$107.3	$94.4
State Costs (Annual)		$9.0	$4.0	$0.9	$0.8	$0.4
Total Costs (Annual)		$217.2	$203.3	$78.2	$108.0	$94.8
Low Corrective Action / Low Significant Defect	7%					
System Costs (Annual)		$190.7	$204.3	$81.4	$113.7	$93.3
State Costs (Annual)		$10.8	$4.8	$1.0	$0.9	$0.4
Total Costs (Annual)		$201.5	$209.1	$82.4	$114.6	$93.7
High Corrective Action / Low Significant Defect	7%					
System Costs (Annual)		$241.7	$220.4	$84.4	$117.1	$102.9
State Costs (Annual)		$10.8	$4.8	$1.0	$0.9	$0.4
Total Costs (Annual)		$252.5	$225.2	$85.4	$118.0	$103.3
Low Corrective Action / High Significant Defect	7%					
System Costs (Annual)		$192.9	$205.4	$82.0	$114.3	$93.8
State Costs (Annual)		$10.8	$4.8	$1.0	$0.9	$0.4
Total Costs (Annual)		$203.7	$210.2	$83.1	$115.2	$94.2
High Corrective Action / High Significant Defect	7%					
System Costs (Annual)		$243.9	$221.6	$85.0	$117.7	$103.4
State Costs (Annual)		$10.8	$4.8	$1.0	$0.9	$0.4
Total Costs (Annual)		$254.7	$226.3	$86.1	$118.6	$103.8

Exhibit D–11. Total Costs by PWS Size for Option 4: Across-the-Board Disinfection *(continued)*

	DISCOUNT RATE	SYSTEM SIZE CATEGORIES			
		10,001-50,000	50,001-100,000	100,001-1,000,000	TOTAL
Low Corrective Action / Low Significant Defect	3%				
System Costs (Annual)		$45.2	$43.7	$10.9	$718.7
State Costs (Annual)		$0.3	$0.1	$0.0	$25.2
Total Costs (Annual)		$45.5	$43.8	$11.0	$743.9
High Corrective Action / Low Significant Defect	3%				
System Costs (Annual)		$42.7	$44.0	$11.5	$779.8
State Costs (Annual)		$0.3	$0.1	$0.0	$25.2
Total Costs (Annual)		$43.1	$44.1	$11.6	$805.0
Low Corrective Action / High Significant Defect	3%				
System Costs (Annual)		$45.4	$43.8	$11.0	$723.9
State Costs (Annual)		$0.3	$0.1	$0.0	$25.2
Total Costs (Annual)		$45.7	$43.8	$11.0	$749.1
High Corrective Action / High Significant Defect	3%				
System Costs (Annual)		$43.0	$44.1	$11.5	$785.0
State Costs (Annual)		$0.3	$0.1	$0.0	$25.2
Total Costs (Annual)		$43.3	$44.1	$11.6	$810.2
Low Corrective Action / Low Significant Defect	7%				
System Costs (Annual)		$50.2	$48.0	$12.6	$794.1
State Costs (Annual)		$0.4	$0.1	$0.1	$28.6
Total Costs (Annual)		$50.6	$48.1	$12.7	$822.7
High Corrective Action / Low Significant Defect	7%				
System Costs (Annual)		$47.5	$48.2	$13.2	$875.3
State Costs (Annual)		$0.4	$0.1	$0.1	$28.6
Total Costs (Annual)		$47.9	$48.3	$13.2	$903.9
Low Corrective Action / High Significant Defect	7%				
System Costs (Annual)		$50.4	$48.1	$12.6	$799.6
State Costs (Annual)		$0.4	$0.1	$0.1	$28.6
Total Costs (Annual)		$50.8	$48.2	$12.7	$828.2
High Corrective Action / High Significant Defect	7%				
System Costs (Annual)		$47.7	$48.2	$13.2	$880.7
State Costs (Annual)		$0.4	$0.1	$0.1	$28.6
Total Costs (Annual)		$48.1	$48.3	$13.3	$909.3

Exhibit D–12. Total Costs by PWS Type for Option 4: Across-the-Board Disinfection

	DISCOUNT RATE	SYSTEM TYPE Community Water Systems	Non-Transient/Non-Community Water Systems	Transient/Non-Community Water Systems	TOTAL
Low Corrective Action / Low Significant Defect	3%				
System Costs (Annual)		$376.3	$81.5	$260.9	$718.7
State Costs (Annual)		$3.6	$2.1	$9.8	$25.2
Total Costs (Annual)		$379.9	$83.5	$270.7	$743.9
High Corrective Action / Low Significant Defect	3%				
System Costs (Annual)		$397.0	$85.5	$297.3	$779.8
State Costs (Annual)		$3.6	$2.1	$9.8	$25.2
Total Costs (Annual)		$400.6	$87.5	$307.1	$805.0
Low Corrective Action / High Significant Defect	3%				
System Costs (Annual)		$378.8	$82.0	$263.1	$723.9
State Costs (Annual)		$3.6	$2.1	$9.8	$25.2
Total Costs (Annual)		$382.5	$84.0	$272.8	$749.1
High Corrective Action / High Significant Defect	3%				
System Costs (Annual)		$399.5	$86.0	$299.5	$785.0
State Costs (Annual)		$3.6	$2.1	$9.8	$25.2
Total Costs (Annual)		$403.2	$88.1	$309.2	$810.2
Low Corrective Action / Low Significant Defect	7%				
System Costs (Annual)		$414.8	$89.6	$289.7	$794.1
State Costs (Annual)		$4.3	$2.5	$11.8	$28.6
Total Costs (Annual)		$419.0	$92.1	$301.5	$822.7
High Corrective Action / Low Significant Defect	7%				
System Costs (Annual)		$438.1	$96.1	$341.0	$875.3
State Costs (Annual)		$4.3	$2.5	$11.8	$28.6
Total Costs (Annual)		$442.4	$98.6	$352.8	$903.9
Low Corrective Action / High Significant Defect	7%				
System Costs (Annual)		$417.4	$90.2	$292.0	$799.6
State Costs (Annual)		$4.3	$2.5	$11.8	$28.6
Total Costs (Annual)		$421.7	$92.6	$303.8	$828.2
High Corrective Action / High Significant Defect	7%				
System Costs (Annual)		$440.8	$96.7	$343.3	$880.7
State Costs (Annual)		$4.3	$2.5	$11.8	$28.6
Total Costs (Annual)		$445.0	$99.1	$355.1	$909.3

Exhibit D–13.

Household Costs of the GWR

(High Corrective Action/Low Significant Defect Scenario)

Option 1: Sanitary Survey Only

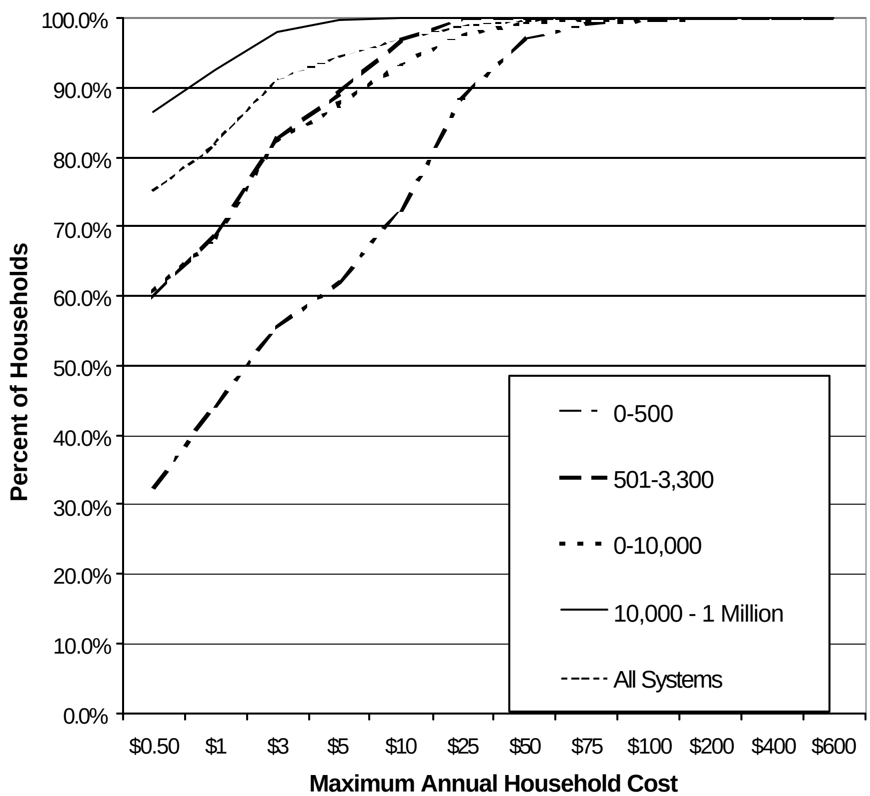

Exhibit D–14.

Household Costs of the GWR

(High Corrective Action/Low Significant Defect Scenario)

Option 2: Sanitary Survey and Triggered Monitoring

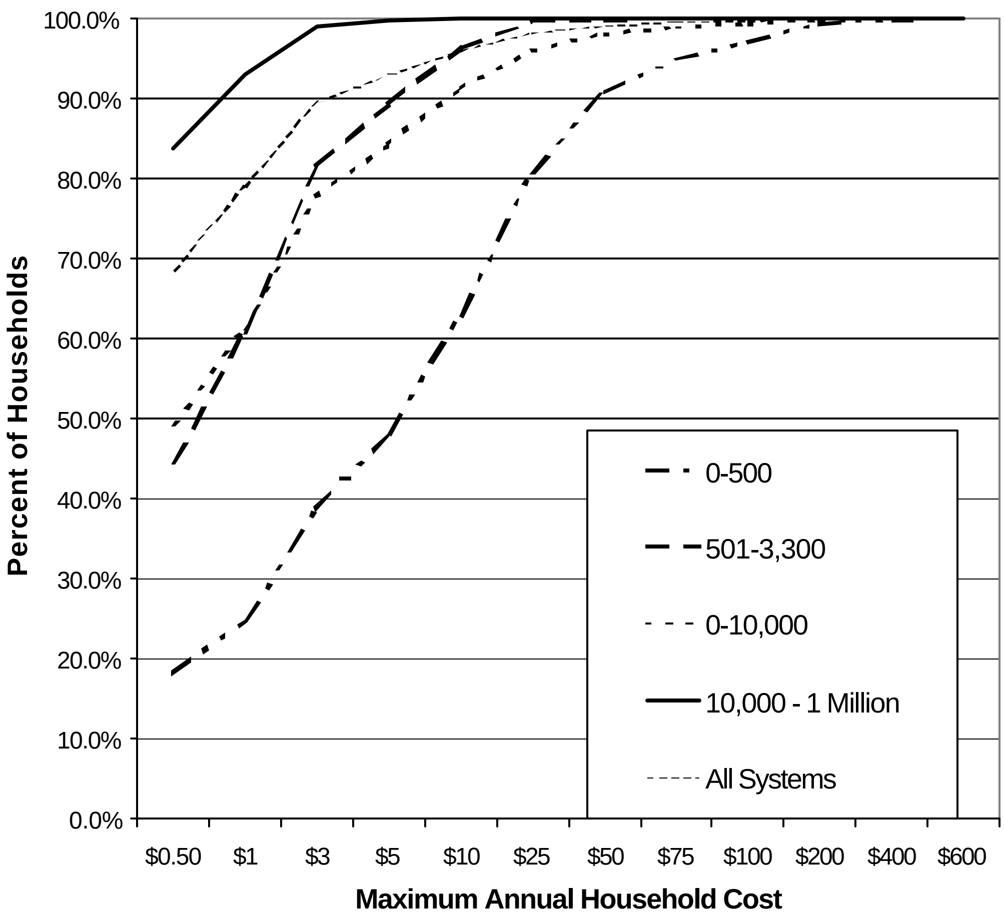

Exhibit D–15.

Household Costs of the GWR

(High Corrective Action/Low Significant Defect Scenario)

Option 3: Multi Barrier Approach

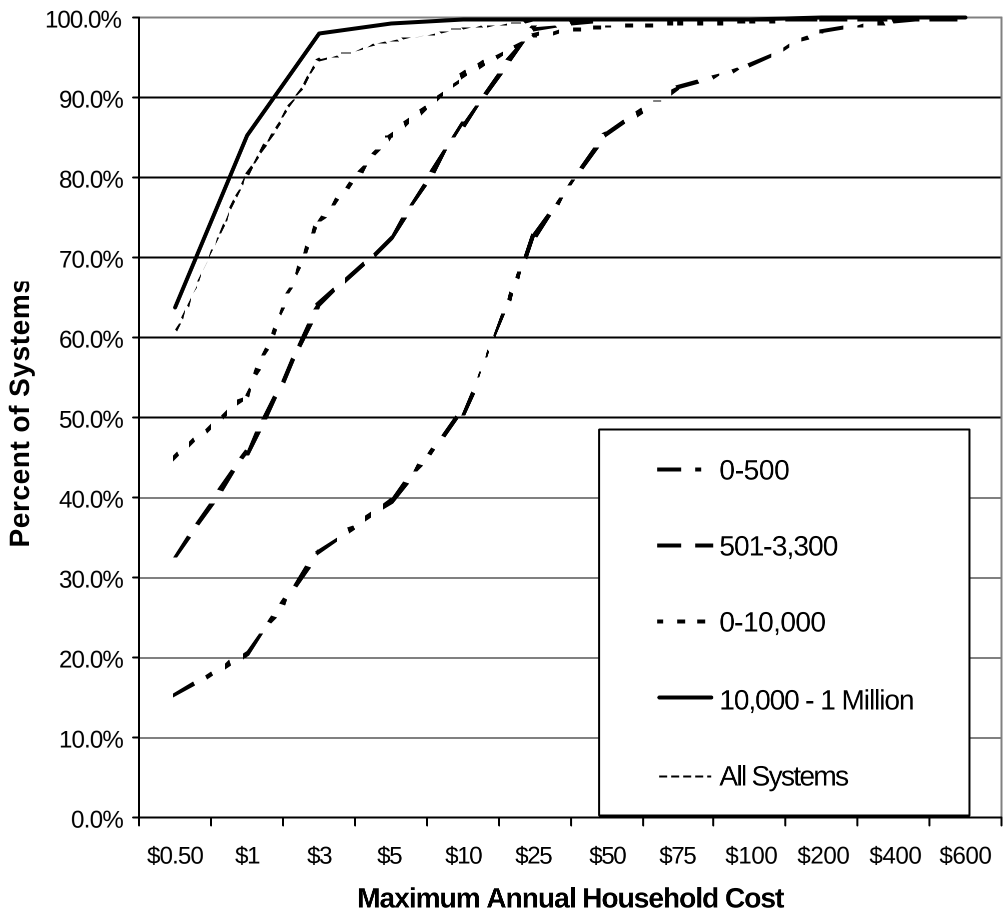

Exhibit D-16.

Household Costs of the GWR

(High Corrective Action/Low Significant Defect Scenario)

Option 4: Across-the-Board Disinfection

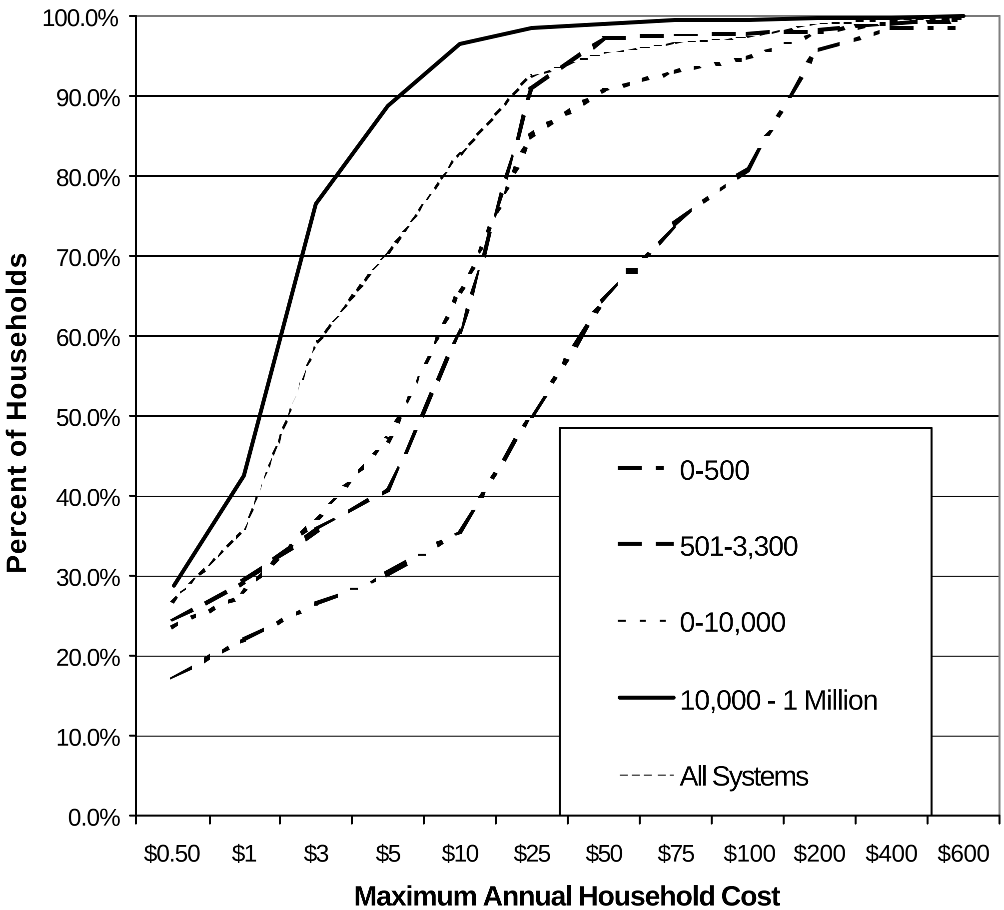

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Exhibit D–17.

Comparative Household Costs of the GWR Across Regulatory Options

For Systems Serving 0–500 People

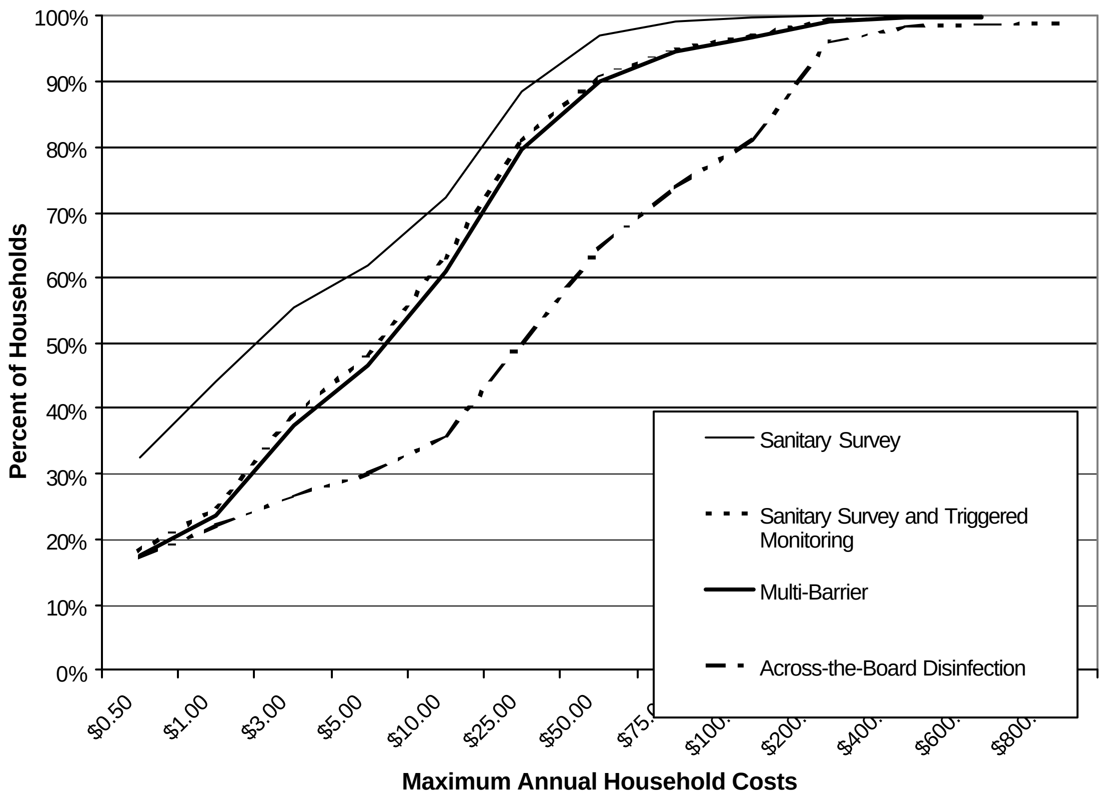

Exhibit D–18.

Comparative Household Costs of the GWR Across Regulatory Options

For All System Size Categories