PRELIMINARY HEALTH RISK REDUCTION AND COST ANALYSIS

REVISED NATIONAL PRIMARY DRINKING WATER STANDARDS FOR RADIONUCLIDES

Review Draft

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and
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Prepared by:
Industrial Economics, Incorporated
2067 Massachusetts Avenue
Cambridge, MA 02140
(617) 354 - 0074

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PREFACE

This report was completed by Industrial Economics, Incorporated (IEc) for the U.S. Environmental Protection Agency (EPA) under Work Assignment 2-43 of Contract 68-W6-0061, building upon work completed under previous work assignments. The Work Assignment Manager is William Labiosa of EPA's Office of Ground Water and Drinking Water. In addition to drafting this report, IEc conducted the occurrence analyses (reported in Chapters 2 and 5) and the risk analysis (reported in Chapter 3). The cost analysis (reported in Chapter 4) was conducted by William Labiosa of EPA.

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EXECUTIVE SUMMARY

The U.S. Environmental Protection Agency (EPA) is considering changes to the regulations governing the allowable levels of radionuclides in drinking water. The Notice of Proposed Rulemaking for these revisions was published in 1991. Since that time, additional information on the impacts of changes to these standards has become available, and EPA is publishing a Notice of Data Availability to publicize this new information. The Notice summarizes the risks and costs potentially associated with revisions to the standards; this report provides more detailed information on these impacts.

BACKGROUND

EPA first promulgated standards regulating the concentrations of radionuclides in drinking water in 1976 as National Interim Drinking Water Regulations (see 40 CFR 141). In 1986, EPA published an Advance Notice of Proposed Rulemaking, which discussed additional information on the occurrence and risks associated with radionuclides in drinking water. The Notice of Proposed Rulemaking (NPRM) for revisions to the radionuclide standards was published in 1991. The subsequent Notice of Data Availability (NODA) that this report supports provides additional information on the topics addressed by the NPRM.

The current regulations establish Maximum Contaminant Levels (MCLs) of 5 pCi/L for radium-226 and radium-228 combined and of 15 pCi/L for gross alpha (net of uranium and radon).[1] In the 1991 NPRM, EPA proposed to revise the combined radium and gross alpha standards and to create an MCL for uranium. Separate, higher standards were proposed for radium-226 and radium-228, while the standard for gross alpha would remain the same but be redefined to exclude radium-226. EPA is now considering instead whether to limit the contribution of radium-228 to the current

[1] The current and proposed standards also address the MCL for beta and photon emitters. This preliminary analysis does not consider the costs or risks associated with changes to the standards for these radionuclides because EPA expects that the impacts of these changes will be relatively small.

combined radium MCL, and whether to revise the gross alpha MCL to equal 10 pCi/L excluding radium-226. EPA is also considering MCLs for uranium at either 20 μg/L (20 pCi/L), 40 μg/L (40 pCi/L), or 80 μg/L (80 pCi/L). The NODA provides more detailed information on the rationale for considering each of these regulatory options.

In addition to revising the MCLs, both the 1991 proposal and the current NODA propose to alter the requirements for monitoring and analysis. The existing regulations include inadvertent loopholes that allow systems to "legally" exceed the current MCLs. These loopholes include: (1) systems may avoid analyzing their water for compliance with the combined radium standard if their measured gross alpha activity level is reliably below 5 pCi/L; (2) systems may avoid measuring radium-228 in cases where radium-226 does not exceed 3 pCi/L; and (3) systems may hold their gross alpha samples long enough to allow radium-224 to decay below detection limits.

Under the first two loopholes, some systems may legally exceed the MCL of 5 pCi/L for combined radium because the regulations allow them to avoid measuring activity levels for radium-228.[2] Under the third loophole, systems with elevated levels of radium-224 may legally exceed the MCL of 15 pCi/L for gross alpha because of the length of the allowable holding time for the samples. EPA is considering whether to close these loopholes to ensure that all systems achieve radionuclide levels at or below the existing MCLs.

In addition to changing the MCLs and monitoring requirements, the proposed rule would extend the requirements to non-transient non-community water systems. The current regulations apply only to community water systems. The regulations (at 40 CFR 141.2) define a community water system as "a public water system which serves at least 15 service connections used by year-round residents or regularly serves at least 25 year round residents." A non-transient, non-community water system is defined as "a public water system that is not a community water system and that regularly serves at least 25 of the same persons over 6 months per year." These systems often serve locations such as schools or office buildings.

OVERVIEW OF THE ECONOMIC ANALYSIS

Analysis of the costs, benefits and other impacts of regulations is required under the Safe Drinking Water Act Amendments of 1996, Executive Order 12866 ("Regulatory Planning and Review") and EPA's internal guidance. Related requirements have been revised substantially since EPA published the 1991 proposal for changes to the radionuclides regulations, and the new requirements guide the economic analysis presented in this report. In addition, there are several new

[2] Radium-228 is a beta emitter, whereas radium-226 is an alpha emitter and included in the measurement of compliance with both the gross alpha and combined radium MCLs.

statutory and administrative requirements for assessing the distribution of costs and benefits and equity concerns, focusing on groups such as small businesses and children.

The analysis in this report represents the first step in the development of a comprehensive economic analysis for the radionuclides rule. It provides preliminary estimates of national costs and benefits, and presents information on the data sources and analytic approach used for review by interested stakeholders. This analysis will be subsequently refined as needed to respond to comments, incorporate new data, and address key sources of uncertainty. In addition, it will be expanded to include assessment of distributional effects (e.g., on small systems and sensitive sub-populations) as required by various statutes and administrative orders.

The basic steps in a comprehensive economic analysis include: (1) estimating baseline conditions in the absence of revisions to the regulations; (2) predicting responses to each regulatory option; (3) estimating changes in national costs; (4) estimating changes in national benefits; and (5) assessing distributional impacts and equity concerns. In this report, we develop preliminary estimates of national costs and benefits, focusing on monitoring and compliance costs and reductions in cancer risks. Other national costs and benefits (e.g., state administrative costs and risk reductions from incidental treatment of co-occurring contaminants) and potential distributional impacts are described qualitatively.

The first step in the economic analysis, defining the baseline, provides unusual challenges in the case of the radionuclides regulations. Several community water systems are not complying with the existing regulations, in part because they are anticipating the proposed changes to these requirements and hope to avoid unnecessary costs. Also, as discussed earlier, there are loopholes in the current monitoring requirements that allow some systems to legally avoid compliance with the current MCLs. To address these issues, this preliminary analysis considers two baselines.

- Initial baseline: Under this scenario, we assume that systems would be required to comply with the existing regulations as currently written. Community water systems could exceed the existing MCLs only in cases where they can legally avoid compliance due to the loopholes in the monitoring requirements.

- Revised baseline: Under this scenario, we assume that EPA would alter the current regulations to eliminate the monitoring loopholes, so that all community water systems would be required to achieve the existing MCLs.

This dual baseline approach allows us to separate the costs and benefits of changes in the monitoring requirements and from the costs and benefits of changes in the MCLs. It also avoids attributing costs to the new regulations that are in fact attributable to achieving compliance with the regulations now in force.

APPROACH FOR ASSESSING OCCURRENCE, RISKS AND COSTS

The first step in the economic analysis involves estimating baseline occurrence in the absence of revisions to the regulations. To develop these estimates for community water systems, we begin by extrapolating from data obtained through EPA's National Inorganics and Radionuclides Survey (NIRS). This survey measures radionuclide concentrations at 990 community ground water systems between 1984 and 1986. We adjust these data to address certain of their limitations, including (1) the small size of the sample for systems serving populations greater than 3,300 persons; (2) the decay of radium-224 prior to analysis of the NIRS water samples; (3) the need to convert mass measurements of uranium to activity levels; and, (4) the lack of information on surface water systems.

Because of uncertainties related to extrapolation from this sample to national estimates, we apply two approaches. First, we assume that national occurrence is directly proportional to the occurrence levels measured in NIRS. In other words, if one percent of the systems in a particular size class in NIRS are out of compliance with a regulatory option, we assume that one percent of all systems in that size class nationally are out of compliance. Under the second approach, we fit a lognormal distribution to the NIRS data for each system size class and group of radionuclides, then uses this distribution to estimate the percentage of systems out of compliance nationally. The properties of the lognormal distribution depend on the underlying NIRS data, but applying this distribution often increases the estimates of the proportion of systems out of compliance as well as the amount by which they exceed the MCL of concern. This approach recognizes that actual national occurrence levels will vary from the levels observed for the systems included in NIRs.

Under both the direct proportions and lognormal approaches, we develop an initial baseline for combined radium and gross alpha that reflects full compliance with the existing regulations as written. We implement these adjustments by identifying systems in illegal compliance status and adjusting their gross alpha and combined radium concentrations downwards, to reflect the impacts of installing treatment or taking other actions to achieve compliance (such as changing water sources, blending contaminated and uncontaminated water, or closing contaminated wells). A similar approach is used to subsequently adjust the data to account for closure of the monitoring loopholes, which leads to development of the revised baseline where all systems are at or below the current MCLS. These adjustments are not applied to uranium, which is not currently regulated and tends not to occur above levels of concern in systems affected by the existing monitoring loopholes.

After determining the number of systems out of compliance with each regulatory option under consideration, we assess the risk reductions associated with requiring compliance. The approach for the risk analysis begins with the development of risk factors for each group of radionuclides. These factors involve multiplying the mortality and morbidity cancer risk coefficients for each group of radionuclides by standard assumptions regarding drinking water ingestion to determine the risks associated with annual exposure. We then apply the individual annual risk factors to the estimates of the reduction in occurrence associated with each regulatory change under consideration, taking into account the population exposed.

Once we estimate the reductions in fatal and nonfatal cancer risks associated with each regulatory option, we assess the value of these reductions using generally accepted economic valuation techniques. To estimate the monetary value of the reduced fatal risks (i.e., the risks of premature death from cancer) predicted under different regulatory options, we apply the value of a statistical life approach. A "statistical" life is the sum of small individual risk reductions across an entire exposed population, not the value of saving the life of a particular individual. For nonfatal cancer risks, we use data on the cost of illness to value the risk reductions.

The third component of the analysis involves estimating the costs of the compliance under each regulatory option. The options under consideration will increase the costs of monitoring for all systems as well require certain systems to take action to reduce the concentrations of radionuclides in their water. These latter actions may include installing treatment or changing the water source used. The analysis considers both capital costs and operations and maintenance costs, and includes a number of treatment technologies. The options of complying by purchasing water from neighboring systems, blending, or using alternative water sources are also considered.

SUMMARY OF FINDINGS

In Exhibit ES-1 below, we estimate the number of systems likely to be out of compliance with each of the regulatory options assessed in this preliminary analysis.

Exhibit ES-1
NUMBER OF COMMUNITY WATER SYSTEMS EXCEEDING STANDARDS

Option	Number of Systems
Illegally out of compliance with existing MCLs (combined radium = 5 pCi/L, gross alpha = 15 pCi/L) [1]	
Illegal noncompliance: gross alpha	400 systems
Illegal noncompliance: combined radium	420 systems
Total number of systems in illegal noncompliance (adjusts for overlap)	670 systems
Legally out of compliance with existing MCLs (due to monitoring loopholes) [2]	
Legal noncompliance (due to monitoring loopholes): gross alpha	210 - 250 systems
Legal noncompliance (due to monitoring loopholes): combined radium	270 - 320 systems
Total number of systems in legal noncompliance (adjusts for overlap)	310 - 400 systems
Out of compliance with options for revising MCLs [3]	
Gross alpha at 10 pCi/L net of radium 226	500 - 610 systems
Combined radium at 5 pCi/L with radium-228 limit at 3 pCi/L	210 systems
Total number of systems out of compliance with revised radium or gross alpha MCL (adjusts for overlap)	570 - 670 systems
Out of compliance with options for uranium MCL	
Uranium at 20 pCi/L (20 μg/L)	830 - 970 systems
Uranium at 40 pCi/L (40 μg/L)	300 - 430 systems
Uranium at 80 pCi/L (80 μg/L)	40 - 170 systems

Notes:
Ranges based on directly proportional versus lognormal distribution approach. Combined radium and gross alpha analyses include ground water systems only; uranium analysis includes both ground water and surface water systems.
1. Costs and risk reductions associated with complying with existing requirements for these systems are not assessed because these impacts are not attributable to the changes in requirements now under consideration.
2. Compared to initial baseline (i.e., occurrence data are adjusted to eliminate illegal noncompliance).
3. Compared to revised baseline (i.e., occurrence data are adjusted to eliminate legal noncompliance with both gross alpha and combined radium MCLs).

As indicated by the exhibit, closing the monitoring loopholes will affect about 310 to 400 systems once potential double-counting is taken into account, and the MCL revisions for gross alpha and combined radium will affect a total of about 570 to 670 systems. The low end estimates generally result from the direct proportions approach to estimating occurrence, while the lognormal approach leads to higher estimates of the number of systems out of compliance for most (but not all) of the options . The uranium options will affect between 40 and 970 systems depending on the MCL selected and the approach used to estimate the number of systems out of compliance.

In Exhibit ES-2 and ES-3 below, we summarize the risk reductions and compliance costs resulting from closing the regulatory loopholes for gross alpha and combined radium to eliminate legal noncompliance with the current regulations. We also report the impacts associated with alternative MCLs. Exhibit ES-2 provides the results for the direct proportions approach, while Exhibit ES-3 provides the results for the lognormal approach.

Exhibit ES-2
SUMMARY OF QUANTIFIED ANNUAL COSTS AND BENEFITS: DIRECT PROPORTIONS APPROACH
(community water systems)

	Total Cancer Cases Avoided (fatal cases)	**Value of Avoided Cases (range)**	**Total Change in Compliance Costs**
Compliance with existing MCLs after closing monitoring loopholes (combined radium = 5 pCi/L, gross alpha = 15 pCi/L)[1]			
Eliminate gross alpha monitoring loophole only	0.04 cases total (0.03 fatal)	$0.2 million ($<0.1 - $0.3 million)	$2.5 million
Eliminate combined radium monitoring loophole only	0.31 cases total (0.21 fatal)	$1.2 million ($0.3 - $2.4 million)	$21.6 million
Eliminate both loopholes[2]	0.32 cases total (0.22 fatal)	$1.3 million ($0.3 - $2.5 million	$22.2 million
Compliance with revised MCL options [3]			
Revise gross alpha MCL to 10 pCi/L net of radium-226 only	0.53 cases total (0.35 fatal)	$2.1 million ($0.5 - $4.0 million)	$62.7 million
Limit radium-228 at 3 pCi/L within combined radium MCL of 5 pCi/L only	0.50 cases total (0.34 fatal)	$2.0 million ($0.5 - $3.9 million)	$40.7 million
Revise both gross alpha and radium MCLs[2]	0.78 cases total (0.52 fatal)	$3.1 million ($0.8 - $6.0 million)	$82.5 million
Compliance with new uranium MCL options			
Establish uranium MCL at 20 pCi/L (20 μg/L)	0.15 cases total (0.10 fatal)	$0.6 million ($0.2 - $1.2 million)	$31.6 million
Establish uranium MCL at 40 pCi/L (40 μg/L)	0.04 cases total (0.02 fatal)	$0.1 million ($<0.1 - $0.2 million)	$6.7 million
Establish uranium MCL at 80 pCi/L (80 μg/L)	0.01 cases total (<0.01 fatal)	$<0.1 million	$5.0 million

Notes:
See text for discussion of non-quantified impacts and limitations in the analysis.
Gross alpha and combined radium risk estimates include risk reductions due to incidental treatment; e.g., the removal of gross alpha by treatments installed to address combined radium and vice-versa.
1. Compared to full compliance baseline (i.e., occurrence data are adjusted to eliminate illegal noncompliance).
2. Removes double-counting of systems affected by both options.
3. Compared to revised baseline (i.e., occurrence data are adjusted to eliminate legal noncompliance).

Exhibit ES-3
SUMMARY OF QUANTIFIED ANNUAL COSTS AND BENEFITS: LOGNORMAL DISTRIBUTION APPROACH
(community water systems)

	Total Cancer Cases Avoided (fatal cases)	**Value of Avoided Cases (range)**	**Total Change in Compliance Costs**
Compliance with existing MCLs after closing monitoring loopholes (combined radium = 5 pCi/L, gross alpha = 15 pCi/L)[1]			
Eliminate gross alpha monitoring loophole only	0.35 cases total (0.22 fatal)	$1.3 million ($0.3 - $2.6 million)	$34.5 million
Eliminate combined radium monitoring loophole only	0.54 cases total (0.37 fatal)	$2.2 million ($0.6 - $4.3 million)	$38.8 million
Eliminate both loopholes[2]	0.86 cases total (0.57 fatal)	$3.4 million ($0.9 - $6.6 million)	$71.9 million
Compliance with revised MCL options[3]			
Revise gross alpha MCL to 10 pCi/L net of radium-226 only	0.70 cases total (0.45 fatal)	$2.7 million ($0.7 - $5.2 million)	$71.6 million
Limit radium-228 at 3 pCi/L within combined radium MCL of 5 pCi/L only	0.63 cases total (0.43 fatal)	$2.6 million ($0.7 - $5.0 million)	$37.9 million
Revise both gross alpha and radium MCLs[2]	1.08 cases total (0.72 fatal)	$4.3 million ($1.1 - $8.3 million)	$83.7 million
Compliance with new uranium MCL options			
Establish uranium MCL at 20 pCi/L (20 μg/L)	2.12 cases total (1.37 fatal)	$8.2 million ($2.1-$15.8 million)	$157.0 million
Establish uranium MCL at 40 pCi/L (40 μg/L)	1.54 cases total (1.00fatal)	$6.0 million ($1.5 - $11.6 million)	$68.0 million
Establish uranium MCL at 80 pCi/L (80 μg/L)	1.03 cases total (0.67 fatal)	$4.0 million ($1.0 - $7.7 million)	$29.9 million

Notes:
See text for discussion of non-quantified impacts and limitations in the analysis.
Gross alpha and combined radium risk estimates include risk reductions due to incidental treatment; e.g., the removal of gross alpha by treatments installed to address combined radium and vice-versa.
1. Compared to full compliance baseline (i.e., occurrence data are adjusted to eliminate illegal noncompliance).
2. Removes double-counting of systems affected by both options.
3. Compared to revised baseline (i.e., occurrence data are adjusted to eliminate legal noncompliance).

As indicated by the exhibits, most of the regulatory options would change the statistical risks of incurring fatal or nonfatal cancers by less than two cases per year; many options lead to reductions of less than one case. In general, fatal cases are roughly two-thirds of the total cases avoided. The best estimate of the value of these risk reductions ranges from less than $0.1 million to slightly over $8.0 million annually, depending on the regulatory option considered and the approach used to estimate occurrence. Compliance costs range from $2.5 million to over $150 million annually. The options with the lowest and highest costs vary depending on the approach used for estimating occurrence. While in most cases the lognormal approach leads to higher costs and larger risk reductions, in a few cases the lognormal estimates are lower because of the distribution of the underlying data.

Although these results are preliminary and subject to uncertainty, they suggest that the regulatory options under consideration may have costs in excess of benefits in all cases, if only quantified costs and benefits are considered. However, when all of the sources of uncertainty are taken into account, EPA believes that costs may exceed benefits by a much smaller amount than indicated by the above exhibits, and for some options costs and benefits may be relatively equal. EPA plans to conduct more research as well as develop a probabilistic model to reduce, and better quantify, the effects of these uncertainties.

The cost estimates assume that systems will often install treatment to comply with the MCLs, while recent research suggests that in reality they generally select less costly options such as blending water from contaminated and uncontaminated sources. Selection of such options may reduce compliance costs significantly. The benefits associated with risk reductions may be understated because the analysis does not consider the effects of treatment on other contaminants present nor does it include the effects of uranium on the kidneys. (There are also substantial uncertainties in the risk models used to estimate the coefficients used in this analysis.) In addition, the benefits analysis does not consider other impacts such as improvements in the aesthetic qualities of the water (taste, odor, color) or reduced material damages associated with the treatment or other actions undertaken to comply with the new requirements.

The analysis also does not quantify other impacts that will have more uncertain effects on the relationship between costs and benefits. For example, it does not quantify the impacts of the regulatory options on systems serving populations more than one million (information collected to-date suggests that few, if any of these systems may be affected by the regulations). It also does not include cost or risk reduction estimates for non-transient non-community systems, which EPA plans to address in more detail in an Addendum to this report.

EPA also plans to conduct more research on other topics not addressed in detail in this report. For example, the preliminary analysis also does not consider the impact of the regulations on other programs, such as the use of MCLs in site clean-up decisions. In addition, it does not quantify the impacts of the regulatory options on certain groups of concern, such as health risks posed to children, members of low income or minority groups, or sensitive sub-populations. It also does not address unfunded mandates or options for minimizing costs for small systems. All of these factors are of interest to decision-makers and will be taken into account in the final selection of the regulatory options to be implemented.

INTRODUCTION AND REGULATORY FRAMEWORK CHAPTER ONE

The U.S. Environmental Protection Agency (EPA) is considering changes to the regulations governing the allowable levels of radionuclides in drinking water. The Notice of Proposed Rulemaking for these revisions was published in 1991. Since that time, additional information on the impacts of changes to these standards has become available. EPA has chosen to publicize this information through a Notice of Data Availability, which summarizes the risks and costs potentially associated with revisions to the standards. This report provides more detailed information on these impacts.

This introductory chapter provides background information on the current and proposed radionuclides regulations. It then discusses federal requirements for the economic analysis of new or revised drinking water standards, and presents an overview of the preliminary analysis contained in this report. The subsequent chapters and appendices discuss the analytic approach and results in more detail.

REGULATORY OPTIONS

EPA first promulgated standards regulating the concentrations of radionuclides in drinking water in 1976 as National Interim Drinking Water Regulations (see 40 CFR 141). In 1986, EPA published an Advance Notice of Proposed Rulemaking, which discussed additional information on the occurrence of radionuclides in drinking water, as well as the associated risks. The Notice of Proposed Rulemaking (NPRM) for revisions to the radionuclide standards was published in 1991. The Notice of Data Availability (NODA) that this report supports provides additional information on the topics addressed by that NPRM.

The current regulations establish Maximum Contaminant Levels (MCLs) of 5 pCi/L for radium-226 and radium-228 combined, and of 15 pCi/L for gross alpha (net of uranium and radon).[1]

[1] The NODA also addresses changes to the MCL for beta and photon emitters. This preliminary analysis does not consider the effects of these changes because EPA expects that the national impacts will be relatively small.

In the 1991 NPRM, EPA proposed to revise the combined radium and gross alpha standards and to create an MCL for uranium. Separate, higher standards were proposed for radium-226 and radium-228, while the standard for gross alpha would remain the same but be redefined to exclude radium-226.

As discussed in the NODA, EPA believes that the proposed changes to the gross alpha and combined radium MCLs are no longer appropriate. Hence those changes are not assessed in this report. Instead, EPA is interested in providing information on the costs and risk reductions associated with limiting the contribution of radium-228 to the current combined radium MCL, and with lowering the gross alpha MCL but excluding radium-226 from its definition. In both the 1991 proposal and the NODA, EPA also considers whether it is appropriate to establish an MCL for uranium, and this report provides updated information on the potential impacts of alternative uranium MCLs. The MCL options addressed by each of these efforts are summarized in Exhibit 1-1.

Exhibit 1-1

ALTERNATIVE REGULATORY LEVELS

Radionuclide	**Current MCL**	**1991 Proposed MCLs**	**MCL Options Assessed in this Report**
Combined radium-226 and radium-228	5 pCi/L	20 pCi/L for radium-226; 20 pCi/L for radium-228	5 pCi/L, limiting the contribution of radium-228 to 3 pCi/L
Gross alpha	15 pCi/L, net of uranium and radon	15 pCi/L, net of radium-226, uranium, and radon	10 pCi/L, net of radium-226, uranium, and radon
Uranium	None	20 μg/L (20 pCi/L)	20 μg/L (20 pCi/L); 40 μg/L (40 pCi/L); 80 μg/L (40 pCi/L)

Note:
These analyses assume a one-to-one mass-to-activity level ratio for the uranium options. The NODA provides information on alternative ratios, which are also discussed in Chapter 2 of this report.
Sources:
<u>Current MCLs</u>: U.S. Environmental Protection Agency, "National Primary Drinking Water Regulations," 40 CFR 141.15.
<u>1991 Proposed MCLs</u>: U.S. Environmental Protection Agency, "National Primary Drinking Water Regulations, Radionuclides, Notice of Proposed Rulemaking," 36 FR 33050, July 18, 1991.
<u>MCL Options</u>: U.S. Environmental Protection Agency, "National Primary Drinking Water Regulations, Radionuclides, Notice of Data Availability," forthcoming.

In addition to revising the MCLs, EPA is considering whether to alter the requirements for monitoring and analysis. The existing regulations include inadvertent loopholes that allow systems to "legally" exceed the current MCLs. These loopholes are as follows:

- Under 40 CFR 141.26(a)(1)(i), systems may avoid analyzing their water for compliance with the combined radium standard if the measured gross alpha activity level is reliably below 5 pCi/L.[2]

- Under 40 CFR 141.26(a)(1)(ii), systems may avoid measuring radium-228 in cases where radium-226 does not exceed 3 pCi/L.

- Under 40 CFR 141.26, systems may hold their gross alpha samples long enough to allow radium-224 to decay below detection limits.

Under the first two loopholes, some systems may legally exceed the MCL of 5 pCi/L for combined radium because the regulations allow them to avoid measuring activity levels for radium-228.[3] Under the third loophole, systems with elevated levels of radium-224 may legally exceed the MCL of 15 pCi/L for gross alpha because of the length of the allowable holding time for the samples. EPA is considering various options for closing these loopholes to ensure that all systems achieve radionuclide levels at or below the existing MCLs.

In addition to changing the MCLs and the monitoring requirements, EPA is considering whether to extend these requirements to non-transient non-community water systems. The current regulations apply only to community water systems. The regulations (at 40 CFR 141.2) define a community water system as "a public water system which serves at least 15 service connections used by year-round residents or regularly serves at least 25 year round residents." A non-transient, non-community water system is defined as "a public water system that is not a community water system and that regularly serves at least 25 of the same persons over 6 months per year." These systems often serve locations such as schools or office buildings.

REQUIREMENTS FOR ECONOMIC ANALYSIS

EPA is required to assess the costs, benefits, and other impacts of major regulations by a number of statutes and administrative orders. These requirements have changed significantly since EPA published the 1991 proposal for revisions to the radionuclides regulations. General guidance for economic analysis was developed by the Office of Management and Budget (OMB) in 1996 for

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[2] Under certain conditions, states may lower this cut-off to 2 pCi/L.

[3] Radium-228 is a beta emitter, whereas radium-226 is an alpha emitter and included in the measurement of compliance with both the gross alpha and combined radium MCLs.

all Federal agencies, and EPA is now finalizing its own more detailed guidance on these issues. In addition, there are several new statutory and administrative requirements for assessing the distribution of costs and benefits and equity concerns, focusing on groups such as small businesses and children. The Safe Drinking Water Act (SDWA) Amendments of 1996 also include new requirements for the analysis of regulations establishing MCLs.

The preliminary analysis documented in this report is consistent with the general requirements for economic analysis, and will be supplemented as needed by additional analyses to support the final rulemaking. Proposed and final regulations promulgated under SDWA are subject to three sets of general requirements for economic analysis.

The 1996 SDWA Amendments impose significant new requirements for assessing the benefits and costs of drinking water standards. Specifically, when proposing an MCL, EPA must publish an analysis of the benefits and costs of compliance with the MCL, including discussion of issues such as: (1) the quantifiable and non-quantifiable health risk reductions of controlling the regulated contaminants as well as co-occurring contaminants; (2) the quantifiable and non-quantifiable costs of compliance with the proposed MCL; (3) the incremental costs and benefits associated with each alternative MCL under consideration; and, (4) the effects of the contaminant on the general population and on groups that are likely to be at greater risk of adverse health effects (i.e., sensitive sub-populations). The analysis must also consider other factors such as the quality of the available information and uncertainties in the analysis, and the degree and nature of the identified risks [SDWA, Section 1412(b)(3)(C)(i)]. SDWA also requires the Agency to consider the impacts of the regulations on small water systems, and includes provisions addressing affordability and criteria for variances or exemptions [SDWA Sections 1412(b), 1415(e), 1416].

OMB's 1996 Guidance for implementing Executive Order 12866 (on "Regulatory Planning and Review") requires Federal agencies to conduct economic analyses of significant regulatory actions as a means to improve regulatory decision-making. Significant regulatory actions include those that may "(1) [h]ave an annual effect on the economy of $100 million or more or adversely affect in a material way the economy, a sector of the economy, productivity, competition, jobs, the environment, public health or safety, or State, local, or tribal governments or communities; (2) [c]reate a serious inconsistency or otherwise interfere with an action taken or planned by another agency; (3) [m]aterially alter the budgetary impact of entitlements, grants, user fees, or loan programs or the rights and obligations of recipients thereof; or (4) [r]aise novel legal or policy issues arising out of legal mandates, the President's priorities, or the principles set forth in this Executive Order."[4]

[4] Executive Order 12866, "Regulatory Planning and Review," September 30, 1993; U.S. Office of Management and Budget, *Economic Analysis of Federal Regulations Under Executive Order 12866*, January 11, 1996.

As outlined in the OMB guidance, analyses of these actions should be designed to provide information for decision-makers on the potential benefits to society of alternative regulatory and non-regulatory approaches to risk management in comparison to potential costs, recognizing that not all benefits and costs can be described in monetary or even in quantitative terms. The guidance also focuses on ensuring that decisions are based on the best available scientific, technical, and economic information. The specific topics addressed include determining whether federal regulation is warranted, examining alternative regulatory and non-regulatory approaches, and assessing the benefits, costs, and other impacts of the alternatives.

EPA's *Guidelines for Preparing Economic Analyses*, which provide substantially more detailed information on the topics introduced in OMB's guidance, are now being updated and finalized.[5] The draft EPA guidelines discuss the statutory and executive order requirements for conducting economic analyses; the procedures and analyses used to identify the environmental problem to be addressed and justify federal intervention; the regulatory and non-regulatory approaches to consider; and the theoretical foundation for environmental economic analyses. The EPA guidelines also provide detailed information and guidance on baseline specification, social discounting, and treatment of uncertainty; on assessment of benefits, social costs, economic impacts and equity effects; and on the use of economic analyses in decision-making.

The three sets of requirements noted above each discuss the need for analysis of distributional impacts and equity concerns. In addition, consideration of these types of concerns is required by the following statutes and executive orders.[6]

- **The Unfunded Mandates Reform Act of 1995** (UMRA) requires that the government consider the costs and benefits of any proposed or final rule that includes a Federal mandate resulting in the "expenditure by State, local and tribal governments, in the aggregate, or by the private sector, of $100,000,000 in any 1 year" [UMRA Section 202(a)]. Title II of UMRA directs agencies to prepare an economic analysis that assesses: the anticipated benefits and costs of the mandate; the extent to which federal resources and financial assistance are available to offset the costs imposed; any disproportionate budgetary effects on any particular geographic area or sector; and any effects on the national economy.

[5] U.S. Environmental Protection Agency, *Guidelines for Preparing Economic Analyses: Review Draft*, June 1999.

[6] These and other statutes and executive orders also include requirements that apply to the regulatory development process (e.g., for consultation with representatives of the groups of concern). The discussion in this section focuses solely on the requirements for economic analysis.

- **The Regulatory Flexibility Act of 1980, as amended by the Small Business Regulatory Enforcement Fairness Act of 1996** (SBREFA/RFA) requires agencies to evaluate the impacts of the reporting, record-keeping, and other compliance requirements imposed on small entities, and to consider regulatory alternatives and other measures that can minimize these impacts while accomplishing the stated objectives of the applicable statutes. Analysts may first conduct a screening analysis to determine if effects on small entities are significant. A detailed analysis is not required if the agency can certify that the rule "will not, if promulgated, have a significant economic impact on a substantial number of small entities."

- **Federal Actions to Address Environmental Justice in Minority Populations and Low Income Populations** (Executive Order 12898; 1994) refers to the desire to avoid disproportional adverse effects on minority and low income groups. While the Executive Order and associated guidance do not outline specific requirements for economic analyses, they discuss the need to consider whether such effects may be significant.

- **Protection of Children from Environmental Health Risks and Safety Risks** (Executive Order 13045; 1997) requires agencies to provide "...(a) an evaluation of the environmental health or safety effects of the planned regulations on children; and (b) an explanation of why the planned regulation is preferable to other potentially effective and reasonably feasible alternatives considered by the agency."

In addition to these requirements for analyses of effects on certain groups of concern, the Paperwork Reduction Act requires that EPA submit an Information Collection Request to OMB for approval prior to promulgating regulations containing information collection requirements. This request must describe and justify the requirements and discuss the use of the resulting data. The request must include estimates of the burden (i.e., labor hours) and dollar costs associated with the information collection requirements.

This preliminary analysis focuses on the national impacts of the regulations and is consistent with the above guidance applicable to this type of assessment. It does not assess distributional impacts or equity concerns in detail, although relevant information is provided both in this report and in the other documents referenced in the NODA. EPA plans to address these concerns in more detail prior to development of the final rule.

COMPARISON TO 1991 ANALYSIS

The analysis reported in this document differs from the analysis conducted in 1991 in many ways.[7] As noted earlier, the 1991 analysis considers different regulatory options and was written prior to implementation of several new requirements for regulatory impact analysis. In addition, the 1991 report does not separate the effects of non-compliance with the existing regulations from the effects of changes to these regulations. The Agency also has refined the approach for assessing the occurrence of radionuclides, developed better estimates of compliance costs, created a new cost model, and altered its estimates of the risks associated with ingestion of individual radionuclides.

Because the 1991 analysis considers different regulatory options and does not separately assess the impacts of non-compliance with the current regulations, it is difficult to compare the two analyses and to come to any general conclusions about the effects of the changes in analytic approach. However, EPA believes that the analysis reported in this document provides a more realistic picture of the costs and benefits of the options. It reflects several years of research on related issues and implements many enhancements to the data and analytic approach used in each part of the analysis. The following sections provide an overview of this approach, which is described in more detail in the following chapters.

GENERAL APPROACH

The analysis in this report represents the work completed to date in the development of a comprehensive economic analysis for the radionuclides rule, as required under the statutes, executive orders, and EPA guidance discussed above. It provides preliminary estimates of national costs and benefits, and presents information on the data sources and analytic approach used for review by interested stakeholders. This analysis subsequently will be refined as needed to respond to comments, incorporate new data, and provide additional assessments of uncertainty in the estimates. In addition, it will be expanded to include analysis of distributional effects (e.g., on small systems and children) as required by various statutes and administrative orders.

The basic steps in a comprehensive economic analysis are illustrated in Exhibit 1-2 and include the following:

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[7] Wade Miller Associates, Incorporated, *Regulatory Impact Analysis of Proposed National Primary Drinking Water Regulations for Radionuclides*, prepared for the U.S. Environmental Protection Agency, July 17, 1991.

1. Estimate baseline conditions: This step involves estimating current and future conditions in the absence of the revised rule. It includes identifying and characterizing the potentially affected universe (e.g., those community and non-community water systems required to comply with the rule) and determining the contaminant levels likely if no new regulations are promulgated.

2. Predict responses to the new regulations: The second step in the analysis involves predicting the responses of the regulated community to the new regulations. Typically, analysts assume that water systems will select the least cost compliance option. In the case of the radionuclides rule, these options may include installing various treatment technologies (such as water softening), installing point-of-use devices (i.e., home water treatment devices), or switching water sources (e.g., drilling new wells in uncontaminated areas or purchasing water from another system).

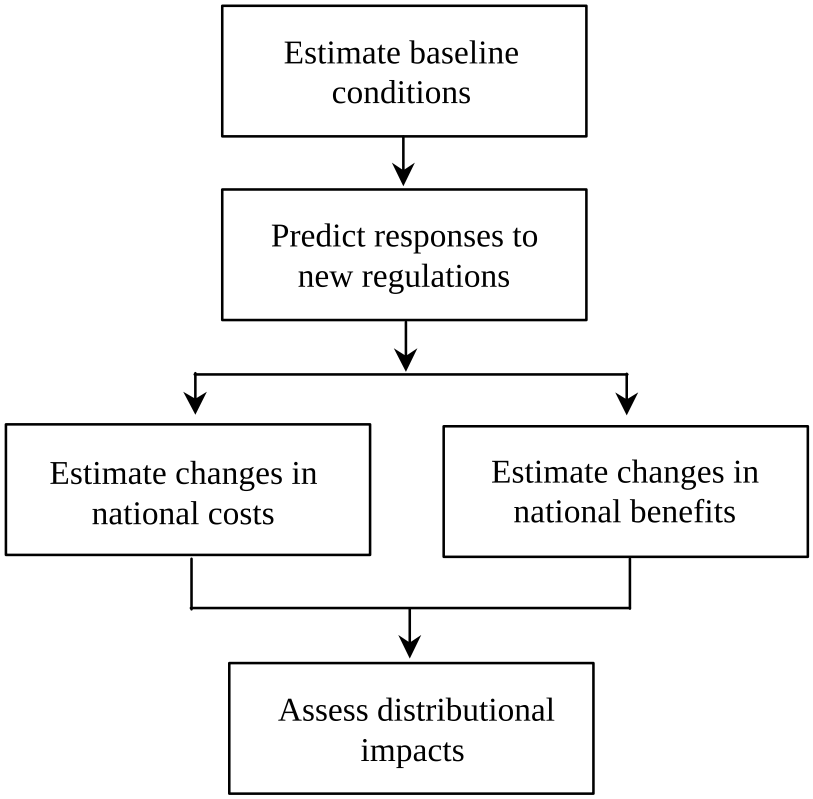
3. Estimate changes in national costs: The third step is to determine the total national costs attributable to the new regulations. The conceptually correct approach to estimating these costs includes consideration of market impacts (e.g., decreases in water consumption due to price increases). However, in cases where market effects are likely to be small, analysts often simply sum compliance costs nationally.

4. Estimate changes in national benefits: The fourth step in the analysis involves estimating the national benefits of the new regulations. For drinking water regulations, these benefits primarily include reduced risks to human health, but may also include reduced damages to materials (e.g., pipe corrosion), improved aesthetics (taste, odor, color), or reduced ecological risks. For radionuclides, the primary benefits are reductions in cancer risks; other beneficial health effects (particularly reductions in kidney damage from exposure to uranium) are also possible.

5. Assess distributional impacts: While Steps 3 and 4 focus on the national effects of the regulations, decision-makers and stakeholders are also interested in the effects of the regulations on specific groups, such as small water systems or sensitive sub-populations (e.g., children). As discussed earlier, analyses of these concerns are required by statute and administrative order. These distributional analyses may consider the costs and/or the benefits of the regulations for the groups of concern.

Exhibit 1-2

MAJOR COMPONENTS OF A COMPREHENSIVE ECONOMIC ANALYSIS



In this report, we develop preliminary estimates of national costs and benefits, focusing on monitoring and compliance costs and reductions in cancer risks. Other national costs and benefits (e.g., state administrative costs and risk reductions from treatment of co-occurring contaminants) and potential distributional impacts are described qualitatively in this report as well as in other documents supporting the NODA. As noted earlier, EPA plans to conduct further analysis of these issues prior to finalizing the revised radionuclides regulations.

BASELINE DEFINITION

The first step in the economic analysis, defining the baseline, provides unusual challenges in the case of the radionuclides regulations. Several community water systems are not complying with the existing regulations for gross alpha and combined radium, in part because they are anticipating the proposed changes in these requirements and hope to avoid unnecessary costs. Also, as discussed earlier, there are loopholes in the current monitoring requirements that allow some systems to legally avoid compliance with the current MCLs. To address these issues, this preliminary analysis sequentially considers two baselines.

- **Initial baseline**: Under this scenario, we assume that all systems will ultimately comply with the existing regulations as currently written. Community water systems would be required to achieve the current MCLs except in cases where they can legally avoid compliance due to the loopholes in the monitoring requirements.

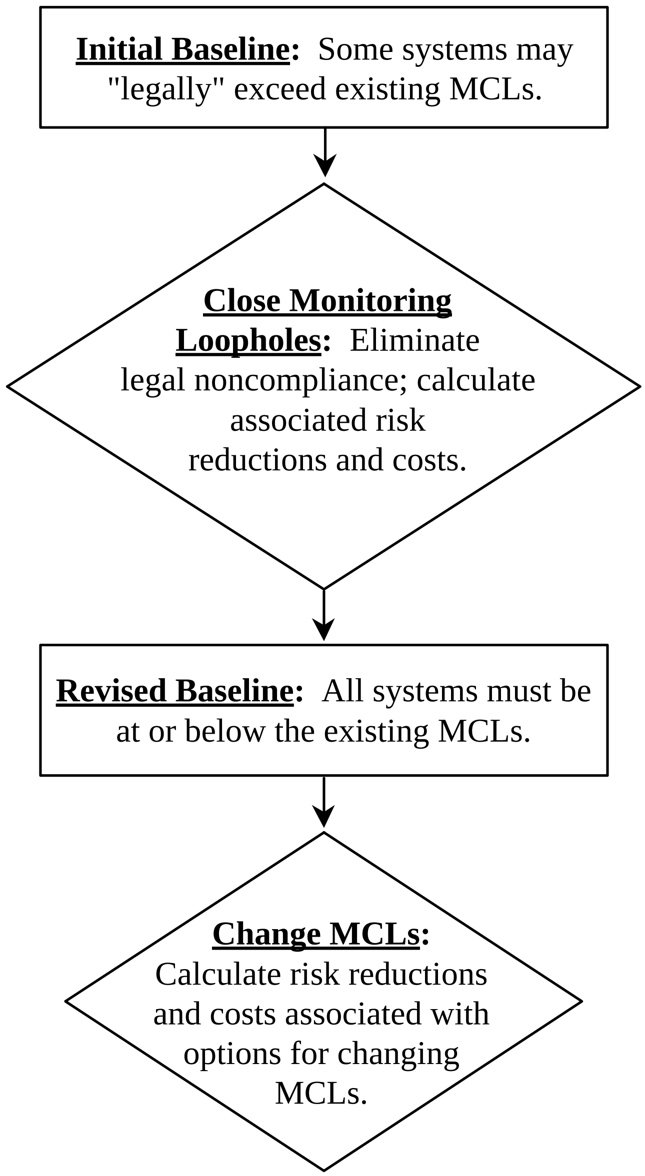
- **Revised baseline**: Under this scenario, we assume that EPA would alter the current regulations to eliminate the monitoring loopholes, so that all community water systems would be required to achieve the existing MCLs.

This dual baseline approach allows us to separate the costs and benefits of changes in the monitoring requirements from the costs and benefits of changes in the MCLs. It also avoids attributing costs to the new regulations that are in fact attributable to achieving compliance with the regulations now in force.

The steps in the preliminary national benefit-cost analysis are illustrated in more detail in Exhibit 1-3. First, we develop the initial baseline, under which some systems may be legally out of compliance with the existing MCLs. We use this baseline to assess the risk reductions and costs associated with closing the monitoring loopholes. This step leads directly to the revised baseline, under which all systems must be at or below the existing MCLs. We use this revised baseline to estimate the incremental risk reductions and costs associated with changes to the MCLs. The analysis is conducted sequentially so that the costs and benefits of changing the MCLs can be added to the costs and benefits of closing the monitoring loopholes to assess the total impact of potential changes to the regulations.

Exhibit 1-3

INITIAL AND REVISED BASELINES



The analysis of the risk reductions and costs associated with changes to the standards for radionuclides in drinking water consists of three inter-related components. The first involves estimating the occurrence of radionuclides under the baseline scenarios, including the frequency with which radionuclide concentrations are likely to exceed levels of concern. The second component involves determining the potential changes in risks associated with the regulatory options, focusing on the risks of incurring fatal and nonfatal cancers. The third component consists of estimating the costs associated with changes to the regulatory requirements, including the costs associated with monitoring and analysis as well as treatment or other options for complying with the MCLs. The following chapters discuss each of these topics for community water systems, describing our analytic approach, the results of the analysis, and its limitations and implications. These chapters are followed by a discussion of the impacts on non-transient non-community water systems.

BASELINE OCCURRENCE CHAPTER TWO

In this chapter, we discuss the prevalence and concentrations of radionuclides in water provided by community systems in the absence of changes to the existing regulations.[1] The analysis involves estimating radionuclide concentrations under the initial baseline (assuming full compliance with the regulations as currently written) and then under the revised baseline (assuming the regulations are altered to close existing monitoring loopholes and eliminate legal exceedences of the current MCLs). Below, we first discuss our approach to the analysis; we then present our findings and their limitations.

ANALYTIC APPROACH

The approach for the occurrence analysis includes three separate components. First, we begin by extrapolating from data obtained through EPA's National Inorganics and Radionuclides Survey (NIRS).[2] We use two different extrapolation methods, one based directly on the NIRS proportions and a second that fits a lognormal probability distribution to the NIRS data. Second, we adjust the data to address compliance issues and develop initial and revised baselines for the analysis. Because NIRS does not include very large systems (those serving one million or more people), the third component of the analysis entails using other data sources to provide information on baseline occurrence levels for these systems.

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[1] See Chapter 5 for a discussion of non-transient non-community water systems.

[2] Beginning in late 1999, water systems were required to develop Consumer Confidence Reports that provide data on water quality. Over the next several months, we plan to review a sample of these documents to determine whether reported occurrence levels differ significantly from the data and assumptions used in this preliminary analysis.

NIRS Data

The most comprehensive source of nationwide estimates of radionuclide concentrations in drinking water is the National Inorganics and Radionuclides Survey (NIRS).[3] NIRS is a national survey designed to estimate the occurrence of various contaminants in finished drinking water from community ground water systems in the United States. To conduct the survey, EPA selected a random sample of 1,000 community ground water systems, stratified into four population size classes, from the inventory of 47,700 public water systems reported in the Federal Reporting Data System in 1983. The researchers collected water samples from 990 of these systems from 1984 to 1986, and tested them for occurrence of radium-226, radium-228, uranium, and gross alpha as well as other contaminants.

As indicated in Exhibit 2-1 below, most of the NIRS systems sampled served relatively small populations (less than 3,300 persons).[4] For comparison, the exhibit also reports the number of ground water systems now operating in each of the size classes, based on validated December 1997 data from EPA's Safe Drinking Water Information System (SDWIS).[5] Appendix A provides more detailed information from SDWIS on the number of systems and populations served by size class, ownership and water source.

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[3] Jon P. Longtin, "Occurrence of Radon, Radium, and Uranium in Groundwater," *Journal of the American Water Works Association*, July 1988; Jon P. Longtin, "Occurrence of Radionuclides in Drinking Water, A National Study," *Radon, Radium and Uranium in Drinking Water*, (C. Richard Cothern and Paul A. Rebers, eds.), Chelsea, Michigan: Lewis Publishers, 1990.

[4] The data reported in Exhibit 2-1 reflect the final NIRS database used in this analysis. The number of systems in each size strata in the original sample are reported in the Longtin articles cited above.

[5] We exclude systems classified as "other" ownership from this exhibit because the 1997 SDWIS validation effort indicates that these systems are probably inactive. We also exclude systems serving fewer than 25 people because they do not meet the definition of public water systems subject to the regulations. Of the 42,781 systems included in the exhibit, 1,918 rely on purchased water. These systems are included to ensure that the populations they serve are addressed in the analysis (available data on populations served includes retail populations only). Ground water systems reported as under the influence of surface water (327 systems nationally) are included in the surface water system data because they tend to have similar contamination problems. Systems serving more than one million persons are assessed separately.

Exhibit 2-1

RELATIONSHIP BETWEEN EPA AND NIRS SIZE CATEGORIES

EPA System Size Classes		**NIRS Stratification**	
Population Served	**Number of Community Ground Water Systems Operating (SDWIS, 1997)**	**Population Served**	**Number of Community Ground Water Systems Sampled (NIRS, 1984 - 1986)**
25 - 100	28,502	≤ 500	675
101 - 500			
501 - 1,000	10,319	501 - 3,300	233
1,001 - 3,300			
3,301 - 10,000	2,472	3,301 - 10,000	54
10,001 - 50,000	1,488	> 10,000	28
50,001 - 100,000			
100,001 - 1,000,000			
Total	42,781	**Total**	990

Sources:
1997 SDWIS data: International Consultants, Incorporated, *Drinking Water Baseline Handbook: First Edition (draft),* prepared for the U.S. Environmental Protection Agency, March 2, 1999, Table B4.1.1(a).
1984 - 1986 NIRS data: IEc analysis of final NIRS database provided by David Huber, EPA/OGWDW, January 8, 1999.

For this analysis, we adjust the NIRS data to address certain of its limitations. These limitations include: (1) the small size of the sample for systems serving populations greater than 3,300 persons; (2) the decay of radium-224 prior to analysis of the NIRS water samples; (3) the need to convert mass measurements of uranium to activity levels; (4) the lack of information on surface water systems; and, (5) the relationship between the NIRS data and the actual national distribution of occurrence levels. Our approach for addressing each of these issues in the preliminary analysis is discussed below. The implications of uncertainties associated with our analytic approach are discussed at the end of this chapter.

Systems Serving Populations of 3,300 to 1,000,000: Due to time and funding constraints, the NIRS researchers could sample only a limited number of systems. They chose to stratify their sample so that it was proportional to the actual number of community ground water systems operating in each size class. For example, about 71 percent of the systems operating in 1985 served

25 to 500 people, and about 71 percent of the sites in the original NIRS sample served populations in this size category. As a result of this stratification, very few systems (82 total) serving populations greater than 3,300 were included in the final sample.

This small sample size may mean that the systems included in NIRS are not representative of the systems operating nationally in these size classes. Statistical theory suggests that a sample of 200 systems or more would be needed to provide reasonably accurate and reliable estimates for systems in each of the two larger size classes, whereas the sample sizes for the smaller size classes may be adequate.

Data collected by EPA suggest that larger systems tend to have better water quality than smaller systems. For example, SDWIS data suggest that systems serving small populations more frequently exceed the existing radionuclides MCLs than do systems serving larger populations.[6] If we divide the number of 1997 gross alpha violations in SDWIS by the estimated number of sites (e.g., individual wells) operated by systems relying on ground water, we find that 0.13 to 0.14 percent of the sites may be in violation for systems serving populations of 3,300 or less. This figure drops to 0.08 to 0.09 percent for systems serving between 3,301 and 100,000 persons, and to 0.03 percent for systems serving more that 100,000 persons. The frequency of combined radium violations show a similar pattern: 0.20 to 0.26 percent of the sites may be in violation for systems serving populations of 3,300 or less; 0.17 to 0.11 percent may be in violation for systems serving between 3,301 and 100,000 persons; and less than 0.01 percent may be in violation for systems serving more that 100,000 persons. Investigation of SDWIS data for other years shows similar relationships between system size and violation rates.[7]

This relationship between system size and water quality is also suggested by data on other contaminants. For example, EPA's 1989 analysis of alternative MCLs for inorganic chemicals

[6] Analysis of SDWIS data conducted by William Labiosa of EPA/OGWDW (September 9, 1999). This comparison is provided for illustrative purposes only. Information reported to SDWIS may be inconsistent and incomplete; some violations may be reported multiple times while others may not be reported at all. In addition, the methods used to estimate the number of sites used by ground water systems may be inconsistent with the definition of compliance points used in SDWIS reporting.

[7] The reporting of fewer violations by large systems may be due in part to their ability to react immediately to potential water quality problems (for example by blending water from different sources, changing the operation of their treatment plant, or closing affected wells) without having to report a violation or purchase capital equipment.

indicates that occurrence of inorganic chemicals is negligible in the larger system size categories.[8] Systems serving over 50,000 persons generally implement more sophisticated and extensive treatment processes, conduct more comprehensive monitoring, have more options for immediately addressing water quality problems, and use operators with higher levels of expertise than smaller systems. As a result, inorganic chemicals tend to occur at lower levels in larger systems.

Due to the concerns about the small number of systems sampled for the larger size classes in NIRS, this preliminary analysis uses data on systems in the smaller size classes to estimate occurrence levels for larger systems. Specifically, we assume that the frequency of non-compliance will be the same in systems serving 3,301 to one million persons as in systems serving 501 to 3,300 persons. For example, if one percent of the systems in the 501 - 3,300 size class would be out of compliance with a particular regulatory level, we assume that one percent of the systems serving 3,301 - one million persons also would be out of compliance. This approach may overstate the extent to which concentrations exceed levels of concern in the larger systems, given the likelihood that water quality improves as system size increases.

Decay of Radium-224: Radium-224 is an alpha emitter with a 3.66 day half-life. If a water system does not analyze its samples quickly (i.e., within three days), it will not detect concentrations of radium-224 that may be present in drinking water at the point of use. Because the existing regulations allow water systems to hold their samples for long time periods, radium-224 is not likely to be detected.[9] Depending on whether a composite sample is prepared, the holding time under the existing regulations can range from six to 12 months. Systems with significant radium-224 levels therefore may be in "legal noncompliance" status, since the existing regulations allow them to hold their samples until radium-224 decays below detection limits.

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[8] Wade Miller Associates, Incorporated, *Regulatory Impact Analysis: Benefits and Costs of Proposed National Primary Drinking Water Regulations for Inorganic Chemicals*, prepared for the U.S. Environmental Protection Agency, March 31, 1989. Because many of the treatment technologies used to remove inorganic chemicals from drinking water supplies (e.g., lime softening, ion exchange, reverse osmosis, activated alumina) are the same as those commonly used for radionuclides removal, effective treatment of inorganics may also reduce radionuclide concentrations in finished water.

[9] EPA has recommended that states require more timely analysis of gross alpha samples, but has not promulgated this recommendation as a regulation. We are uncertain about the extent to which this approach it has been implemented by the states. See: Memorandum to Water Management Division Directors, Regions 1-X, from Cynthia C. Dougherty, Director, Office of Ground Water and Drinking Water, "Recommendations Concerning Testing for Gross Alpha Emitters in Drinking Water," January 27, 1999.

It appears that the NIRS samples were held long enough to allow radium-224 to decay below detection limits. Most of the NIRS samples were shipped directly to the Technical Support Division of the Office of Drinking Water in Cincinnati, Ohio, via two-day express service, while the quality assurance samples were shipped via express service to the Eastern Environmental Radiation Facility in Montgomery, Alabama.[10] Upon receipt of the samples, the two facilities logged the sample information into a data management system, ensured that pH levels of the samples were stabilized at less than 2.0, and distributed the samples to the appropriate laboratory for analysis. The NIRS researchers indicate that at least one month elapsed before the samples were analyzed.[11]

To assess the effect of changing the monitoring requirements to mandate more timely analysis, we estimate the levels of radium-224 likely to be detected based on a study that the U.S. Geological Survey (USGS) is currently conducting. This study considers the correlation between the occurrence of radium-224 and radium-228 in samples from approximately 100 ground water systems.[12] The analysis found that there tends to be a one-to-one ratio between occurrence of radium-228 and radium-224. When the daughter products of radium-224 are taken into account, the effect on the level of gross alpha emitters measured is to add three times the radium-228 level. Hence to estimate the effects of capturing radium-224 in the analysis, we add the value of radium-228 multiplied by three to the gross alpha levels reported in NIRS.

For example, if a system reports radium-228 occurrence at 2 pCi/L and gross alpha occurrence at 12 pCi/L, we would add 6 pCi/L (2 pCi/L * 3) to the gross alpha level to reflect the presence of radium-224 and its daughter products, for a total gross alpha level of 18 pCi/L (12 pCi/L + 6 pCi/L). A system with these values technically would be in compliance with the existing gross alpha standard of 15 pCi/L (because 12 pCi/L is less than 15 pCi/L) under the current monitoring requirements. If the requirements were changed to require more timely analysis, such a system would exceed the current MCL (because 18 pCi/L is above 15 pCi/L).

Uranium Mass-to-Activity Ratio: In NIRS, uranium levels were reported in mass units (as μg/L). For the economic analysis, we need to translate these values to measures of radioactivity (pCi/L) for two reasons. First, the uranium MCLs under consideration by EPA would limit both mass and activity levels. Second, the regulatory definition of gross alpha excludes both radon and

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[10] Jon P. Longtin, "Occurrence of Radon, Radium, and Uranium in Groundwater," *Journal of the American Water Works Association*, July 1988.

[11] Personal communication between David Huber, EPA/OGWDW and Richard J. Velton, March 29, 1999.

[12] Personal communication between Michael Focazio, EPA and Zoltan Szabo, USGS, February 18, 1999.

uranium, while the gross alpha values reported in NIRS (in pCi/L) exclude radon but include uranium. Hence, we must subtract the uranium values from the gross alpha values as reported in NIRS to determine whether the system exceeds the regulatory levels for gross alpha.

Analysis conducted by EPA indicates that the mean mass-to-activity ratio is approximately 1.3 pCi per μg across all uranium samples assessed.[13] However, if only samples with uranium activity levels greater than 3.4 pCi/L are considered, the mean ratio drops to 0.9 pCi per μg. Most of the uranium values reported in NIRS would be below this level (i.e., below 3.4 pCi/L) regardless of which mass-to-activity ratio is used; however, we are most concerned with the systems reporting values above the MCLs under consideration. For this preliminary analysis, we apply a mass-to-activity level of 1:1 both in adjusting the reported gross alpha values to exclude uranium and in assessing the uranium MCL options.

Surface Water Systems: The NIRS data do not address radionuclide concentrations in surface water, and other data sources do not provide comprehensive or representative national estimates of radionuclide concentrations in finished water from surface water sources. Hence, for this preliminary analysis, we use information from other studies to determine how to best extrapolate from the NIRS ground water activity levels to surface water levels.

Based on the available literature, we assume that radium-226, radium-228, and gross alpha do not occur above levels of concern in surface water sources.[14] The studies we reviewed indicate that the radium content of surface water is usually very low. Because gross alpha levels are often comprised largely of radium-226, we also assume that occurrence of alpha emitters at levels of concern in surface water is rare. For example, for systems included in the NIRS sample serving 501 - 3,300 persons, radium-226 is on average approximately 39 percent of the gross alpha values. Therefore, the analysis of regulatory options for combined radium and gross alpha considers only systems relying primarily on ground water sources.

Furthermore, we assume that uranium occurrence in surface water is one-third of the level reported in ground water. This ratio results from research conducted by Oak Ridge National

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[13] Memorandum from J. Scott Telofski, National Air and Radiation Environmental Laboratory, to David Huber, EPA/OGWDW, "Maximum Contaminant Level for Uranium in Drinking Water," March 25, 1999.

[14] C. T. Hess, J. Michel, T. R. Horton, H. M. Prichard, and W. A. Coniglio, "The Occurrence of Radioactivity in Public Water Supplies in the United States," *Health Physics*, Vol. 48, No. 5, May 1985, page 553; Jacqueline Michel, "Relationship of Radium and Radon with Geological Formations." Chapter 7 in C. R. Cothern and P. A. Rebers, eds., *Radon, Radium, and Uranium in Drinking Water*, 1990, page 83.

Laboratory (ORNL).[15] In analyses of 55,433 U.S. ground water samples and 34,561 U.S. surface water samples, ORNL found that the average concentration of uranium was 3.18 pCi/L in ground water and 1.06 pCi/L in surface water (these data are for raw water, not finished drinking water supplies). The median concentration ranges from these samples were 0.2 to 0.5 pCi/L for ground water and 0.1 to 0.2 pCi/L for surface water. Based on these ranges, the ratio of ground water occurrence to surface water occurrence varies from 1:1 to 5:1, with an average of 3:1. Using either mean or median results therefore leads to an average ratio of ground water occurrence to surface water occurrence of 3:1.

Extrapolation to National Estimates: In this preliminary analysis, we use two different approaches to estimate national occurrence levels based on the NIRS data. The first approach assumes that radionuclide occurrence nationally is exactly in proportion to the NIRS results. For example, if two percent of the NIRS systems in a particular size class would require a removal rate of between 30 and 50 percent to comply with a specific MCL, we assume that two percent of the systems nationally in that size class would require the same removal rate.

The second approach recognizes that actual occurrence will be spread over a wider range, and that some systems will report values in-between (and above and below) the values reported in NIRS. Inspection of the NIRS data (see Appendix B) suggests that it is distributed in a roughly lognormal pattern, with most systems reporting concentration levels below the MCLs of concern. Several other studies also suggest that the distribution of radionuclide occurrence in drinking water systems is likely to follow a lognormal distribution.[16] Thus, under the second approach, we use a statistical software package (Stata) to estimate a lognormal distribution that best fits the data for systems in each size class. We then use the log means and log standard deviations of the resulting distributions to estimate the number of systems out of compliance with each regulatory option.

The difference between these two approaches is illustrated by the hypothetical example in Exhibit 2-2. The lognormal distribution follows the pattern of the bars (which indicate the

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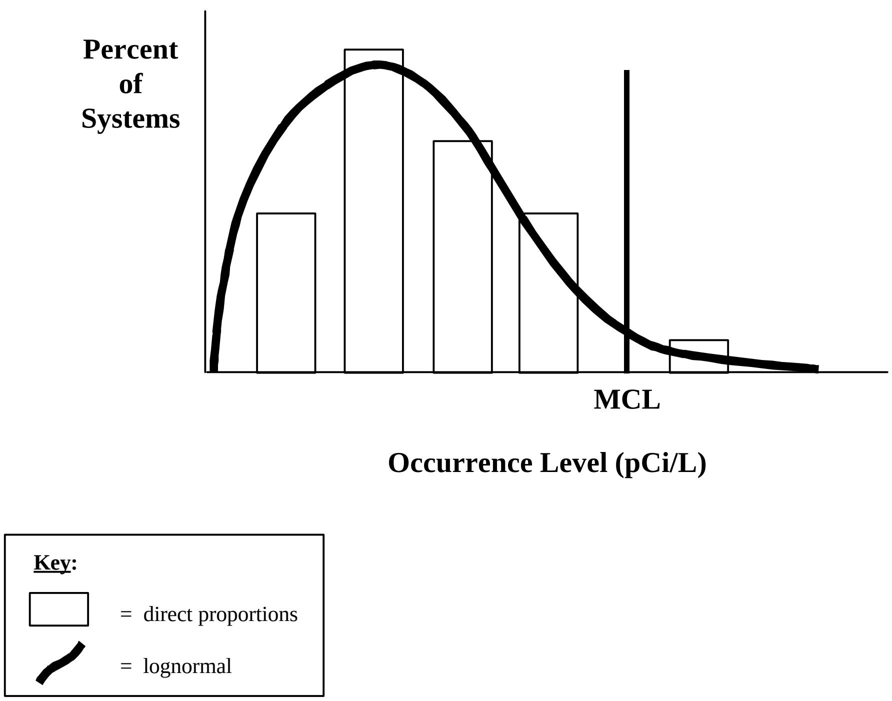
[15] Oak Ridge National Laboratory, *Uranium in U.S. Surface, Ground, and Domestic Waters, Volume 1*, prepared for the U.S. Environmental Protection Agency, April 1981; R. C. Cothern and W. L. Lappenbusch, U.S. Environmental Protection Agency, Office of Drinking Water, "Occurrence of Uranium in Drinking Water in the U.S." *Health Physics*, Vol. 45, No. 1., pp. 89-99, July 1983.

[16] See, for example, Jon P. Longtin, "Occurrence of Radon, Radium, and Uranium in Groundwater," *Journal of the American Water Works Association*, July 1988; and, Wade Miller Associates, Incorporated, *Addendum to the Occurrence and Exposure Assessments for Radon, Radium-226, Radium-228, Uranium and Gross Alpha Particle Activity in Public Drinking Water Supplies* (Draft), prepared for the U.S. Environmental Protection Agency, September 3, 1993, Appendix.

proportions extrapolated directly from NIRS), but spreads systems more evenly over the continuum of possible concentration levels. It also often tends to push systems into the right tail of the distribution (i.e., to lead to higher estimates of occurrence for those systems most out of compliance). However, the exact relationship between the direct proportion and lognormal estimates depends on the underlying NIRS data, and is indicated by the estimates reported in the "Findings" section of this chapter.

Exhibit 2-2

HYPOTHETICAL ILLUSTRATION OF DIRECT PROPORTIONS VS. LOGNORMAL



Initial and Revised Baselines

As discussed in Chapter 1, some community water systems are not complying with the existing MCLs for combined radium and/or gross alpha. This noncompliance may be "illegal" if the system is not following the requirements in the current regulations. Alternatively, it may be "legal" because the existing regulations include some loopholes in the monitoring requirements that allow systems to avoid analyzing for the presence of certain radionuclides.

To address these issues, we first develop an initial baseline for combined radium and gross alpha that reflects full compliance with the existing regulations as written. This approach assumes that, in the absence of changes to the regulations, all systems will eventually fully comply with the existing regulations. This approach allows us to separate out the effects of different types of noncompliance from the effects of changes to the MCLs. Second, we develop a revised baseline that adjusts the data to reflect closure of the monitoring loopholes, and use this baseline to assess the incremental impacts of changing the MCLs.

These baseline adjustments are not applied to uranium, which is not currently regulated. While the treatments installed to eliminate illegal and legal noncompliance with the gross alpha and combined radium MCLs may also affect uranium, we do not quantify these impacts in this preliminary analysis. We make no adjustment for two reasons. First, the NIRS data suggest that systems with elevated levels of gross alpha or combined radium rarely report uranium concentrations above levels of concern.[17] Second, some types of treatment used to remove gross alpha or radium are less effective in removing uranium, and hence will have little impact on occurrence levels.

The adjustments (discussed below) that we make to estimate each baseline are summarized in Exhibit 2-3.

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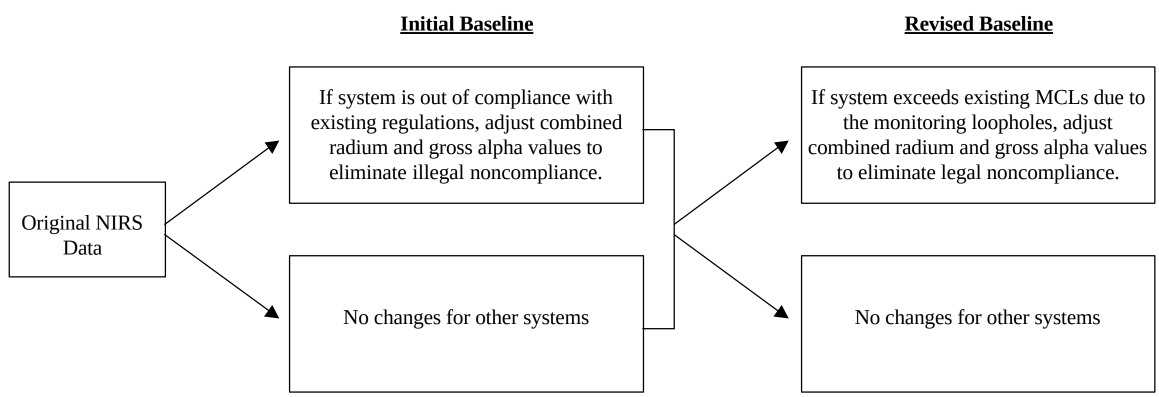
[17]This finding is consistent with information on the conditions under which each radionuclide tends to occur at elevated levels: radium tends to occur at higher levels in areas with low dissolved oxygen and high total dissolved solids, while uranium tend to occurs at higher levels in oxygen-rich waters with low total dissolved solids (Zapecza, O.S. and Z. Szabo, "Natural Radioactivity in Groundwater — A Review," US Geological Survey National Water Summary 1986, *Groundwater Quality: Hydrologic Conditions and Events,* US Geological Survey Water Supply Paper 2325, 1987, pp. 50 - 57). EPA has also studied the co-occurrence of radium-226, uranium-235, and uranium-238; however, the number of samples assessed was too small to be representative of national conditions. (Science Applications International Corporation, *Co-Occurrence of Drinking Water Contaminants: Primary and Secondary Constituents - Draft Report*, prepared for the U.S. Environmental Protection Agency, May 21, 1999.)

Exhibit 2-3

BASELINE ADJUSTMENTS



Initial Baseline -- Compliance under Current Monitoring Requirements

Developing the initial baseline for gross alpha and combined radium involves a series of steps to eliminate illegal noncompliance. Because both gross alpha and combined radium are removed by the same treatment techniques, the adjustments we make for gross alpha are accompanied by adjustments in the combined radium values, and vice-versa. The steps for making these adjustments are described below; the assumptions used in these steps (e.g., for the ratio of mass to activity levels and the presence of radium-224) are discussed in the previous section. Steps A.1 through A.4 are used under both the direct proportions and lognormal approaches described earlier; developing the lognormal estimates requires one additional step, as discussed under Step A.5.

Step A.1: Identify Systems in Illegal Noncompliance with Gross Alpha MCL: We first adjust the NIRS data to be consistent with the regulatory definition of gross alpha by subtracting the reported values for uranium from reported values for gross alpha.[18] We then determine whether the

[18] In this and all other adjustments, NIRS values reported as "below the minimum reporting level (MRL)" are treated as one-half of the MRL. The MRLs are 2.6 pCi/L for gross alpha, 0.08 μg/L for uranium, 0.18 pCi/L for radium-226, and 1.0 pCi/L for radium-228. Hence, for example, a uranium value reported as below the MRL would be treated as 0.04 μg/L when subtracting the uranium values from the reported gross alpha values, or 0.04 pCi/L assuming a 1:1 ratio between mass and activity levels.

resulting gross alpha value for each NIRS system is above the current MCL (15 pCi/L), excluding any adjustment for radium-224. If yes, we flag the system as in illegal noncompliance.

Step A.2: Identify Systems in Illegal Noncompliance with Combined Radium MCL: Second, we determine whether systems are illegally out of compliance with the combined radium MCL of 5 pCi/L, taking into account the monitoring loopholes in the existing regulations. Due to these loopholes, systems are in illegal noncompliance status only if: (1) they report gross alpha levels above 5 pCi/L; (2) they report radium-226 levels above 3 pCi/L; and, (3) the sum of radium-226 and radium-228 exceeds 5 pCi/L.

Step A.3: Estimate Post-Compliance Gross Alpha and Combined Radium Levels: For those systems in illegal noncompliance status for either gross alpha or combined radium, we use the removal rates from EPA's cost model (discussed in Chapter 4) to estimate post-compliance activity levels.[19]

- In the case where a system is illegally out of compliance for both radium and gross alpha, we assume that the system will install treatment with a removal rate that achieves compliance for both MCLs. For example, if a system requires a 30 percent removal rate to achieve gross alpha compliance and a 50 percent removal rate to achieve radium compliance, we assume it will install treatment to achieve a 50 percent removal rate.

- For systems in illegal compliance with only the gross alpha or the combined radium MCL (not both), we assume that the treatment installed will reduce the occurrence of both groups of radionuclides -- because the types of technologies installed are generally effective in removing both gross alpha and combined radium. For example, if a system is illegally out of compliance for gross alpha (but not for combined radium) and requires a removal rate of 80 percent to achieve the gross alpha MCL, we reduce radium-226 and radium-228 levels (as well as gross alpha levels) by 80 percent.[20]

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[19] The removal rates used are 30, 50, 80, or 95 percent. We apply the lowest of these rates needed to reach the MCL, which in most cases leads to post-compliance activity levels below the MCL.

[20] Actual removal rates for the co-occurring contaminants will vary depending on influent concentrations and other factors.

Step A.4: Estimate Radium-224 Levels and Add to Gross Alpha: Because closing the monitoring loopholes will require systems to conduct more timely analysis to detect the presence of radium-224 and its daughter products, we add three times the adjusted value for radium-228 (i.e., the radium-228 value that results from Steps A.1 through A.3 above) to the adjusted value for gross alpha. Under the direct proportions approach, the data resulting from this step are used to estimate the proportion of systems legally out of compliance with the current MCLs.

Step A.5: Estimate Lognormal Distributions: Under the lognormal approach, the final step in the analysis involves estimating lognormal probability distributions that best fit the data that results from Step A.4. The log means and log standard deviations from these distributions are then used to estimate the percentage of systems legally out of compliance with the current MCLs.

The resulting data provide the initial baseline for the analysis. Under this baseline, some systems will legally exceed the current gross alpha and combined radium MCLs. These data are the input to the cost and risk analysis completed to assess the effects of changes to the monitoring requirements, since such changes will eliminate legal noncompliance and require all systems to achieve concentration levels below the MCL.

Revised Baseline -- Compliance under New Monitoring Requirements

To develop the revised baseline for gross alpha and combined radium, we begin with the initial baseline estimates discussed above, and then adjust them to reflect closure of the monitoring loopholes and elimination of legal noncompliance with the existing regulations.[21] The result of this step is that all systems are at or below the current MCLs of 15 pCi/L for gross alpha (net of uranium and radon and including radium-224) and 5 pCi/L for combined radium-226 and radium-228.[22] This step provides us with the full compliance occurrence estimates that are used to assess changes to the gross alpha and radium MCLs. Again, the initial steps (Steps B.1 through B.4) are undertaken for both the direct proportions and lognormal approaches described earlier; the lognormal distributions are then estimated as part of Step B.5.

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[21] Note that this adjustment assumes that EPA will close the monitoring loopholes for both gross alpha and combined radium. The results would be slightly different if EPA decides to close only one of the loopholes. The number of systems affected by each loophole is reported in the "Findings" section of this chapter.

[22] Under the lognormal approach, a small fraction of the systems will exceed the MCL because we did not truncate the right tail of the distribution at the existing MCL (see illustration in Exhibit 2-2). However, this fraction represents very few systems, each of which exceeds the MCL by a very small amount; therefore, we expect this issue will have a negligible impact on our results.

Step B.1: Identify Systems in Legal Noncompliance with Gross Alpha MCL: First, we determine whether the gross alpha value resulting from Steps A.1 through A.4 above exceeds the current MCL (15 pCi/L) when radium-224 and its daughter products are included. If yes, we flag the system as in legal noncompliance.

Step B.2: Identify Systems in Legal Noncompliance with Combined Radium MCL: Next, we determine whether the combined radium-226 and radium-228 value resulting from Steps A.1 through A.4 above exceeds the current MCL (5 pCi/L) once the monitoring loopholes are closed. If yes, we flag the system as in legal noncompliance.

Step B.3: Estimate Post-Compliance Gross Alpha and Combined Radium Levels: For those systems in legal noncompliance status for either gross alpha or radium, we again use the removal rates from EPA's cost model to estimate post-compliance activity levels. As in the analysis of the initial baseline, if a system is legally out of compliance for both radium and gross alpha, we assume that it will install treatment to achieve the highest removal rate needed. Also consistent with the analysis of the initial baseline, we estimate the effects of treatment for gross alpha on radium occurrence levels and vice-versa by applying the same removal rates to the data on gross alpha, radium-226, and radium-228 to estimate post-compliance occurrence. The data that results from this step is used to assess the combined radium MCL option under the direct proportions approach.

Step B.4: Subtract Radium-226 From Gross Alpha Levels: Because EPA is considering changing the definition of gross alpha to exclude radium-226, we next subtract the radium-226 value from the gross alpha value that results from the above steps. The estimates that result from this step are used to assess the gross alpha MCL option under the direct proportions approach.

Step B.5: Estimate Lognormal Distributions: Under the lognormal approach, the final step in the analysis involves estimating lognormal probability distributions that best fit the data that results from the above steps. Because the combined radium MCL under consideration limits the contribution of radium-228 to the total (but does not change the MCL), we estimate the radium distributions based solely on the radium-228 data from Step B.3. For gross alpha, the distributions are based on the data from Step B.4. The log means and log standard deviations from these distributions are then used to estimate the percentage of systems out of compliance with the alternative MCLs.

<u>Systems Serving Populations Greater than One Million</u>

The NIRS sample does not include any systems serving populations of greater than one million. These systems tend to be unique in many respects due to their large size. Therefore, rather than extrapolating from the smaller system size classes, we reviewed data on 16 individual systems to determine whether they might be affected by the regulatory changes EPA is considering.[23] We obtained data from system water quality reports, most of which are posted on the Internet. In a few cases, we followed up with individual water systems to request published reports that were more detailed than those available electronically. In the near future, we plan to conduct additional research to fill in remaining data gaps.

In analyzing the data, we make several assumptions that relate largely to determining whether the systems are in "legal non-compliance" status due to the loopholes in the existing monitoring requirements. First, we assume that systems are not analyzing gross alpha samples quickly enough to detect radium-224 before it decays to below detection limits, and that the reported gross alpha values therefore exclude radium-224. We also assume that when systems report combined radium occurrence as "not detected" (rather than reporting radium-226 and radium-228 separately), it means that both radium-226 and radium-228 occurrence is below detectable limits. In other words, we assume that such systems have not used the monitoring loopholes to avoided analyzing for both radionuclides.[24] In addition, some systems report occurrence data for each of their plants, while other systems report a single value for each MCL. In the latter case, we assume that no plants within the system exceed the single value reported. Finally, uranium data are lacking for many systems because it is not currently regulated; we therefore use data from another source to determine whether the system is located in a state with potentially elevated uranium levels.[25]

FINDINGS

Below, we present the results of the occurrence analysis in four sections. First, we address occurrence of gross alpha and combined radium under the initial and revised baselines. Second, we describe the occurrence of uranium. Third, we summarize these results. Fourth, we discuss occurrence in systems serving more than one million people. These sections are followed by a

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[23] We address 16 systems with retail populations above one million; if wholesale populations are included, a total of 25 systems exceed this threshold. This focus on retail populations avoids double-counting with the systems addressed in other parts of the analysis, which include systems purchasing water from wholesalers. This approach is necessary because the available national data on populations served addresses only retail populations (see Appendix A).

[24] If instead the system reports combined radium as "not reported," we are unsure whether this reflects use of the monitoring loopholes or other factors (such as receipt of a waiver) that allow them to avoid reporting.

[25] Oak Ridge National Laboratory, *Uranium in U.S. Surface, Ground, and Domestic Waters, Volume 1,* prepared for the U.S. Environmental Protection Agency, April 1981.

discussion of the implications of the limitations of our analysis. Detailed information on the results for community water systems by system size class are provided in Appendix E, which also provides the results of the cost analysis.

Gross Alpha and Combined Radium

For gross alpha and combined radium, we assess occurrence under three scenarios. First, we consider the extent to which systems were illegally out of compliance with the existing requirements when the NIRS data were collected. Then, we address the extent to which systems exceed the current MCLs legally (due to loopholes in the current monitoring requirements) after illegal noncompliance is eliminated. Finally, we assess the extent to which systems are likely to exceed each of the MCL options under consideration, after both of the monitoring requirements are altered to ensure full compliance with the existing MCLs. In all cases, we consider only systems relying primarily on ground water sources, because (as discussed above) we expect that gross alpha and radium levels will be below levels of concern in systems relying primarily on surface water sources.

Illegal Noncompliance

When the NIRS data were collected in the mid-1980s, some systems were not complying with the existing regulations in part because they were anticipating regulatory changes. Below, we discuss the extent of non-compliance at that time, then review more recent date on noncompliance.

NIRS Data: In Exhibit 2-4, we estimate the percent of systems in illegal noncompliance status nationally based on NIRS. This estimate applies data on the percent of NIRS systems in illegal noncompliance status (in 1984 - 1986) to 1997 data on the number of ground water systems in each size category. The exhibit first reports the percent of systems out of compliance for each size class as a fraction of the total systems in that class. It then reports the percentage out of compliance for all systems in all size classes combined.

Exhibit 2-4

SYSTEMS ILLEGALLY OUT OF COMPLIANCE WITH EXISTING MCLS
(community ground water systems only)

Regulatory Option	System Size Class (population served)	Percent of Systems Illegally Out of Compliance	Number of Systems Illegally Out of Compliance
Exceed gross alpha MCL (15 pCi/L) only	25 - 500 persons	0.4 percent	130 systems
	501 - 1 million persons	0.9 percent	120 systems
	Subtotal	**0.6 percent**	**250 systems**
Exceed combined radium MCL (5 pCi/L) only	25 - 500 persons	0.7 percent	210 systems
	501 - 1 million persons	0.4 percent	60 systems
	Subtotal	**0.6 percent**	**270 systems**
Exceed both gross alpha and combined radium MCLs	25 - 500 persons	0.3 percent	80 systems
	501 - 1 million persons	0.4 percent	60 systems
	Subtotal	**0.3 percent**	**150 systems**
TOTAL	**All systems**	**1.6 percent**	**670 systems**

Notes:
Estimates based on NIRS data collected in 1984 - 1986; may overstate current level of noncompliance.
Detail does not add to totals due to rounding.

As indicated by the exhibit, we estimate that 1.6 percent (about 670 systems) of the approximately 42,781 ground water systems in these size classes nationally are illegally exceeding the current MCLs, assuming that the extent of noncompliance has not changed since the NIRS data were collected. Of this total, we estimate that about 400 systems (250 plus 150) are in illegal noncompliance status for gross alpha, and that about 420 systems (270 plus 150) are in illegal noncompliance status for combined radium. There is some overlap between these two categories; about 150 systems are in illegal noncompliance status for both MCLs.[26]

Other sources of noncompliance data: Since the NIRS data were collected, some of these systems may have complied with the existing standards. This compliance may have resulted from

[26] We present these data on illegal noncompliance primarily as background information (we do not assess related costs or risks since they are attributable to the current regulations), and hence do not provide alternative estimates using a lognormal distribution.

the installation of treatment to comply with other recently promulgated regulations, consolidation with neighboring systems with lower contaminant levels, or in response to the enforcement penalties (and negative public reactions) associated with continued noncompliance with the radionuclides standards.[27] Below, we discuss data on non-compliance from other data sources. While none of these sources provide estimates comparable to the NIRS data, they provide insights into current rates of noncompliance.

We first reviewed violations data from SDWIS. These estimates are not directly comparable to the NIRS estimates above, in part because they are reported by monitoring location (not by system), and a system may have several monitoring sites. In addition, some violations are not reported to SDWIS. However, these data provide some indication of the trends in compliance over time.

Exhibit 2-5 lists the gross alpha and combined radium violations reported in SDWIS for three years. In 1997, 117 violations of the gross alpha MCL and 189 violations of the combined radium MCL were reported. While comparison of this 1997 data to the 1987 data suggest that the number of reported violations may be decreasing, the surge in gross alpha violations in 1992 suggests that violations may fluctuate from year to year rather than consistently decrease over time.

Exhibit 2-5

SDWIS VIOLATIONS DATA
(for selected years)

MCL	Number of Violations		
	1987	1992	1997
Gross Alpha	135 violations	236 violations	117 violations
Combined Radium	233 violations	204 violations	189 violations

Notes:
Violations indicate MCL exceedences at individual monitoring points, of which there may be several within a single water system. Hence these data are not directly comparable to the data on NIRS systems provided above. In addition, some violations are not reported to SDWIS.
Source:
Personal communication with William Labiosa, EPA/OGWDW, July 21, 1999.

[27] Since 1984, EPA has promulgated eight final regulations establishing MCLs for numerous contaminants. Many of these contaminants (e.g., certain inorganic chemicals) require the same treatment technologies as radionuclides.

To provide further insights into the extent of illegal noncompliance, we reviewed two additional data sources. The first is a July 1998 report on the actual cost of compliance with the radionuclides MCLs, which includes counts of the number of systems illegally out of compliance with the combined radium MCL in Illinois, Indiana, Ohio, Wisconsin, and Wyoming.[28] Data in the report were collected in early 1998 and may be from years as recent as 1996 to 1997. The second source of information is a copy of the Illinois Environmental Protection Agency's historical database of community water systems formerly or currently illegally out of compliance with the current MCLs for gross alpha and combined radium.[29]

The five states included in the "Actual Cost" report are among those most likely to report elevated radium 226 and radium 228 concentrations, according to previous studies of radionuclide concentrations in raw ground water samples.[30] Other areas likely to have elevated levels of combined radium include parts of Florida, Idaho, California, Colorado, Texas, and the area along the Southern Appalachian Mountains. We expect that the majority of the violations of the existing MCLs will occur in these areas.[31] The number of systems out of compliance in each state is listed in Exhibit 2-6.

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[28] International Consultants, Incorporated, *Actual Cost For Compliance with the Safe Drinking Water Act Standard for Radium 226 and Radium 228 - Final Report*, prepared for the U.S. Environmental Protection Agency. July 1998.

[29] Database provided by Dianna Heaberlin of the Illinois Environmental Protection Agency, July 30, 1999.

[30] Michel, J. and M.J. Jordana, "Nationwide Distribution of Radium-228, Radium-226, Radon-222 and Uranium in Ground Water," *Radon, Radium, and Other Radioactivity in Ground Water: Hydrogeologic Impact and Application to Indoor Airborne Contamination*, edited by B. Graves, Lewis Publishers, Chelsea, Michigan: 1987, pp. 227 - 240.

[31] Violations counts from the SDWIS database for the years 1992 to the second quarter of 1999 indicate that, out of a total of 333 violations for combined radium, 152 (46 percent) occur in Illinois, and 41 (12 percent) occur in Wisconsin. Other states with large numbers of combined radium violations include Kansas, Missouri, South Dakota, and Texas, with a combined total of 67 violations (20 percent). Again, a system may have more than one SDWIS violation, and not all systems report to SDWIS. SDWIS data provided by William Labiosa, EPA/OGWDW, August 4, 1999.

Exhibit 2-6

STATE DATA ON ILLEGAL NONCOMPLIANCE WITH COMBINED RADIUM MCL
(community ground water systems)

State	System Size Class (population served)	Percent of Systems Reporting Violations	Number of Systems Reporting Violations
Illinois[1]	25 - 500 persons	6.5 percent	40 systems
	501 - 1 million persons	8.6 percent	55 systems
	Subtotal	**7.6 percent**	**95 systems**
Indiana	25 - 500 persons	0.5 percent	2 systems
	501 - 1 million persons	0.2 percent	1 system
	Subtotal	**0.4 percent**	**3 systems**
Ohio	25 - 500 persons	1.0 percent	6 systems
	501 - 1 million persons	none	none
	Subtotal	**0.5 percent**	**6 systems**
Wisconsin	25 - 500 persons	0.7 percent	5 systems
	501 - 1 million persons	4.4 percent	19 systems
	Subtotal	**2.2 percent**	**25 systems**[2]
Wyoming	25 - 500 persons	0.6 percent	1 system
	501 - 1 million persons	none	none
	Subtotal	**0.5 percent**	**1 systems**
TOTAL FOR FIVE STATES	**All System Sizes**	**2.9 percent**	**130 systems**

Notes:
(1) Illinois data are based on IEc analysis of the Illinois database; the "Actual Cost" report does not include information on system size classes for this state.
(2) The system size class for one system in violation is unknown.
Sources:
Database provided by Dianna Heaberlin of the Illinois Environmental Protection Agency, July 30, 1999.
International Consultants, Incorporated, *Actual Cost For Compliance with the Safe Drinking Water Act Standard for Radium 226 and Radium 228 - Final Report.* Prepared for the U.S. Environmental Protection Agency. July 1998.

In these five states, a total of 130 systems are illegally non-compliant with the current MCL for combined radium (5 pCi/L), which is about 31 percent of the total of 419 systems predicted by

NIRS. Because other areas with high combined radium occurrence (not included in this exhibit) generally have low population densities, and therefore few community water systems, the violations from these five states may possibly account for the majority of the radium violations in the U.S. This information, combined with the SDWIS counts of violations, suggests that NIRS may overestimate the number of systems currently illegally noncompliant with the MCL for combined radium.

Similar data on gross alpha violations is available only for Illinois.[32] Based on the Illinois database, we are able to calculate the number of systems illegally out of compliance with one or both of the combined radium and gross alpha MCLs as of January 1, 1999. The results are presented in Exhibit 2-7.

[32] Between 1992 and the second quarter of 1999, 353 violations of the gross alpha MCL were reported to SDWIS. Seventy-one violations (20 percent) were reported in Illinois, and 136 (39 percent) were reported in Florida. (In contrast, Florida only reported seven out of 333 violations for the combined radium MCL, as discussed in the footnote above, during the same time period.) SDWIS data provided by William Labiosa, EPA/OGWDW, August 4, 1999.

Exhibit 2-7

ILLINOIS SYSTEMS ILLEGALLY OUT OF COMPLIANCE WITH EXISTING MCLS
(community ground water systems only)

Regulatory Option	System Size Class (population served)	Percent of Systems Reporting Violations	Number of Systems Reporting Violations
Exceed gross alpha MCL (15 pCi/L) only	25 - 500 persons	0.2 percent	1 systems
	501 - 1 million persons	0.6 percent	4 systems
	Subtotal	**0.4 percent**	**5 systems**
Exceed combined radium MCL (5 pCi/L) only	25 - 500 persons	4.2 percent	26 systems
	501 - 1 million persons	4.8 percent	31 systems
	Subtotal	**4.5 percent**	**57 systems**
Exceed both gross alpha and combined radium MCLs	25 - 500 persons	2.3 percent	14 systems
	501 - 1 million persons	3.7 percent	24 systems
	Subtotal	**3.0 percent**	**38 systems**
TOTAL	**All systems**	**8.0 percent**	**100 systems**

Notes:
Detail does not add to totals due to rounding.
Sources:
IEc analysis of data provided by Dianna Heaberlin of the Illinois Environmental Protection Agency, dated July 30, 1999.
Percentages are based on the total number of systems by size class for Illinois as reported in: International Consultants, Incorporated, *Drinking Water Baseline Handbook, First Edition*, prepared for U.S. Environmental Protection Agency, February 24, 1999.

In Illinois, this exhibit shows that about eight percent of all community water systems are illegally out of compliance with either the combined radium or gross alpha MCL, compared with the national noncompliance rate of less than two percent in Exhibit 2-4. In addition, about four percent of the systems in Illinois exceed only the combined radium MCL and three percent exceed both the gross alpha and combined radium MCLs. These percentages are six to ten times greater than the proportions reported nationally. This information suggests that Illinois will be disproportionately affected by efforts to eliminate illegal noncompliance under the existing regulations.

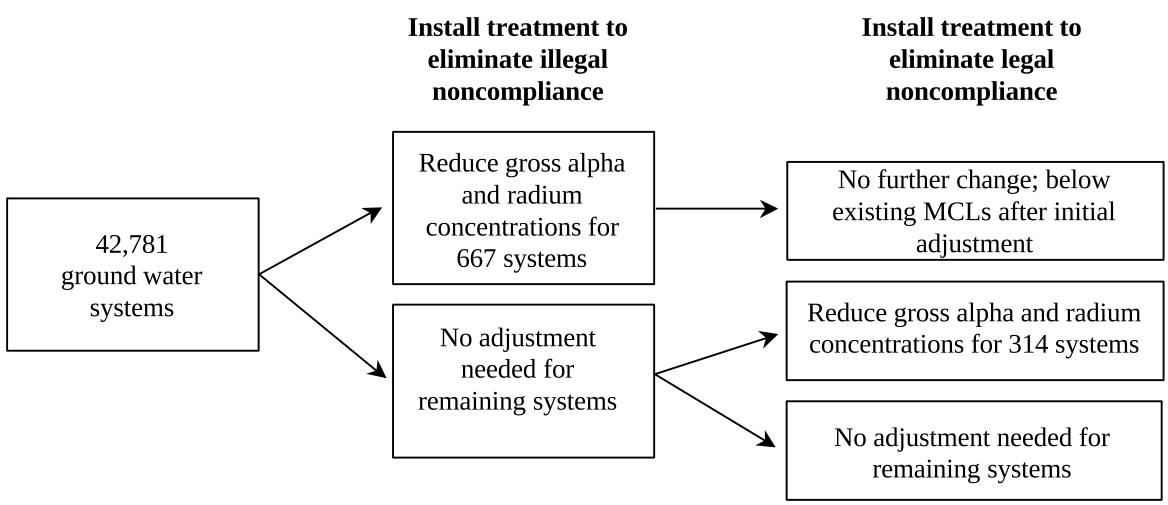
Legal Noncompliance

In characterizing the baseline (i.e., radionuclide occurrence in the absence of revisions to the regulations) we assume that all systems will eventually comply with the current requirements. This assumption allows us to separate the effects of changes to the regulations (as discussed below) from the effects of more complete compliance with the existing regulations.

After the adjustment for illegal noncompliance, some systems will legally exceed the current MCLs because of the monitoring loopholes in the existing regulations (see Exhibit 2-8). The legal violations of the current MCLs occur because the existing monitoring requirements allow systems to avoid measuring compliance with the combined radium MCL under certain conditions, and to hold their samples long enough for radium-224 (a component of gross alpha) to decay below detection limits.

Exhibit 2-8

EXAMPLE OF ADJUSTMENTS FOR NONCOMPLIANCE
(Direct Proportions Approach)



In Exhibit 2-9, we indicate the percent of systems that are in legal noncompliance status after we adjust the data to eliminate any illegal noncompliance with the existing standards. We first report estimates based directly on NIRS, applying our estimates of the percent of systems out of compliance in each size class to the 1997 validated data on the number of community ground water systems in each size class. For comparison, we also present the results based on fitting a lognormal distribution to the NIRS data, as discussed in the section describing the analytic approach.

Exhibit 2-9

SYSTEMS LEGALLY OUT OF COMPLIANCE WITH EXISTING MCLS
(community ground water systems only)

Regulatory Option	System Size Class (population served)	Number of Systems Legally Out of Compliance (percent of total)	
		Directly Proportional	Lognormal Distribution
Exceed gross alpha MCL (15 pCi/L) only	25 - 500 persons	40 systems (0.1 percent)	<10 systems (<0.1 percent)
	501 - 1 million persons	none	80 systems (0.5 percent)
	Subtotal	**40 systems (0.1 percent)**	**80 systems (0.2 percent)**
Exceed combined radium MCL (5 pCi/L) only	25 - 500 persons	40 systems (0.1 percent)	70 systems (0.2 percent)
	501 - 1 million persons	60 systems (0.4 percent)	70 systems (0.5 percent)
	Subtotal	**100 systems (0.2 percent)**	**150 systems (0.3 percent)**
Exceed both gross alpha and combined radium MCLs	25 - 500 persons	170 systems (0.6 percent)	170 systems (0.6 percent)
	501 - 1 million persons	none	none
	Subtotal	**170 systems (0.4 percent)**	**170 systems (0.4 percent)**
TOTAL	**All systems**	**310 systems (0.7 percent)**	**400 systems (0.9 percent)**

Notes:
Detail does not add to totals due to rounding.
The extent of overlap (170 systems) under the lognormal approach is estimated using the direct proportions approach.

These data indicate the number of systems likely to legally exceed the existing MCLs in the absence of changes to the monitoring requirements in the existing regulations. As indicated by the exhibit, we estimate that less than one percent of the 42,781 ground water systems nationally are legally exceeding either the combined radium or gross alpha MCL. If EPA decides to close only one of the loopholes, the direct proportions approach indicates that 210 (40 + 170) systems exceed the gross alpha MCL, while 270 (100 + 170) systems exceed the combined radium MCL. The lognormal approach increases these estimates to 250 and 320 systems respectively. In total, between 310 and 400 systems may be in legal noncompliance status for one or both of the MCLs.

Compliance with MCL Options

To assess the effects of changes to the MCLs for gross alpha and combined radium, we first adjust the data to reflect closure of both monitoring loopholes. This step brings all systems fully into compliance with the existing MCLs, and allows us to separate the effects of changes in the MCLs from the effects of the monitoring issues.

In this preliminary analysis, we consider two changes in the MCLs: limiting the gross alpha levels to 10 pCi/L net of radium 226, and limiting the contribution of radium-228 to 3 pCi/L within the total combined radium MCL of 5 pCi/L.[33] In Exhibit 2-10, we indicate the percent of systems that would be out of compliance with each of these MCL options after we adjust the data to eliminate all noncompliance with the existing standards. We first report estimates based directly on NIRS; then, for comparison, present the results based on fitting a lognormal distribution to the NIRS data.

[33] In Appendix F, we provide the results of previous analyses that consider the effects of lower limits on the contribution of radium-228 to the combined radium MCL.

Exhibit 2-10

SYSTEMS OUT OF COMPLIANCE WITH GROSS ALPHA AND COMBINED RADIUM MCL OPTIONS (community ground water systems only)

Regulatory Option	System Size Class (population served)	Number of Systems Legally Out of Compliance (percent of total)	
		Directly Proportional Approach	Lognormal Distribution Approach
Exceed revised gross alpha MCL only (10 pCi/L, net of radium 226)	25 - 500 persons	340 systems (1.2 percent)	250 systems (0.9 percent)
	501 - 1 million persons	120 systems (0.9 percent)	110 systems (0.8 percent)
	Subtotal	**460 systems (1.1 percent)**	**360 systems (0.8 percent)**
Exceed revised combined radium MCL only (limiting radium-228 to 3 pCi/L, 5 pCi/L total)	25 - 500 persons	none	40 systems (0.1 percent)
	501 - 1 million persons	60 systems (0.4 percent)	30 systems (0.2 percent)
	Subtotal	**60 systems (0.1 percent)**	**70 systems (0.2 percent)**
Exceed both revised MCLs (combined radium and gross alpha)	25 - 500 persons	80 systems (0.3 percent)	80 systems (0.3 percent)
	501 - 1 million persons	60 systems (0.4 percent)	60 systems (0.4 percent)
	Subtotal	**150 systems (0.3 percent)**	**150 systems (0.3 percent)**
TOTAL	**All systems**	**670 systems (1.5 percent)**	**570 systems (1.3 percent)**

Notes:
Detail does not add to total due to rounding.
The extent of overlap (150 systems) under the lognormal approach is estimated using the direct proportions approach.

These data indicate that the number of systems likely to exceed the revised gross alpha MCL would be more than double the number affected by the potential changes to the combined radium MCL. If considered independently, the direct proportions approach indicates that about 610 (460 + 150) systems would exceed the gross alpha MCL option, while 210 (60 + 150) systems exceed the combined radium MCL option. The lognormal approach changes these estimates to 500 for gross alpha, but also estimates that 210 systems will be out of compliance with the combined radium MCL.[34] In total, between 570 and 670 systems may be out of compliance with one or both MCLs, representing less than two percent of all ground water systems nationally.

Uranium

For uranium, the analysis of occurrence consists of fewer steps. Because uranium is not currently regulated, there is no need to assess the compliance issues addressed for gross alpha and combined radium. Rather, we predict noncompliance with the MCL options from the original NIRS data.[35] As discussed earlier, for the preliminary analysis of the uranium options, we assume a one-to-one mass-to-activity ratio and surface water concentrations at one-third of those of ground water.

In Exhibits 2-11 and 2-12, we indicate the percent of systems that exceed the uranium options under consideration. In Exhibit 2-11, we apply the percentages derived from NIRS to the 1997 validated data on the number of systems in each size class to estimate the number of systems out of compliance. Exhibit 2-12 then presents the results fitting a lognormal distribution to the NIRS data. As indicated in Appendix A, there are approximately 42,781 ground water systems and 10,375 surface water systems operating nationally in these size classes.

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[34] In some cases, the lognormal approach yields lower estimates than the direct proportions approach, because clustering of the underlying data near zero "pulls" the distribution lower (i.e., towards its left tail).

[35] Uranium levels may have changed, however, since the NIRS data were collected. For example, the NIRS data may overstate uranium concentrations if treatments installed to address other water quality problems also affect uranium levels.

Exhibit 2-11

SYSTEMS OUT OF COMPLIANCE WITH URANIUM OPTIONS: DIRECT PROPORTIONS APPROACH (community water systems)

Regulatory Option	System Size Class (population served)	Number of Ground Water Systems (Percent of Total)	Number of Surface Water Systems (Percent of Total)	Total Number of Water Systems (Percent of Total)
Exceed MCL of 20 pCi/L (20 μg/L)	25 - 500 persons	760 systems (2.7 percent)	<10 systems (0.1 percent)	760 systems (2.4 percent)
	501 - 1 million persons	60 systems (0.4 percent)	none	60 systems (0.2 percent)
	Subtotal	**820 systems (1.9 percent)**	**<10 systems (<0.1 percent)**	**830 systems (1.6 percent)**
Exceed MCL of 40 pCi/L (40 μg/L)	25 - 500 persons	300 systems (1.0 percent)	none	300 systems (0.9 percent)
	501 - 1 million persons	none	none	none
	Subtotal	**300 systems (0.7 percent)**	**none**	**300 systems (0.6 percent)**
Exceed MCL of 80 pCi/L (80 μg/L)	25 - 500 persons	40 systems (0.1 percent)	none	40 systems (0.1 percent)
	501 - 1 million persons	none	none	none
	Subtotal	**40 systems (0.1percent)**	**none**	**40 systems (<0.1 percent)**

Note:
Detail does not add to totals due to rounding.

As indicated by the exhibit, we estimate that approximately 40 to 830 systems would be out of compliance with the uranium options under the direct proportions approach. Most of those affected will be very small ground water systems. Almost no systems would be affected by MCLs that are less stringent (i.e., higher) than those reported in the exhibit; the highest uranium level reported in NIRS is 88.2 pCi/L.

Exhibit 2-12

SYSTEMS OUT OF COMPLIANCE WITH URANIUM OPTIONS: LOGNORMAL APPROACH (community water systems)

Regulatory Option	System Size Class (population served)	Number of Ground Water Systems (Percent of Total)	Number of Surface Water Systems (Percent of Total)	Total Number of Water Systems (Percent of Total)
Exceed MCL of 20 pCi/L (20 μg/L)	25 - 500 persons	670 systems (2.3 percent)	20 systems (0.6 percent)	680 systems (2.1 percent)
	501 - 1 million persons	250 systems (1.8 percent)	30 systems (0.4 percent)	290 systems (1.3 percent)
	Subtotal	**920 systems (2.2 percent)**	**50 systems (0.5 percent)**	**970 systems (1.8 percent)**
Exceed MCL of 40 pCi/L (40 μg/L)	25 - 500 persons	300 systems (1.1 percent)	<10 systems (0.3 percent)	310 systems (1.0 percent)
	501 - 1 million persons	110 systems (0.7 percent)	10 systems (0.2 percent)	120 systems (0.5 percent)
	Subtotal	**410 systems (1.0 percent)**	**20 systems (0.2 percent)**	**430 systems (0.8 percent)**
Exceed MCL of 80 pCi/L (80 μg/L)	25 - 500 persons	120 systems (0.4 percent)	<10 systems (0.1 percent)	130 systems (0.4 percent)
	501 - 1 million persons	40 systems (0.3 percent)	<10 systems (<0.1 percent)	40 systems (0.2 percent)
	Subtotal	**160 systems (0.4 percent)**	**10 systems (<0.1 percent)**	**170 systems (0.3 percent)**

Note:
Detail does not add to totals due to rounding.

For the uranium options, the use of the lognormal approach increases the number of systems likely to be out of compliance with each MCL option in comparison to the direct proportions approach. As indicated by the exhibit, we estimate that approximately 170 to 970 systems would be out of compliance with the uranium options under consideration.

Summary of Results

In Exhibit 2-13 below, we summarize the results for community water systems reported in the earlier sections.

Exhibit 2-13
NUMBER OF COMMUNITY WATER SYSTEMS EXCEEDING STANDARDS

Option	Number of Systems
Illegally out of compliance with existing MCLs (combined radium = 5 pCi/L, gross alpha = 15 pCi/L):	
Illegal noncompliance: gross alpha [1]	400 systems
Illegal noncompliance: combined radium [1]	420 systems
Total number of systems in illegal noncompliance (adjusts for overlap) [2]	670 systems
Legally out of compliance with existing MCLs (due to monitoring loopholes):	
Legal noncompliance (due to monitoring loopholes): gross alpha [3]	210 - 250 systems
Legal noncompliance (due to monitoring loopholes): combined radium [3]	270 - 320 systems
Total number of systems in legal noncompliance (adjusts for overlap) [2,3]	310 - 400 systems
Out of compliance with options for revising MCLs:	
Gross alpha at 10 pCi/L net of radium 226 [4]	500 - 610 systems
Combined radium at 5 pCi/L with radium-228 limit at 3 pCi/L [4]	210 systems
Total number of systems out of compliance with revised radium or gross alpha MCL (adjusts for overlap) [2,4]	570 - 670 systems
Out of compliance with options for uranium MCL:	
Uranium at 20 pCi/L (20 μg/L)	830 - 970 systems
Uranium at 40 pCi/L (40 μg/L)	300 - 430 systems
Uranium at 80 pCi/L (80 μg/L)	40 - 170 systems

Notes:
Ranges based on directly proportional versus lognormal distribution approach. Combined radium and gross alpha analyses include ground water systems only; uranium analysis includes both ground water and surface water systems.
1. Costs and risk reductions associated with complying with existing requirements for these systems are not assessed because these impacts are not attributable to the changes in requirements now under consideration.
2. Overlap analysis based on direct proportions approach.
3. Compared to initial baseline (i.e., occurrence data are adjusted to eliminate illegal noncompliance).
4. Compared to revised baseline (i.e., occurrence data are adjusted to eliminate legal noncompliance with both gross alpha and combined radium MCLs).

For gross alpha and combined radium, the NIRS data suggest that 670 systems were illegally out of compliance when the NIRS data were originally collected, if we adjust for double-counting. More recent data suggest that illegal noncompliance may have decreased somewhat since that time. Once we adjust the data to eliminate this illegal noncompliance, we estimate that between about 310 and 400 systems will be in legal noncompliance status with one or both of the existing MCLs, depending the approach used to estimate non-compliance (direct proportions or lognormal distribution). After the monitoring loopholes are closed, a total of 570 to 670 systems may be out of compliance with one or both of the options for revising the MCLs for gross alpha and combined radium. In addition, the MCL options for uranium may affect from about 40 to almost 1,000 systems, depending on the option selected and the approach used to estimate noncompliance. In general, the estimates of the number of systems out of compliance are higher under the lognormal approach than under the direct proportions approach.

Systems Serving Populations Greater than One Million

In Exhibit 2-14, we list the 16 systems with retail populations greater than one million, and summarize the data reviewed to-date on radionuclide concentrations. These data are taken from the Consumer Confidence Reports provided by each system as of December 1999. In the case of uranium (which is not currently regulated) we also indicate whether the system is located in an area of the country with potentially elevated levels if no occurrence data are reported.[36] As indicated by the exhibit, only some systems report actual concentrations for the radionuclides of concern and, in many cases, the concentrations are reported as below detection limits.[37] We are now contacting selected systems to collect additional information in cases where no data are reported.

[36] Areas with potentially elevated levels of uranium were identified based on: Oak Ridge National Laboratory, *Uranium in U.S. Surface, Ground, and Domestic Waters, Volume 1,* prepared for the U.S. Environmental Protection Agency, April 1981.

[37] Under the existing regulations, the analytical method used to determine compliance with the gross alpha or combined radium MCL must have a detection limit no greater than 3 pCi/L or 1 pCi/L respectively (40 CFR 141.25(c)(1)).

Exhibit 2-14
RADIONUCLIDE OCCURRENCE FOR SYSTEMS SERVING RETAIL POPULATIONS GREATER THAN ONE MILLION

Utility	Retail Population	Gross Alpha	Combined Radium	Uranium
City of New York DEP*	8,000,000	Not detected	Not reported	Not reported
City of Los Angeles*	3,515,451	12 pCi/L or less	2.7 pCi/L or less	5.7 pCi/L or less
Chicago Water Department	2,800,000	1 pCi/L or less	Not reported	Not reported
Philadelphia Water Department	1,600,000	Not detected	Not reported	Not reported
City of Houston, DPU*	1,608,069	9.3 pCi/L or less	1.52 pCi/L or less	Not reported**
City of Baltimore Bureau of Water and Waste	1,600,000	Not detected	Not detected	Not reported
City of Atlanta, Bureau of Water	1,500,000	Not detected	Not detected	Not reported
Washington Suburban Sanitary Commission (Maryland)	1,497,000	Not detected	Not detected	Not reported
San Juan Metropolitano	1,429,385	Not available***		
Miami-Dade Water and Sewer Department*	1,355,007	4.8 pCi/L or less	Not detected	Not reported
East Bay Municipal Utility District	1,200,000	Not detected	Not reported	Not detected
Phoenix Municipal Water System*	1,140,000	9.5 pCi/L or less	"Not applicable"	Not reported**
Cleveland Division of Water	1,135,226	3.3 pCi/L or less	Not reported	Not reported
Dallas Water Utilities	1,039,100	Not detected	Not detected	Not reported**
City of Detroit Water and Sewerage Department	1,027,974	Not detected	Not detected	Not reported
Suffolk County Water Authority* (New York)	1,017,800	Not detected	Not reported	Not reported

<u>Notes:</u>
* System relies at least in part on groundwater; other systems rely primarily on surface water (personal communication with Yvette Selby, EPA/OGWDW, March 5, 1999).
** System does not report uranium concentration, but is located in a state with potentially elevated uranium levels (Oak Ridge National Laboratory, *Uranium in U.S. Surface, Ground, and Domestic Waters, Volume 1,* prepared for the U.S. Environmental Protection Agency, April 1981).
*** The San Juan system has a waiver that provides exemption from radionuclide monitoring.
<u>Sources:</u>
Population served data: *Radon and Arsenic Regulatory Compliance Costs for the 25 Largest Public Water Systems (with Treatment Plant Configurations)*, EPA/OGWDW, August 10, 1999.
Concentration data: IEc review of Consumer Confidence Reports available as of December, 1999.

Because of the limited data available for many systems, it is difficult to quantify their radionuclide occurrence levels. These data suggest that none of these systems are illegally out of compliance with the current MCLs. In the case of the gross alpha options, data are not reported on concentrations of radium-224 (which would be included in the measurement of gross alpha if the monitoring loophole was closed), and many of the systems do not report an individual value for radium-226 (which would be netted out of gross alpha to determine compliance with the option of setting the MCL at 10 pCi/L). However, it appears that three systems (Los Angeles, Phoenix, and Houston) could possibly have high enough gross alpha levels to be potentially affected by the regulatory options.

For combined radium, nine of the 16 systems provide data suggesting that they would not be affected by any of the regulatory options, either because the reported value is below both the current MCL (5 pCi/L) as well as the potential limit on radium-228 (3 pCi/L), or because these radionuclides are not detected.[38] For the remaining seven systems, the available data are limited. These systems often do not report values for radium-226 and/or radium-228, and, in many cases, also do not report values for gross alpha and gross beta (radium-226 is included in the measurement of gross alpha and radium-228 is included in the measurement of gross beta). More research is needed to determine radium concentrations for these systems.

Uranium, which is not currently regulated, is addressed by the water quality reports for only two systems and appears to be well below the regulatory levels under consideration in these cases. Three additional systems (Phoenix, Dallas, and Houston) are located in states with potentially elevated uranium concentrations, but their reports do not indicate whether the system itself is likely to find concentrations above levels of concern.

Despite the lack of concentration data, we expect that few, if any, of these systems would be significantly affected by the regulatory options under consideration for two reasons. First, most of these systems rely wholly or in part on surface water sources. As discussed earlier in this chapter, radionuclides rarely occur at levels of concern in surface water. Second, large systems can often accommodate small changes in the regulatory requirements relatively easily, because of their ability to blend contaminated and uncontaminated water sources, adjust existing treatment operations, and/or discontinue use of the contaminated portion of their supplies. In the near future, we plan to contact selected systems to determine whether additional information is available on these issues.

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[38] If the system reports a value for combined radium, rather than separate values for radium-226 and radium-228, we assume that the value includes both radionuclides (i.e., the system is not taking advantage of the existing monitoring loopholes).

IMPLICATIONS OF LIMITATIONS IN THE ANALYSIS

Below we discuss the major limitations of our approach for estimating radionuclide occurrence, and the extent to which these limitations may lead us to under- or overstate the actual occurrence of radionuclides in drinking water. In the near future, we plan to collect additional data to better address these sources of uncertainty.

Factors with indeterminate effects: The analysis of community water supplies relies heavily on the NIRS data, which has several limitations (discussed earlier in this chapter), including: (1) the small size of the sample for systems serving populations greater than 3,300; (2) the decay of radium-224 prior to analysis of the NIRS water samples; (3) the need to convert mass measurements of uranium to activity levels; and, (4) the lack of information on surface water systems. We are uncertain whether our adjustments to the NIRS data to address these limitations will lead us to over- or understate occurrence.

In addition, when we extrapolate directly from the NIRS data, multiplying the sampled systems by weights indicating the number of systems operating nationally in each size class, we generally derive lower estimates than when we fit a lognormal distribution to the data. Without more research into actual occurrence levels, it is difficult to determine the reasonableness of the resulting ranges due to the other factors leading to uncertainty in the NIRS estimates.

Factors that may lead us to overstate occurrence: The NIRS data are over 10 years old and may not reflect current conditions. Since the data were collected, EPA has finalized several rules establishing MCLs, many of which may require treatments that will reduce radionuclide concentrations. Systems may also have installed treatment (or changed the water sources used) due to local water quality problems.

In addition, the system counts used in the analysis include both systems that rely on their own water sources and systems that purchase water from other systems. Because treatment is likely to be installed at the wholesaler (not by the purchasing system), these counts will overstate the total number of systems required to install treatment or take other compliance measures by a small amount. Overall, about five percent of the ground water systems nationally rely on purchased water. We include these systems because the available data on population served (used in the risk analysis in Chapter 3) addresses only retail populations; excluding the systems relying on purchased water would lead us to understate total risk reductions.

Finally, several water systems are in the process of combining to create larger, regional water systems, and the extent to which this consolidation is being off-set by the creation of new systems is unclear. By the time that any changes to the radionuclides regulations are implemented, the total number of systems operating may have decreased below the 1997 estimates used in this analysis.

Because large systems generally have better water quality than smaller systems (as discussed earlier in this chapter), consolidation may mean that fewer systems will be out of compliance when the regulations are implemented.

Factors that may lead us to understate occurrence: As mentioned previously, we adjust the occurrence data to eliminate legal compliance to isolate the effects of revising the MCLs. In the analysis, we assume that EPA closes both the gross alpha and the combined radium monitoring loopholes prior to revising the MCLs. If EPA instead decides to implement only one of these changes, our analysis may understate the number of systems affected by subsequent changes to the MCLs by a small amount.

In addition, while we expect that few, if any, of the very large systems (those serving one million people or more) will be affected by the regulatory options, definitive data are not available for some systems. We do not include the very large systems in our preliminary quantitative analysis of benefits and costs; hence this analysis will understate total impacts if some of these systems are affected.

RISK REDUCTIONS — CHAPTER THREE

This chapter provides estimates of the risk reductions attributable to changes in the regulation of radionuclides in drinking water supplied by community water systems. We focus on the cancer risk reductions associated with each regulatory change EPA is considering, and assess the monetary value of these reductions. As discussed later, the regulations may have other benefits. For example, treatment installed to reduce radionuclide concentrations will also reduce the concentrations of other contaminants, leading to additional risk reductions. Decreases in the adverse effects of uranium on the kidneys are also not quantified. Below, we first discuss our approach to the analysis, then present our findings and describe their limitations.

ANALYTIC APPROACH

The approach for the risk analysis includes three separate components. First, we develop the risk factors to be used in the analysis. Second, we apply these risk factors to the data on community water systems to estimate the risk reductions associated with each regulatory option. Third, we estimate the dollar value of these reductions in risk. We do not quantify risk reductions associated with the impacts of the regulatory options on systems serving populations greater than one million because, as discussed in the previous chapter, the available evidence suggests that few (if any) of these systems may be significantly affected by the regulatory options under consideration.

Risk Factors

The development of risk factors begins with first determining the appropriate mortality and morbidity cancer risk coefficients for each radionuclide or group of radionuclides considered in the analysis; these coefficients indicate the change in lifetime cancer risks associated with ingestion intake of one unit of activity (e.g., one pCi), averaged over different age categories. Next, we use these coefficients to develop factors indicating the individual lifetime risks associated with changes in exposure, taking into account the amount of water ingested over time.[1]

The risk factors applied in this analysis represent small changes in an individual's probability of developing cancer in his or her lifetime. While these probabilities can be summed across a population to indicate the number of statistical "cases" of cancer avoided, these cases represent the expected cumulative effects of small changes in risk experienced by a relatively large exposed population, not actual individual cases.

For each individual radionuclide, EPA developed a coefficient that expresses the estimated incremental lifetime risk of radiogenic cancer morbidity or mortality per unit activity intake.[2] For this analysis, we use the September 1999 risk coefficients developed as part of EPA's revisions to *Federal Guidance Report 13* (FGR-13).[3] FGR-13 compiles the results of several risk models predicting the cancer risks associated with radioactivity. The cancer sites considered in these models include the esophagus, stomach, colon, liver, lung, bone, skin, breast, ovary, bladder, kidney, thyroid, red marrow (leukemia), as well as residual impacts on all remaining cancer sites combined.

The available occurrence data (described in the previous chapter) do not provide information on the contribution of individual radionuclides or isotopes to the total concentrations of gross alpha or uranium. Therefore, we cannot apply the individual risk coefficients directly from FGR-13 in these cases. Our approach to estimating the risk coefficients is described below.

Gross Alpha: Alpha emitters found in drinking water generally result from three natural decay series, including the radionuclides listed in Exhibit 3-1 below. The exhibit also reports the risk coefficients for these radionuclides (i.e., the risk of cancer mortality or morbidity per picocurie (pCi) ingested) from FGR-13.

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[1] This analysis focuses on changes in cancer risks from tap water ingestion. Individuals may be exposed to radionuclides in drinking water through other pathways (e.g., inhalation while showering), and uranium may have toxic effects on the kidneys; however, we expect that any changes in these types of risks will be significantly smaller than the changes in cancer risks from ingestion and hence do not quantify them in this preliminary analysis.

[2] Morbidity indicates total cancer incidence (fatal and nonfatal); mortality indicates the incidence of fatal cancers.

[3] Eckerman, Keith F., Richard W. Leggett, Christopher B. Nelson, Jerome S. Pushkin, and Allan C.B. Richardson, *Cancer Risk Coefficients for Environmental Exposure to Radionuclides, Federal Guidance Report No. 13 (Draft)*, September 1999.

Exhibit 3-1

RISK COEFFICIENTS FOR NATURALLY-OCCURRING ALPHA EMITTERS

Series	Radionuclide	Half Life	Mortality Risk Coefficient (per pCi)	Morbidity Risk Coefficient (per pCi)
Th-232	Th-232	1.4E10 years	6.92E-11	1.01E-10
Th-232	Th-228	1.9 years	6.73E-11	1.07E-10
Th-232	Ra-224	3.66 days	1.01E-10	1.67E-10
Th-232	Po-216	0.15 seconds	NA	NA
Th-232	Bi-212	61 minutes	5.00E-13	7.10E-13
Th-232	Po-212	3.0E-6 seconds	NA	NA
U-238	Ra-226	1,600 years	2.65E-10	3.85E-10
U-238	Po-218	3 minutes	NA	NA
U-238	Po-214	1.6E-4 seconds	NA	NA
U-238	Po-210 (inorganic)	138 days	2.74E-10	3.77E-10
U-235	Po-231	3.3E4 years	NA	NA
U-235	Th-227	18.7 days	2.67E-11	4.74E-11
U-235	Ra-223	11 days	1.48E-10	2.38E-10
U-235	Po-215	1.8E4 seconds	NA	NA
U-235	Bi-211	2.2 minutes	NA	NA

Notes:
NA indicates that the coefficient is not available.
Lifetime risk coefficients are based on Table 2.2a of the September 1999 draft of *Federal Guidance Report No. 13*; becquerels (Bq) are converted to picocuries using a conversion factor of 3.70E-02 Bq/pCi.

Ideally, we would employ a risk coefficient for gross alpha that reflects the actual mix of alpha emitters in drinking water from those systems affected by each potential regulatory change. However, sufficient information on the prevalence of the individual alpha emitters is not available. Instead, we focus on the risk factors for two prevalent alpha emitters: radium-224 and radium-226.

For the preliminary analysis, we use a weighted average value of the risk coefficients for radium-224 and radium-226 to calculate the cancer risks associated with the changes to the monitoring requirements for gross alpha. This approach is intended to provide a "central tendency" national estimate. As indicated by the above exhibit, individual systems may achieve significantly different risk reductions if other radionuclides are present.

Based on the occurrence data in Chapter 2, we weight the risk coefficients by the relative presence of these two radionuclides. The resulting coefficients are used in assessing the affects of closing the gross alpha monitoring loophole, assuming that no other alpha emitters are present. For risk reductions associated with changing the gross alpha MCL, we employ the mortality and morbidity risk coefficients for radium-224 alone because the revised MCL would exclude radium-226.[4]

Exhibit 3-2 presents the resulting risk coefficients. The values in the last row of the table, the weighted averages of the risk coefficients for radium-224 and radium-226, are used in the analysis of risk reductions associated with decreases in gross alpha concentrations due to closure of the monitoring loopholes.

Exhibit 3-2

RISK COEFFICIENTS USED IN GROSS ALPHA ANALYSIS

Radionuclide	Half Life	Mortality Risk Coefficient (per pCi)	Morbidity Risk Coefficient (per pCi)
Ra-224	3.6 days	1.01E-10	1.67E-10
Ra-226	1,600 years	2.65E-10	3.85E-10
Average Weighted by Relative Prevalence of Ra-224 and Ra-226		1.14E-10	1.83E-10

Notes:
Lifetime risk coefficients are based on Table 2.2a of the September 1999 draft of *Federal Guidance Report No. 13*; becquerels are converted to picocuries using a conversion factor of 3.70E-02 Bq/pCi.
Weighted average values for gross alpha are based on the estimated relative prevalence of these two radionuclides in systems affected by closure of the monitoring loopholes.

Combined Radium: The approach used to develop risk coefficients for combined radium is similar to the approach used for gross alpha. To estimate cancer risk reductions from changes to the monitoring requirements for combined radium, we use a weighted average of the risk coefficients for radium-226 and radium-228; this weighted average is based the occurrence data presented in Chapter 2 for those systems legally out of compliance with the combined radium

[4] As discussed lin the section on incidental treatment, we also assess the effects of treatment installed to remove gross alpha on risks from certain other radionuclides present, using the risk factors appropriate for each radionuclide.

standard. For risk reductions resulting from limiting the contribution of radium-228 to the MCL, we use the risk coefficient for radium-228 alone. Exhibit 3-3 below presents the risk coefficients employed in the preliminary analysis for combined radium.[5]

Exhibit 3-3

RISK COEFFICIENTS USED IN COMBINED RADIUM ANALYSIS

Radionuclide	Half Life	Mortality Risk Coefficient (per pCi)	Morbidity Risk Coefficient (per pCi)
Ra-226	1,600 years	2.65E-10	3.85E-10
Ra-228	5.75 years	7.40E-10	1.04E-09
Average Weighted by Relative Prevalence of Ra-226 and Ra-228		5.66E-10	8.03E-10

<u>Notes:</u>
Lifetime risk coefficients are based on Table 2.2a of the September 1999 draft of *Federal Guidance Report No. 13*; becquerels are converted to picocuries using a conversion factor of 3.70E-02 Bq/pCi.
Weighted average values for combined radium are based on the estimated relative prevalence of these two radionuclides in systems affected by closure of the monitoring loopholes, based directly on the NIRS data.

Uranium: To determine the cancer risk coefficients for uranium, we calculate the simple average of the coefficients for uranium-234, -235, and -238, due to the lack of data on the prevalence of each isotope in those drinking water supplies potentially affected by each regulatory option. As shown in Exhibit 3-4, the coefficients for each of these isotopes are similar, so we expect that this simplified approach will not result in significant under- or over-estimates of risk even though the three uranium isotopes are prevalent in different proportions than implied by the averaging process.

[5] As discussed in the section on incidental treatment, we also assess the risk reductions attributable to removal of certain other radionuclides by the treatments installed to achieve the radium standards, using the appropriate risk factors for each radionuclide considered.

Exhibit 3-4

RISK COEFFICIENTS USED IN URANIUM ANALYSIS

Radionuclide	Half Life	Mortality Risk Coefficient (per pCi)	Morbidity Risk Coefficient (per pCi)
U-238	4.5E9 years	4.18E-11	6.40E-11
U-235	7.4E6 years	4.48E-11	6.96E-11
U-234	2.4E5 years	4.59E-11	7.07E-11
Simple Average for Uranium (U-234, U-235, U-238)		4.40E-11	6.81E-11

Notes:
Lifetime risk coefficients are based on Table 2.2a of the September 1999 draft of *Federal Guidance Report No. 13*; becquerels are converted to picocuries using a conversion factor of 3.70E-02 Bq/pCi.
The average values for uranium are simple (unweighted) averages of the risk coefficients for the isotopes listed, based directly on the NIRS data.

Next, we use the coefficients discussed above to determine lifetime and annual factors that indicate the cancer risks faced by individuals who ingest tap water. We assume water ingestion occurs over a life span of 70 years (the estimate of average life expectancy generally used in analyses of drinking water regulations) and that a year includes 365.25 days on average.

We convert the risk coefficients from FGR-13 into individual risk factors (expressed in terms of activity concentration -- per pCi/L of water) by assuming that, on average, an individual consumes 1.12 liters of water per day. This value is an estimate of the mean daily water ingestion rate for the total U.S. population (all ages), derived by averaging the mean ingestion rate for (1) community water supplies and (2) all sources (including tap, other, bottled, or missing sources of water). These two ingestion rates are averaged because the first value may underestimate daily average ingestion of drinking water from community water supplies since survey respondents may have erroneously reported consumption of tap water as "missing" or "other" sources. While the second value may be an overestimate, some of the other sources it includes may be derived from public water supplies.[6]

For comparison, we also calculate the average individual risk factors using a water ingestion rate of 2.21 liters per day, based on the average of the 90th percentile values for ingestion from the same data source. These "high end" factors are not used directly in the preliminary economic

[6] Based on EPA recalculation of data from: U.S. Environmental Protection Agency, *Estimated Per Capita Water Ingestion in the United States (Draft)*, June 1999; provided by John Bennett of EPA/OGWDW on November 10, 1999.

analysis (which focuses on providing central tendency estimates), but are taken into consideration by EPA when developing the regulations to ensure protection of sensitive sub-populations (consistent with Safe Drinking Water Act (SDWA) Section 1412(b)).

Using these assumptions, we calculate risk factors for both morbidity and mortality in terms of the change in cancer risks per person per pCi/L. The risk factors presented in Exhibit 3-5 (for average annual water consumption) are then employed in the following steps in the analysis.

Exhibit 3-5

ESTIMATED INDIVIDUAL RISK FACTORS (per pCi/L)

Regulatory Option	Morbidity		Mortality	
	lifetime ingestion	annual ingestion	lifetime ingestion	annual ingestion
Average Individual Risk Factors, Average Water Consumption (1.12 liters per day)				
Gross Alpha: changes in monitoring requirements (weighted average of Ra-224 and Ra-226)	5.24E-06	7.48E-08	3.26E-06	4.65E-08
Gross Alpha: changes in MCL (Ra-224 only)	4.77E-06	6.81E-08	2.90E-06	4.15E-08
Combined Radium: changes in monitoring requirements (weighted average of Ra-226 and Ra-228)	2.30E-05	3.28E-07	1.63E-05	2.32E-07
Combined Radium: changes in MCL (Ra-228 only)	2.98E-05	4.26E-07	2.12E-05	3.03E-07
Uranium: establish MCL (simple average of U-234, U-235, and U-238)	1.95E-06	2.79E-08	1.26E-06	1.81E-08
Average Individual Risk Factors, 90th Percentile Water Consumption (2.21 liters per day)				
Gross Alpha: changes in monitoring requirements (weighted average of Ra-224 and Ra-226)	1.03E-05	1.47E-07	6.39E-06	9.13E-08
Gross Alpha: changes in MCL (Ra-224 only)	9.37E-06	1.34E-07	5.70E-06	8.15E-08
Combined Radium: changes in monitoring requirements (weighted average of Ra-226 and Ra-228)	4.51E-05	6.44E-07	3.19E-05	4.56E-07
Combined Radium: changes in MCL (Ra-228 only)	5.85E-05	8.35E-07	4.16E-05	5.95E-07
Uranium: establish MCL (simple average of U-234, U-235, and U-238)	3.83E-06	5.47E-08	2.48E-06	3.55E-08

Changes in Occurrence and Exposure

The next steps in the analysis involve applying the individual risk factors from Exhibit 3-5 to the estimates of the reductions in occurrence associated with each regulatory change under consideration. We use the risk factors for annual ingestion for consistency with the cost analysis which presents results on an annual basis. The starting point for the analysis is the occurrence data presented in Chapter 2 of this report. For this preliminary analysis, we apply the categorization scheme used in EPA's cost model to calculate pre- and post-regulatory occurrence levels (in pCi/L) and estimate the percentage of systems in each system size category that would be required to achieve various removal rates under each regulatory option. We next estimate the number of people served by these systems and apply the risk factors discussed above to predict the risk reductions attributable to each option. We then assess the additional cancer risk reductions attributable to incidental treatment of other radionuclides present.

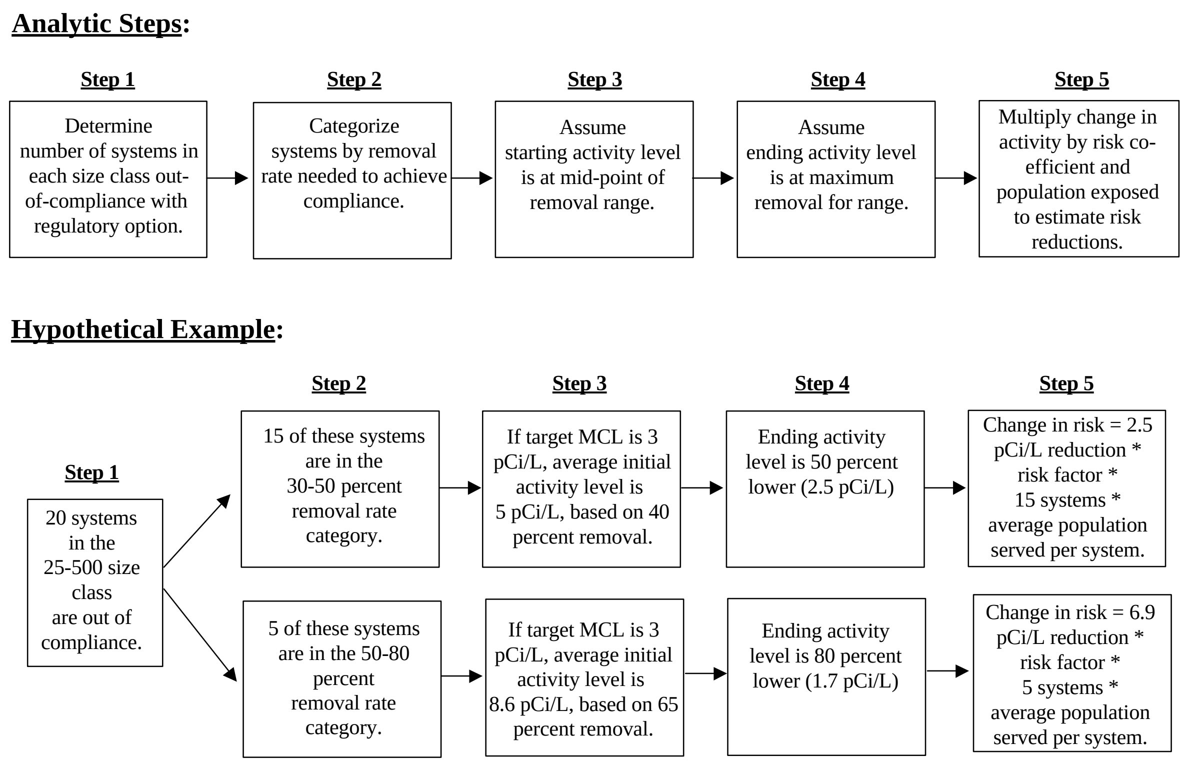
These steps are discussed in detail below. We begin by describing the approach for assessing the risk reductions associated directly with removal of the regulated radionuclides, then discuss the approach for assessing the risk reductions associated with the removal of other radionuclides present.

Direct Impacts

To assess the direct effects of each regulatory option on risks, we follow the steps illustrated in Exhibit 3-6. Appendix A presents the data on populations served that we used in the analysis.

Exhibit 3-6

OVERVIEW OF RISK ANALYSIS



Step 1: Using the occurrence data from Chapter 2, we first determine the number of systems that will be out of compliance with the regulatory option we are examining -- either closing a monitoring loophole or adjusting an MCL. These systems are identified in the "Findings" section of the prior chapter.[7]

Step 2: We further subdivide these systems by the removal rate needed to achieve compliance with the regulatory option, based on the occurrence level from the adjusted NIRS data. The removal rate categories are less than 30 percent removal, 30 to 50 percent, 50 to 80 percent, and above 80 percent, consistent with the categories used in the cost analysis.

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[7] This part of the risk analysis follows the same methodology regardless of whether the occurrence was calculated directly from NIRS or using a lognormal probability distribution.

Step 3: For each removal rate category, we next estimate the systems' original occurrence levels by back-calculating from the regulatory level to the mid-point of the removal rate range. (We use the mid-point to avoid biasing the results.)

For example, as illustrated in Exhibit 3-6, systems categorized as requiring between 30 and 50 percent removal are assumed to require 40 percent removal on average. If the desired occurrence level (i.e., the target or post-regulatory MCL) is 3 pCi/L, we assume that the original (or baseline) occurrence level is 5 pCi/L, since a system with occurrence at 5 pCi/L would require 40 percent removal to achieve compliance with an MCL of 3 pCi/L.

Step 4. For each category, we assume that the removal rate actually achieved is the maximum for the removal rate category. In other words, we assume the system achieves a higher level of removal than necessary to meet the MCL on average (e.g., due to the difficulties in fine-tuning treatments to exactly achieve the regulatory standards and the desire to assure that there is little chance of occasionally exceeding the MCL). Thus the actual removal rates are assumed to be 30, 50, or 80 percent, or the maximum for the system size category (generally 95 percent).

Continuing with the above example, we assume that these systems (with an original occurrence level of 5 pCi/L) would install a treatment with 50 percent removal efficiency on average, thus reducing their actual post-compliance occurrence levels to 2.5 pCi/L (5 * (1 - 0.5) = 2.5). The resulting change in occurrence, therefore, is 2.5 pCi/L (5 - 2.5 = 2.5) for these systems.

Step 5. Next, we estimate the number of people affected nationally by the reduction in occurrence and calculate the resulting change in cancer risks. We use data on the populations served for each size class (in Appendix A) to estimate the average number of people affected per system. We then multiply the change in activity level by the risk coefficient and by the population exposed to determine the cancer risks avoided.

For example, if 15 systems in the 25 - 500 size class require between 30 and 50 percent removal, and these systems serve 158 persons on average, 2,370 people will be affected nationally by the 2.5 pCi/L reduction calculated above. If the annual risk factor for this regulatory option is 2.0E-6, then this change in exposure will lead to a reduction of 0.01 statistical cancer cases annually.

To determine the total number of statistical cancer cases avoided (morbidity), we perform these steps for the radionuclides directly addressed by each regulatory option (closing the monitoring loopholes and adjusting the MCLs) for each system size category and sum the results. We then repeat these steps to assess mortality risks. To determine the number of nonfatal cases avoided, we subtract the results for mortality from the results for morbidity.

Incidental Treatment

After completing the above steps for each individual regulatory option, we assess the incidental effects of treatment on other radionuclides present. As discussed in Chapter 2, we estimate radionuclide occurrence based on two different approaches. First, we assume that national occurrence is directly proportional to the occurrence levels found in the NIRS database. Second, we fit a lognormal distribution to the NIRS data and estimate national occurrence based on this distribution. For this preliminary analysis, we estimate co-occurrence of radionuclides based only on the direct proportions approach. We then use this estimate to determine the incremental effect of removal of other radionuclides under both the direct proportions and lognormal approaches. In other words, if the direct proportion approach leads us to estimate that incidental treatment increases risk reductions by 0.1 case annually, we assume incidental treatment will also increase risk reductions by 0.1 case under the lognormal approach.

Consistent with the assumptions elsewhere in this analysis, we continue to assume that treatment to remove gross alpha is equally effective in removing combined radium and vice-versa. Furthermore, we assume that treatment for radium and gross alpha has a negligible effect on uranium levels and vice-versa. This latter assumption is based on our finding that uranium often does not occur at levels of concern in systems that also have elevated levels of gross alpha or combined radium. In addition, treatments installed to remove uranium are not always as effective in removing alpha emitters or radium.[8]

The approach for assessing these impacts varies depending on the assumptions regarding which regulatory options ultimately will be implemented. We first discuss the analysis of incidental treatment assuming that only some of the options for gross alpha or combined radium are implemented, and then discuss the analysis under the assumption that all of the options are implemented.

Independent implementation: EPA could choose to close only one of the monitoring loopholes (e.g., to close the gross alpha loophole but not the combined radium loophole) or to implement only one of the revised MCLs (e.g., to limit gross alpha to 10 pCi/L but leave the combined radium MCL unchanged). The effects of incidental treatment will depend on the option selected. For example, if the gross alpha loophole is closed, but the combined radium regulations remain the same, only those systems that take action (i.e., install treatment, increase blending, or change water sources) to comply with the revised gross alpha requirements will reduce their concentrations of combined radium. We assume that the co-occurring radionuclides (e.g., combined

[8] Treatment to remove the radionuclides assessed in this report will also reduce the levels of other contaminants in the water; we do not quantify these other impacts in this preliminary analysis.

radium) will be reduced by a percentage equal to the removal rate for the radionuclides directly addressed by the regulatory option (e.g., gross alpha).

To avoid double-counting the risk reduction resulting from the incidental treatment of radium-226, which is currently included in the definition of both combined radium and gross alpha, our approach varies depending on the regulatory scenario. The risk factors and occurrence data used to assess the direct impacts of closing the gross alpha loophole include radium-226, so we add only the incidental decrease in radium-228. The risk factors and occurrence data used to assess the change in the gross alpha MCL do not include radium-226 (since the MCL is redefined to exclude this radionuclide), and the incidental risk reductions include both radium-226 and radium-228. For combined radium, we follow a similar approach. Both radium-226 and radium-228 are included in the analysis of the direct impacts for closing the loophole, so we calculate the incidental effects of treatment on gross alpha than subtract the radium-226 value to avoid double-counting. For the radium MCL (which limits radium-228), radium-226 is included in the analysis of the effects of incidental treatment on gross alpha.[9]

Joint implementation: EPA may decide to close both loopholes and/or implement both proposed MCLs. Under this scenario, we conduct the analysis of incidental treatment in two steps, first considering the additional risk reductions that may occur for systems that are out of compliance with the regulatory options for both gross alpha and combined radium, and then considering the additional risk reductions that may occur for systems that are out of compliance with only one of the options. In both cases, we adjust the results to insure that the risk reduction attributed to removal of radium-226 is only counted once (as noted above, radium-226 is included in the current regulatory definition of both gross alpha and combined radium).

For systems out of compliance for both gross alpha and combined radium, consideration of joint implementation requires adjustments for two factors: (1) avoiding double-counting of removal of radium-226, and (2) taking into account differences in removal rates. Hence we net out any double counting of radium-226, and, in cases where different removal rates are required to achieve the gross alpha and combined radium standards, we apply the higher removal rate to both groups of radionuclides. For example, considering the two groups of radionuclides separately may lead us to use a removal rate of 50 percent for gross alpha and 80 percent for combined radium; whereas, if we assess them jointly, we would apply an 80 percent removal rate in both cases. Thus, we first identify systems with differing removal rates, then calculate the incremental effects of the additional removal.

[9] The revised baseline used to assess the changes in the MCLs assumes that both loopholes are first closed. If the MCLs are changed without first closing the monitoring loopholes, the risk reductions will differ somewhat from the estimates presented in this preliminary analysis.

For systems out of compliance for only one group of radionuclides (either gross alpha or combined radium), consideration of joint treatment could have a more significant effect on the risk results. For example, considering the two groups of radionuclides separately may lead us to use a removal rate of 50 percent for gross alpha and assume no removal of combined radium; whereas, if we assess them jointly, we would apply a 50 percent removal rate in both cases. In these cases, we apply the removal rate used for the relevant standard to the occurrence level for the other group of radionuclides. In other words, if a system would apply a 50 percent removal rate to achieve the combined radium standard, we assume their gross alpha levels would decrease by the same percentage (again avoiding double-counting of the risk reductions associated with removal of radium-226). Note that the impact of this additional removal on the risk results is limited by the fact that concentrations of the co-occurring group of radionuclides are relatively low (below the target MCL).

Valuation

The final step in the analysis of risk reductions involves estimating the value of avoiding these risks. Below, we provide background information on the economic concepts that provide the foundation for benefits valuation, and describe the methods that are typically used by economists to value risk reductions, such as wage-risk, cost of illness, and contingent valuation studies. Next, we describe the use of these techniques to estimate the value of the risk reductions attributable to the regulatory options for radionuclides in drinking water. We discuss the approach for valuing the reductions in fatal risks, then the approach for valuing the reductions in nonfatal risks.

Methods for Benefits Valuation

This section provides a brief overview of the theory and methods used to value reductions in human health risks. It describes the concept of "willingness to pay," outlines standard valuation approaches such as wage-risk, cost of illness, and contingent valuation studies, and explains how estimates from these studies can be used to develop benefit values for environmental regulations. Additional information on these topics is available in the EPA and OGWDW guidance documents on benefits assessment.[10]

The practice of benefits valuation is based on the discipline of welfare economics, in which value is measured by the "satisfaction" or "utility" individuals derive from an environmental

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[10]U.S. Environmental Protection Agency, *Guidelines for Preparing Economic Analysis (Review Draft)*, June 1999; U.S. Environmental Protection Agency, *Assessing the Benefits of Drinking Water Regulations: A Guidance Manual*, forthcoming.

improvement. Individuals reveal these values through their willingness to pay for effects of these improvements. Willingness to pay is the maximum amount of money an individual would voluntarily exchange to obtain an improvement (e.g., a reduction in health risks), given his or her available financial resources and desired spending on other goods and services.

Willingness to pay is not the same as price or cost. Price is determined by the interactions of buyers and sellers in the marketplace, while cost is a function of the materials, processes, and labor used to create the good or service. Some individuals' willingness to pay for a particular good or service will exceed the market price, in which case they benefit from the ability to buy the good or service at the (lower) market price. Other individuals' willingness to pay will be less than the market price, in which case they will not buy the good or service.

Because willingness to pay for improved health is difficult to directly observe in the marketplace, economists most commonly use three types of studies to estimate the value of reduced fatal and nonfatal risks: wage-risk studies; cost of illness studies; and contingent valuation studies. EPA regulatory analyses often transfer estimates from existing studies to value the benefits of alternative policies, as discussed below.

Wage-risk studies are often used to value changes in fatal risks; i.e., premature mortality. These studies examine the additional compensation workers demand for taking riskier jobs, typically focusing on small changes in the risk of accidental workplace fatalities. Researchers use statistical methods to separate the changes in compensation that are associated with changes in risks from the changes in compensation that are associated with other job characteristics.

The wage-risk method has several advantages; for example, the data and methods it uses are well-established, and it directly measures changes in the risk of premature mortality. This method is widely used to value reductions in fatal risks, and the available studies have been subject to extensive peer review. However, these studies generally address risks from work place accidents that differ in significant ways from the cancer and other risks associated with environmental regulations.

The differences in the types of risks addressed can result in various types of bias when estimates are transferred from wage-risk studies to value environmental risks. Many of these biases appear to counterbalance each other, although the degree to which they do so is difficult to quantify. For example, death is often more immediate in the case of workplace accidents than in the case of cancers, which may have long latency periods between exposure and onset as well as long periods of illness prior to death. However, the value of this delay may be counterbalanced by people's dread of lengthy illnesses. The characteristics of the population addressed by available wage-risk studies may also differ from the characteristics of the populations affected by the regulations; for example, most wage-risk studies use data on middle-aged laborers, while environmental regulations often affect all members of the population. Despite these limitations, wage-risk studies may currently provide the most defensible available estimates of the value of mortality risk reductions.

Cost of illness studies are often used to value changes in nonfatal (morbidity) risks, but are not a measure of willingness to pay. These studies examine the actual direct (e.g., medical expenses) and indirect (e.g., lost work or leisure time) costs incurred by affected individuals. In general, the logic for using cost of illness studies to value benefits is as follows: if illness imposes the cost of medical expenditures and foregone earnings, then a regulation leading to a reduction in illness yields benefits equal at minimum to the costs saved.

The cost of illness method is well-developed, widely applied, and easily explained. It addresses direct and indirect costs that are relatively easy to measure and has been used to provide estimates for large numbers of illnesses. In most cases, however, cost of illness studies may significantly underestimate individuals' willingness to pay for decreased health risks because they do not address factors such as pain and suffering.[11] In addition, environmental regulations generally reduce future risks, while the cost of illness method considers effects that have already occurred -- and hence does not address risk aversion. Nonetheless, because of their widespread availability and ease of use, cost of illness estimates are often used to value the nonfatal effects of environmental regulations.

Contingent valuation studies use surveys to elicit statements of willingness to pay and are often applied to value both fatal and nonfatal health effects. For example, researchers might ask individuals what they would be willing to pay for a specified reduction in the risk of developing stomach cancer from long-term exposure to contaminants in drinking water. The researchers can define the scenario to address factors that may influence total willingness to pay, such as the pain and suffering associated with an illness, thereby providing a more complete estimate of willingness to pay. Such surveys must be carefully designed and administered, however, if they are to provide reliable and precise estimates, because the individuals surveyed are usually not required to make actual payments and may have difficulty understanding the scenario presented. For example, survey respondents may understate their willingness to pay if they believe that wealthier individuals (or the government) will pay related costs. Contingent valuation surveys have been completed for a relatively small subset of the health effects associated with environmental regulations.

Benefits transfers from the above types of studies are often used in EPA regulatory analyses. Rather than conducting new primary research on the value of reducing risks to human health, analysts often use data from existing wage-risk, cost of illness, contingent valuation, or other

[11] Cost of illness estimates may also occasionally overstate willingness to pay, particularly if the availability of insurance leads people to agree to treatments that they would not fully finance themselves.

studies to estimate these values. Because these studies usually do not address the specific effects of concern (e.g., cancer risks from radionuclides in drinking water), EPA's approach requires the application of "benefit transfer" techniques. Benefit transfer refers to the use of valuation information from one or more existing studies to assess similar, but not identical, effects associated with a regulation or policy. To conduct a benefit transfer, analysts first must evaluate the quality and applicability (e.g., the similarity of the health effects and populations experiencing the effects) of the available studies, then apply the results of selected studies (with any necessary adjustments) to the policy of concern.

Fatal Risks

To estimate the monetary value of reduced fatal risks (i.e., risks of premature death from cancer) predicted under different regulatory options, we apply the value of a statistical life (VSL) approach. VSL does not refer to the value of an identifiable life, but instead to the value of small reductions in mortality risks in a population. A "statistical" life is thus the sum of small individual risk reductions across an entire exposed population.

For example, if 100,000 people would each experience a reduction of 1/100,000 in their risk of premature death as the result of a regulation, the regulation can be said to "save" one statistical life (i.e., 100,000 * 1/100,000). If each member of the population of 100,000 were willing to pay $20 for the stated risk reduction, the corresponding value of a statistical life would be $2 million (i.e., $20 * 100,000). VSL estimates are appropriate only for valuing small changes in risk; they are not values for saving a particular individual's life.

EPA has identified 26 VSL studies (that use the wage-risk or contingent valuation method) which have been peer reviewed and recommended for use in EPA policy analyses.[12] The best estimates from these studies range from $0.8 million to $16.9 million and approximate a Weibull distribution with a mean of $5.9 million (in 1998 dollars). To value the changes in fatal risks associated with the radionuclides regulation, we apply a mean estimate of $5.9 million and low and high end estimates of $1.5 million and $11.5 million, reflecting the uncertainty in these estimates. The low and high end estimates represent the tenth and ninetieth percentile of the distribution of VSL estimates, respectively.

Use of these estimates to value the averted risks of premature death associated with the regulatory options for radionuclides is an example the benefit transfer technique, since the subject of most of the studies (i.e., job-related risks) differs from the fatal cancer risks averted by the regulatory

[12] U.S. Environmental Protection Agency, *The Benefits and Costs of the Clean Air Act, 1970 to 1990*, October 1997, Appendix I; and U.S. Environmental Protection Agency, *Guidelines for Preparing Economic Analysis (Review Draft)*, June 1999, Chapter 7.

options. Applying these studies results in several sources of potential bias; however, quantitative adjustments to address these biases generally have not been developed or adequately tested and may be counterbalancing.

Some of the key sources of bias include the characteristics of the averted risks (whether they are voluntary or involuntary, ordinary or catastrophic, delayed or immediate, natural or man-made, etc.); the demographic characteristics of the group affected (e.g., age, income); the lag between exposure and diagnosis or incidence of the disease (latency) as well as between incidence and death; the baseline health status (i.e., whether a person is currently in good health) of affected individuals; and the presence of altruism (i.e., individual's willingness to pay to reduce risks incurred by others). For example, accidental deaths may be more immediate than cancer-related deaths, which often involve a latency period between exposure and diagnoses. Some argue that the values reported for accidental deaths should be reduced (or discounted) to reflect this latency period when applied to cancers. However, there are several other sources of bias that may counterbalance the effects of latency. These factors include the value of avoiding the dread, pain and suffering associated with a lengthy illness as well as several other factors. The net effect of these sources of biases is difficult to determine, and these issues are currently being investigated in more detail by EPA.[13]

Because of the uncertainties in these estimates, we estimate the value of reductions in fatal risks attributable to the radionuclides regulations using the following estimates, as discussed above:

Mean Estimate: *Value of fatal risk reductions = Statistical lives saved* * $5.9 million *per statistical life*

Low End Estimate: *Value of fatal risk reductions = Statistical lives saved* * $1.5 million *per statistical life*

High End Estimate: *Value of fatal risk reductions = Statistical lives saved* * $11.5 million *per statistical life*

Nonfatal Risks

To estimate the monetary value of reduced nonfatal cancers under different regulatory options, ideally we would be able to predict the types of cancers averted by the regulations. However, exposure to radionuclides can result in a range of cancers. The type of cancer depends largely on where the radionuclides localize in the body as a result of one's metabolism. While some

[13] These issues are discussed in more detail in EPA's draft *Guidelines for Preparing Economic Analysis* (1999).

radionuclides are associated with specific cancer types (such as leukemia, or colon, stomach, thyroid, bone, and liver cancer), many are not, and radiation risk models generally consider several cancer sites including the esophagus, stomach, colon, liver, lung, bone, skin, breast, ovary, bladder, kidney, thyroid, red marrow (leukemia), as well as residual impacts on all remaining cancer sites combined.

Given the difficulties inherent in predicting the types of cancers averted by the radionuclides regulations, we review the cost of illness estimates available for a range of nonfatal cancers that may be most likely to result from exposure to radionuclides via tap water ingestion.[14] EPA has developed cost of illness estimates (medical costs only) for selected cancers, as reported in Exhibit 3-7.[15] Note that these estimates are preliminary and are now undergoing review.

Exhibit 3-7

LIFETIME AVOIDED MEDICAL COSTS FOR SURVIVORS
(1998 dollars)

Type of Cancer	Date Data Collected	Number of Cases Studied	Estimated Survival Rate	Mean Value per Nonfatal Case
Colorectal cancer	1974-1981	19,673 Medicare patients	53 percent (after 10 years)	$109,800 (for typical individual diagnosed at age 70)
Stomach cancer	1974-1981	3,228 Medicare patients	< 20 percent (after 5 years)	$90,800 (for typical individual diagnosed at age 70)
Bone cancer	N/A; theoretical approach		64 percent (after 5 years, includes bone and joint cancers)	$91,800 - $113,200

Notes:
Exhibit reports present value (at the time of onset) of the lifetime costs of the illness (using a 7 percent discount rate). Values were inflated to 1998 dollars based on the consumer price index for the costs of medical commodities and services.
Source: U.S. Environmental Protection Agency, *Cost of Illness Handbook (draft)*, September 1998.

[14] U.S. Environmental Protection Agency, *Cost of Illness Handbook (draft)*, prepared by Abt Associates, September 30, 1998, Chapters II.1, II.2, and II.9.

[15] Because liver cancer has a high mortality rate (approximately 97 percent after 21 years), we do not consider it in the valuation of nonfatal risks; fatal risks are assessed using the VSL method discussed earlier in this section. We also do not include the estimates for kidney cancer, because the cost of illness analysis does not separate the costs for survivors from the costs for non-survivors.

For colorectal and stomach cancers, these estimates of direct medical costs are derived from a study conducted by Baker et al., which uses data from a sample of Medicare records for 1974 - 1981.[16] These data include the total charges for inpatient hospital stays, skilled nursing facility stays, home health agency charges, physician services, and other outpatient and medical services. These costs are inflated using the medical care components of the consumer price index. EPA combines these data with estimates of survival rates and treatment time periods to determine the average costs of initial treatment and maintenance care for patients who do not die of the disease. Information on mean age at diagnosis and survival rates are generally derived from a database maintained by the National Cancer Institute, that covers the years 1973 - 1993.

For bone cancer (which is not addressed by Baker et al.), EPA uses a theoretical approach that combines average values for initial and maintenance care from the Baker study with estimates of the time period over which maintenance care is needed. The range reported in the exhibit above reflects two different assumptions regarding the duration of maintenance care; a 10 year duration vs. a duration based on average life expectancy at the age of diagnosis.

The EPA study also provides estimates of time lost due to illness for colorectal and stomach cancer. For individuals diagnosed at age 70, the average lifetime lost hours are 2,266 for colorectal cancer and 2,942 for stomach cancer. These estimates are based on a study conducted by Hartunian et al., which calculated lost work time for the first year post-diagnoses.[17] EPA then adjusts these estimates to reflect lifetime lost hours including lost leisure time.[18] For the typical stomach and colorectal cancer survivor, all of the lost hours are assumed to occur in the first year post-diagnoses.

Because the cancers most often linked to the radionuclides of concern are usually diagnosed late in life, this lost time is most likely to be leisure time during retirement. Determining the appropriate value for such lost time is difficult, and is hence not included in the valuation estimates.

Studies of other diseases suggest that cost of illness values may significantly understate total willingness to pay; however, little information is available on individuals' willingness to pay to avoid

[16] Baker, Mary S. et al., "Site Specific Treatment Costs for Cancer: An Analysis of the Medicare Continuous History Sample File," *Cancer Care and Cost. DRGs and Beyond*. Richard M. Scheffler and Neil C. Andrews, Editors, Ann Arbor, MI: Health Administration Press Perspectives, 1989.

[17] Hartunian, N.S., C.N. Smart, and M.S. Thompson, *The Incidence of Economic Costs of Major Health Impairments*. Lexington, MA: Lexington Books, 1981.

[18] U.S. Environmental Protection Agency. *Cost of Illness Handbook (draft)*, September 1998, Chapters II.1, II.2, and II.9

cancer risks. Exhibit 3-8 summarizes the studies that compare cost of illness estimates to estimates of total willingness to pay. These studies estimate total willingness to pay based on contingent valuation or averting behavior studies. They vary in terms of the types of expenditures addressed in the cost of illness studies; some exclude lost earnings and some exclude costs borne by others (e.g., through insurance).

Exhibit 3-8

COMPARISON OF COST OF ILLNESS AND WILLINGNESS TO PAY ESTIMATES

Health Effect	Study	Reported Range for Ratio of Willingness to Pay to Cost of Illness Estimates[1]
Several minor health effects (cough, congestion, headache, etc.)	Berger et al., 1987	3.1 - 78.9
Angina episodes	Chestnut et al., 1988, 1996	2.9 - 8.0
Asthma	Rowe and Chestnut, 1985	3.2 - 9.8
Unspecified effects of ozone	Dickie and Gerking, 1991	1.9 - 4.2
Childhood exposure to lead	Agee and Crocker, 1996	2.1 - 20.0
Chronic bronchitis	U.S. EPA, 1997	3.4 - 6.3

[1]For example, the Berger study suggests that, for several minor health effects, willingness to pay to avoid these health effects is anywhere from three to almost 80 times larger than the cost of illness estimates.
For more information on these studies as well as full citations, see: U.S. Environmental Protection Agency, *Handbook for Noncancer Health Effects Valuation (Draft),* September 30, 1998.

The ratios reported in Exhibit 3-8 cover a broad range, suggesting that the relationship between cost of illness and willingness to pay values varies greatly depending on the health effect of concern and the study methodology. Therefore we do not apply these ratios when considering the extent to which cost of illness estimates may understate the value of nonfatal cancer risks averted by the radionuclides rule. However, as discussed in the limitations section of this chapter, these ratios indicate that the use of cost of illness estimates may substantially understate the value of related benefits.

For the preliminary analysis, we use the approximate mid-point and high and low estimates from Exhibit 3-7 to estimate the avoided medical costs attributable to reducing nonfatal cancer risks, as summarized below.

Mid-Point Estimate: *Value of nonfatal risk reductions (medical costs only) = Statistical cases averted * $0.10 million*

Low End Estimate: *Value of nonfatal risk reductions (medical costs only) = Statistical cases averted * $0.09 million*

High End Estimate: *Value of nonfatal risk reductions (medical costs only) = Statistical cases averted * $0.11 million*

As noted earlier, these cost of illness estimates are likely to understate total willingness to pay for avoiding these cancers. They exclude certain types of avoided costs (e.g., lost work or leisure time). In addition, the cost of illness approach does not address other factors that influence willingness to pay, such as risk aversion and the desire to avoid pain and suffering.

FINDINGS

In this section, we present the results of the risk reduction analysis. The initial sections discuss the results for community water systems for gross alpha, combined radium, and uranium. Next we summarize the results and discuss the monetary value of the changes in risk. The final section summarizes the implications of the limitations in our analysis.

Community Water Systems: Gross Alpha and Combined Radium

Below, we present the results of the risk analysis for closing loopholes in the existing monitoring requirements and changing the MCLs for gross alpha and combined radium.[19] These risk reductions are assessed for ground water systems only because we do not expect these radionuclides to occur above levels of concern in surface water. Appendix C presents detailed results for each system size category.

Closing the Monitoring Loopholes

Under the initial baseline for the analysis, some systems legally exceed the current MCLs for combined radium and gross alpha, due to the loopholes in the existing monitoring requirements (discussed in Chapter 1). The first step in the analysis of the regulatory options therefore includes assessing the effects of closing the monitoring loopholes, so that all systems are required to comply with the existing MCLs. Exhibit 3-9 presents the risk reductions attributable to closing each

[19] This chapter does not address risk reductions associated with full compliance with the existing regulations (i.e., with elimination of illegal noncompliance) since these reductions are not attributable to the changes EPA is now considering.

loophole independently and then to closing both loopholes at the same time, under the two approaches for estimating occurrence described in Chapter 2.

Exhibit 3-9

ANNUAL CANCER RISKS AVOIDED: CLOSING THE MONITORING LOOPHOLES
(community water systems)

Regulatory Option	System Size Class (population served)	Directly Proportional: Total Statistical Cases Avoided	Directly Proportional: Fatal Statistical Cases Avoided	Lognormal Distribution: Total Statistical Cases Avoided	Lognormal Distribution: Fatal Statistical Cases Avoided
Close gross alpha loophole <u>only</u> (MCL = 15 pCi/L)	25 - 500 persons	0.04 cases	0.03 cases	0.04 cases	0.03 cases
	501 - 1 million persons	none	none	0.31 cases	0.19 cases
	Subtotal	**0.04 cases**	**0.03 cases**	**0.35 cases**	**0.22 cases**
Close combined radium loophole <u>only</u> (MCL = 5 pCi/L)	25 - 500 persons	0.05 cases	0.04 cases	0.06 cases	0.04 cases
	501 - 1 million persons	0.25 cases	0.17 cases	0.48 cases	0.33 cases
	Subtotal	**0.31 cases**	**0.21 cases**	**0.54 cases**	**0.37 cases**
Close <u>both</u> gross alpha and combined radium loopholes <u>jointly</u>	25 - 500 persons	0.06 cases	0.04 cases	0.07 cases	0.05 cases
	501 - 1 million persons	0.25 cases	0.17 cases	0.79 cases	0.53 cases
	Subtotal	**0.32 cases**	**0.22 cases**	**0.86 cases**	**0.57 cases**

<u>Notes:</u>
1. The risk reductions for each regulatory option include estimates of the benefits of incidental treatment, i.e., of the effects of treatment for gross alpha on combined radium levels and vice-versa.
2. The benefits of incidental treatment are calculated using the directly proportional approach.
3. Detail may not add to total due to rounding.

For all the regulatory scenarios, the risks attributable to closing the monitoring loopholes for gross alpha and combined radium are significantly smaller under the directly proportional approach. These differences result because the lognormal approach generally leads to higher estimates of the number of systems out of compliance, as well as higher estimates of the amount of removal these systems need to achieve to comply with the MCL. If only the gross alpha loophole is closed, the total cancer risk reductions are over eight times larger under the lognormal approach than under the direct proportions approach; 0.35 cases avoided compared to 0.04 cases. If just the combined radium loophole is closed, the risk reductions estimated under the lognormal approach are one and three-quarter times those estimated under the directly proportional approach; 0.54 total cases avoided vs 0.31 cases. Under both occurrence methodologies, the greatest reduction in risk is attributable to large systems treating for combined radium.

Implementing both regulatory options simultaneously leads to risk reductions that are slightly smaller than the sum of the results for the individual options (0.32 to 0.86 cases for the combined options), because many systems are affected by both sets of requirements. As discussed in Chapter 2, we estimate that between 210 and 250 systems are legally exceeding the gross alpha MCL, while 270 to 320 systems are legally exceeding the combined radium MCL. These totals include about 170 systems that are legally exceeding both MCLs. Hence if both loopholes are closed, a total of about 310 to 400 systems would be affected.

Revising the MCLs

Once the monitoring loopholes are closed and all systems comply with the current MCLs, the next step in the analysis considers the effects of changes to the MCLs. Exhibit 3-10 reports the risk reductions attributable to these changes.

Exhibit 3-10

ANNUAL CANCER RISKS AVOIDED:
CHANGING THE GROSS ALPHA AND COMBINED RADIUM MCLS
(statistical cases)

Regulatory Option	System Size Class (population served)	Directly Proportional		Lognormal Distribution	
		Total Statistical Cases Avoided	Fatal Statistical Cases Avoided	Total Statistical Cases Avoided	Fatal Statistical Cases Avoided
Implement gross alpha MCL at 10 pCi/L, net of radium-226, only	25 - 500 persons	0.03 cases	0.02 cases	0.04 cases	0.02 cases
	501 - 1 million persons	0.49 cases	0.32 cases	0.66 cases	0.43 cases
	Subtotal	**0.53 cases**	**0.35 cases**	**0.70 cases**	**0.45 cases**
Implement combined radium MCL at 5 pCi/L, with radium-228 limited at 3 pCi/L, only	25 - 500 persons	0.01 cases	0.01 cases	0.02 cases	0.01 cases
	501 - 1 million persons	0.48 cases	0.33 cases	0.61 cases	0.42 cases
	Subtotal	**0.50 cases**	**0.34 cases**	**0.63 cases**	**0.43 cases**
Implement both gross alpha and combined radium MCLs jointly	25 - 500 persons	0.04 cases	0.02 cases	0.05 cases	0.03 cases
	501 - 1 million persons	0.74 cases	0.49 cases	1.04 cases	0.69 cases
	Subtotal	**0.78 cases**	**0.52 cases**	**1.08 cases**	**0.72 cases**

Notes:
1. The risk reductions for each regulatory option include estimates of the benefits of incidental treatment, i.e., of the effects of treatment for gross alpha on combined radium levels and vice-versa.
2. The benefits of incidental treatment are calculated using the directly proportional approach.
3. Detail may not add to total due to rounding.

The risks attributable to these changes in the MCLs range from 0.53 to 0.70 total cases avoided for gross alpha, 0.50 to 0.63 total cases avoided for combined radium, and 0.78 to 1.08 total cases avoided if both MCLs are revised at the same time. For all three scenarios, the lognormal approach results in larger estimates of risk reductions than does the direct proportions approach.

As discussed in Chapter 2, we estimate that between about 500 to 610 systems would exceed the revised gross alpha MCL, while about 210 systems would exceed the limit on radium-228. The risk results are similar for these options despite the large difference in the number of systems affected largely because we assume that gross alpha poses a lower level of risk (see Exhibit 3-5 and preceding discussion). If both the revised gross alpha standard and the revised combined radium standard are implemented jointly, the number of systems affected ranges from 570 to 670 systems. The associated risks are less than the sum of the risks associated with implementing each option independently because about 150 systems are out of compliance with both revised MCLs.

Community Water Systems: Uranium

In the previous chapter, we estimate that setting an MCL for uranium will affect from 40 to 970 systems, depending on the MCL selected and the approach used to estimate occurrence. Most affected systems would be ground water systems. As indicated in Exhibit 3-11, establishing an MCL for uranium would lead to an annual reduction of less than 0.01 to 2.12 cancer cases, depending on the MCL selected and the occurrence methodology employed. More than half of these cases would be fatal. As noted earlier, we do not assess the effects of treatment to remove uranium on gross alpha and combined radium levels, because these radionuclides rarely co-occur at levels of concern and may require different treatments.

Exhibit 3-11

ANNUAL STATISTICAL CANCER CASES AVOIDED: SETTING AN URANIUM MCL
(community water systems)

Regulatory Option	System Size Class (population served)	Directly Proportional			Lognormal Distribution		
		Ground Water Systems	**Surface Water Systems**	**All Systems**	**Ground Water Systems**	**Surface Water Systems**	**All Systems**
Uranium MCL = 20 pCi/L (20 μg/L)	25 - 500	0.08 cases total (0.05 cases fatal)	<0.01 cases total (<0.01 cases fatal)	0.08 cases total (0.05 cases fatal)	0.12 cases total (0.08 cases fatal)	<0.01 cases total (<0.01 cases fatal)	0.12 cases total (0.08 cases fatal)
	501 - 1 million	0.07 cases total (0.04 cases fatal)	<0.01 cases total (<0.01 cases fatal)	0.07 cases total (0.04 cases fatal)	1.50 cases total (0.97 cases fatal)	0.49 cases total (0.32 cases fatal)	1.99 cases total (1.29 cases fatal)
	Total	**0.15 cases total (0.10 cases fatal)**	**<0.01 cases total (<0.01 cases fatal)**	**0.15 cases total (0.10 cases fatal)**	**1.62 cases total (1.05 cases fatal)**	**0.50 cases total (0.32 cases fatal)**	**2.12 cases total (1.37 cases fatal)**
Uranium MCL = 40 pCi/L (40 μg/L)	25 - 500	0.04 cases total (0.02 cases fatal)	<0.01 cases total (<0.01 cases fatal)	0.04 cases total (0.02 cases fatal)	0.10 cases total (0.06 cases fatal)	<0.01 cases total (<0.01 cases fatal)	0.10 cases total (0.07 cases fatal)
	501 - 1 million	<0.01 cases total (<0.01 cases fatal)	<0.01 cases total (<0.01 cases fatal)	<0.01 cases total (<0.01 cases fatal)	1.12 cases total (0.73 cases fatal)	0.32 cases total (0.21 cases fatal)	1.44 cases total (0.94 cases fatal)
	Total	**0.04 cases total (0.02 cases fatal)**	**<0.01 cases total (<0.01 cases fatal)**	**0.04 cases total (0.02 cases fatal)**	**1.22 cases total (0.79 cases fatal)**	**0.32 cases total (0.21 cases fatal)**	**1.54 cases total (1.00 cases fatal)**
Uranium MCL = 80 pCi/L (80 μg/L)	25 - 500	0.01 cases total (<0.01 cases fatal)	<0.01 cases total (<0.01 cases fatal)	0.01 cases total (<0.01 cases fatal)	0.07 cases total (0.05 cases fatal)	<0.01 cases total (<0.01 cases fatal)	0.07 cases total (0.05 cases fatal)
	501 - 1 million	<0.01 cases total (<0.01 cases fatal)	<0.01 cases total (<0.01 cases fatal)	<0.01 cases total (<0.01 cases fatal)	0.77 cases total (0.50 cases fatal)	0.19 cases total (0.12 cases fatal)	0.95 cases total (0.62 cases fatal)
	Total	**0.01 cases total (<0.01 cases fatal)**	**<0.01 cases total (<0.01 cases fatal)**	**0.01 cases total (<0.01 cases fatal)**	**0.84 cases total (0.54 cases fatal)**	**0.19 cases total (0.12 cases fatal)**	**1.03 cases total (0.67 cases fatal)**

Notes:
1. Detail may not add to total due to rounding.
2. See Chapter 2 text for discussion of directly proportional and lognormal approaches.

Community Water Systems: Summary of Results and Value of Risk Reductions

In Exhibit 3-12 below, we summarize the results of the risk analysis for community water systems, based on the data presented in Exhibits 3-9, 3-10, and 3-11 above. We also provide information on the monetary value of these risk reductions, apply these estimates for fatal and non-fatal risk reductions discussed earlier in this chapter.

Exhibit 3-12
SUMMARY OF ANNUAL RISK REDUCTIONS ASSOCIATED WITH EACH OPTION
(community water systems)

Regulatory Option	Directly Proportional		Lognormal Distribution	
	Total Cancer Cases Avoided (fatal cases)	Value of Avoided Cases (range)	Total Cancer Cases Avoided (fatal cases)	Value of Avoided Cases (range)
Compliance with existing MCLs after closing monitoring loopholes (combined radium = 5 pCi/L, gross alpha = 15 pCi/L):[1]				
Eliminate gross alpha monitoring loophole <u>only</u>	0.04 cases total (0.03 fatal)	$0.2 million ($<0.1 - $0.3 million)	0.35 cases total (0.22 fatal)	$1.3 million ($0.3 - $2.6 million)
Eliminate combined radium monitoring loophole <u>only</u>	0.31 cases total (0.21 fatal)	$1.2 million ($0.3 - $2.4 million)	0.54 cases total (0.37 fatal)	$2.2 million ($0.6 - $4.3 million)
Eliminate <u>both</u> loopholes[2]	0.32 cases total (0.22 fatal)	$1.3 million ($0.3 - $2.5 million)	0.86 cases total (0.57 fatal)	$3.4 million ($0.9 - $6.6 million)
Compliance with revised MCL options:[3]				
Revise gross alpha MCL to 10 pCi/L net of radium-226 <u>only</u>	0.53 cases total (0.35 fatal)	$2.1 million ($0.5 - $4.0 million)	0.70 cases total (0.45 fatal)	$2.7 million ($0.7 - $5.2 million)
Limit radium-228 at 3 pCi/L within combined radium MCL of 5 pCi/L <u>only</u>	0.50 cases total (0.34 fatal)	$2.0 million ($0.5 - $3.9 million)	0.63 cases total (0.43 fatal)	$2.6 million ($0.7 - $5.0 million)
Revise <u>both</u> gross alpha and radium MCLs[2]	0.78 cases total (0.52 fatal)	$3.1 million ($0.8 - $6.0 million)	1.08 cases total (0.72 fatal)	$4.3 million ($1.1 - $8.3 million)
Compliance with new uranium MCL options:				
Establish uranium MCL at 20 pCi/L (20 μg/L)	0.15 cases total (0.10 fatal)	$0.6 million ($0.2 - $1.2 million)	2.12 cases total (1.37 fatal)	$8.2 million ($2.1 - $15.8 million)
Establish uranium MCL at 40 pCi/L (40 μg/L)	0.04 cases total (0.02 fatal)	$0.1 million ($<0.1 - $0.2 million)	1.54 cases total (1.00 fatal)	$6.0 million ($1.5 - $11.6 million)
Establish uranium MCL at 80 pCi/L (80 μg/L)	0.01 cases total (<0.01 fatal)	$<0.1 million	1.03 cases total (0.67 fatal)	$4.0 million ($1.0 - $7.7 million)

<u>Notes:</u>
Gross alpha and combined radium risk estimates include risk reductions due to incidental treatment; e.g., the removal of gross alpha by treatments installed to address combined radium and vice-versa.
1. Closure of loopholes is compared to full compliance baseline (i.e., occurrence data are adjusted to eliminate illegal noncompliance).
2. Removes double counting of systems affected by both options based on direct proportions approach.
3. MCL changes are compared to revised baseline (i.e., occurrence data are adjusted to eliminate legal noncompliance with both gross alpha and combined radium MCLs).

This exhibit indicates that closing the gross alpha monitoring loophole alone will reduce total cancer incidence by 0.04 cases under the direct proportions approach and by 0.35 cases under the lognormal approach, including both direct impacts and the effects of incidental treatment. The central tendency estimate of the value of these cases ranges from $0.2 million to $1.3 million. Eliminating only the combined radium loophole results in a risk reduction of 0.31 total cancer cases under the direct proportions approach and 0.54 total cancer cases under the lognormal approach. The best estimate of the value of these cases ranges from $1.2 million to $2.2 million.

Closing the gross alpha and combined radium monitoring loopholes simultaneously will reduce total annual cancer incidence by 0.32 cases under the direct proportions approach, including both direct impacts and the effects of incidental treatment. This risk reduction increases to 0.86 cases under the lognormal approach. These estimates take into account the overlap between the systems out of compliance under each loophole. About two-thirds of these avoided cases are likely to be fatal. The central tendency estimate of the value of these cases ranges from $1.3 million to $3.4 million.

Setting the gross alpha MCL to 10 pCi/L net of radium-226 without simultaneously changing the combined radium standard reduces total annual cancer incidence by 0.53 total cases under the direct proportions approach, including both direct impacts and the effects of incidental treatment. This risk reduction increases to 0.70 cases under the lognormal approach. The best estimate of the value of these cases ranges from $2.1 million to $2.7 million. Changing the combined radium standard to limit the contribution of radium-228 to 3 pCi/L without also changing the MCL for gross alpha results in a reduction in total annual cancer incidence of 0.50 cases under the direct proportions approach and 0.63 cases under the lognormal approach. The central tendency estimate of the value of these cases ranges from $2.0 million to $2.6 million.

Changing the MCLs for both gross alpha and combined radium will reduce total cancer incidence by 0.78 to 1.08 cases, once the overlap between systems out of compliance for both options is taken into account. The central tendency estimate of the value of these cases ranges from $3.1 million to $4.3 million.

The additional impacts of uranium options range less than 0.01 cases to 2.12 cases avoided, depending on the regulatory option and approach for estimating occurrence. The incremental benefits of these risk reductions are valued at less than $0.1 million to $8.2 million annually.

IMPLICATIONS OF LIMITATIONS IN THE ANALYSIS

In this section, we discuss the major limitations of our methodology and the degree to which they may lead us to under- or overstate the actual risk reductions associated with each regulatory option and the value of averting these risks. First, we discuss the limitations in the estimates of the risk coefficients. Then, we describe other sources of uncertainty. The limitations in the occurrence estimates (discussed in Chapter 2) will also affect the risk analysis.

Risk Coefficients

The risk coefficient estimates (from FGR-13) are characterized by significant uncertainties.[20] These uncertainties result largely from the models and data used to derive key inputs. The researchers estimate that some of the coefficients may change by a factor of more than 10 if plausible alternative models or model inputs are used to predict risks. The starting point for the risk coefficients reported in FGR-13 is risk coefficients from epidemiologic studies, which are then adjusted through a series of steps. Key issues in this process, described in the report, include the following.

> **Risk Models.** These models take cancer coefficients from epidemiologic studies and combine them with vital statistics and cancer mortality data for the U.S. population to produce coefficients which measure the lifetime risk per unit absorbed dose at each age group. Uncertainty in both the underlying epidemiological studies (e.g. in the exposure estimates) and the functional form of the risk model (which combines risk data with population and cancer mortality data) contribute to the overall uncertainty in the FGR-13 estimates. A key concern is the appropriateness of extrapolating the risk coefficients from the epidemiologic studies. For example, the epidemiologic studies used in the analysis involved subjects who experienced high radiation doses over a short time period. Data on the response of humans to low doses of radiation is unavailable; thus responses to low dose exposures must be extrapolated from observations made at high, acutely delivered doses.
>
> **Biokinetic models.** Radionuclide specific biokinetic models are used to predict the distribution of a unit of activity in the body over time following ingestion. The biokinetic models are simplifications of flows between organs in complex biological systems. The degree of realism incorporated into the models depends on the amount and quality of available information regarding the actual paths of movement and the parameter values for specific

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[20] Eckerman, Keith F., Richard W. Leggett, Christopher B. Nelson, Jerome S. Pushkin, and Allan C.B. Richardson, *Cancer Risk Coefficients for Environmental Exposure to Radionuclides, Federal Guidance Report No. 13 (Draft)*, September 1999.

elements in the system. The use of equally plausible alternative biokinetic models results in a range of risk coefficients.

Dosimetric models. Together with the results of the biokinetic models, radionuclide-specific dosimetric models predict internal exposure (in terms of absorbed dose) from ingested radionulides as they decay. The dosimetric models are dependent on available information describing the decay properties of the radionuclides of interest, the parameters describing the source and target organs or regions of the body chosen for consideration and the estimated effects of radiation on those targets. The assumptions used to construct the dosimetric models affect the uncertainty of the resulting risk coefficients.

While the report does not bound the uncertainty for all radionuclides, uncertainty categories are provided by the researchers for selected cases. The researchers estimate that the risk coefficients for uranium-234 and radium-226 may vary by a factor of seven depending on the model inputs used to estimate risk. These estimates reflect current information on the biological behavior of radionuclides in the human body, conversion from internally or distributed radioactivity to absorbed doses to tissues, and extrapolation from tissue dose to cancer risk. The uncertainty categories do not reflect uncertainties associated with the use of a linear, no-threshold model for estimating radiogenic cancer at low doses, absorbed dose as a measure of radiogenic cancer risk, or variations in the distribution of population exposure parameters (e.g., water intake rates).

Other Sources of Uncertainty

In addition to the uncertainties in the risk coefficients and occurrence data, other limitations include the following.

Factors with indeterminate effects: There are significant uncertainties in the ingestion rates used in this analysis. Ingestion rates vary depending on age and other factors, and the average used in this analysis may differ from the average for the particular population affected by these regulatory options. The approach used to estimate the risks associated with gross alpha reflects uncertainties regarding the actual prevalence of different alpha emitters with varying degrees of risk. In addition, statistical cancer incidence is based on average populations for each of the water system categories. If the particular systems experiencing reductions in radionuclide concentrations have larger (or smaller) populations, or are addressing alpha emitters with differ risk levels, the risk reductions will be understated (or overstated).

The approach used to estimate the value of a statistical life is based largely on workplace fatalities, and may under- or overstate individuals' willingness to pay to avoid fatal cancer risks.

The analysis also does not assess the impacts of the regulatory options on other programs; e.g., the use of the uranium MCL as a target level for clean-up of ground or surface water at contaminated sites.

Factors that may lead us to understate benefits: The calculation of the risk factors only includes the ingestion of water from both drinking and meal preparation. It does not include exposure via showering and bathing, laundry and cleaning, or other potential pathways, because these risks are expected to be relatively small compared to the risks from ingestion. The risks of kidney damage from uranium are also not quantified. In addition, the analysis focuses on the risks to a "typical" individual, and does not address impacts on persons who may be particularly sensitive to the effects of radiation. The analysis also does not include the effects of treatment for the radionuclides on other contaminants present; i.e., unregulated radionuclides or toxic (e.g., inorganic) contaminants.

The cost of illness approach used to value nonfatal risks is likely to understate individuals' willingness to pay to avoid these risks, since it does not address risk aversion or the value of avoiding pain and suffering. The value of lost time is also not included in these estimates. Finally, the risk reductions (if any) associated with systems serving populations greater than one million are not quantified in this chapter.

In addition, this analysis does not address benefits other than risk reductions. For example, we do not consider the extent to which compliance with the revised radionuclides regulations could improve the aesthetic properties (taste, odor color) of drinking water or reduce the materials damages (e.g., soiling) associated with use of the water.

CHANGES IN COSTS — CHAPTER FOUR

In this chapter, we estimate compliance costs for community water systems, including the changes in monitoring, treatment, and other costs associated with each regulatory option. As discussed at the end of this chapter, these costs may also have market impacts, affecting the supply and demand for drinking water from public systems. Below, we discuss the approach to the analysis and then present the findings and limitations.[1]

ANALYTIC APPROACH

The analytic approach for assessing changes in costs includes first estimating the costs of alternative compliance actions and then predicting the likelihood that each action will be undertaken. The first section of this chapter describes the components of the cost analysis: monitoring, treatment, and other compliance costs. The second section discusses the model used to predict costs for systems in each size class and to estimate national and per household costs. Note that we do not quantify costs for systems serving populations greater than one million; the analysis reported in Chapter 2 suggests that few (if any) of these systems may be significantly affected by the regulatory options.

Types of Compliance Costs

The regulatory options under consideration will increase the costs of monitoring to determine compliance with each MCL as well as require certain systems to take action to reduce the concentrations of radionuclides in their water. These latter actions may include installing treatment, changing the water source used, or blending water from contaminated and uncontaminated sources.

[1] The analysis reported in this chapter was conducted by William Labiosa of the U.S. Environmental Protection Agency, Office of Ground Water and Drinking Water.

Monitoring Costs

The regulatory options under consideration will increase monitoring costs for most water systems. These increased costs result from the changes in the sampling and analysis requirements needed to close the existing loopholes for gross alpha and combined radium. In addition, systems would need to monitor uranium concentrations if EPA establishes a new MCL.

This preliminary analysis considers the following changes in monitoring requirements (alternative approaches are discussed in EPA's Notice of Data Availability):

- To close the gross alpha loophole, systems would be required to analyze samples within 48 hours to capture the presence of radium-224. The regulatory provisions allowing systems to hold their samples for longer time periods would be eliminated.

- To close the combined radium loophole, systems would be required to analyze both radium-226 and radium-228 concentrations. The provisions currently allowing systems to avoid these analyses if gross alpha or radium-226 concentrations are low would be eliminated.

- To implement a new MCL for uranium, systems would be required to assess uranium levels.

In addition, EPA is considering whether to require sampling at the entry point to the distribution system rather than within the system, as well as whether to change the number of samples and the timing and types of analyses required.

For community water systems, these costs are incremental to the costs of the sampling and analysis currently required under the existing regulations. In other words, current monitoring costs for radionuclides are subtracted from the costs under each regulatory option to determine the net effects of the changes to the regulations. Under the revised regulations, systems with higher radionuclide concentrations would be required to monitor more frequently than systems with lower concentrations, hence monitoring costs would increase as influent concentrations rise.[2]

As indicated in Exhibit 4-1, changes in annual per-site monitoring costs range from net savings of $17 to net costs of $512 on average. These costs are per site (i.e., for individual entry points within a system); total costs per system will depend on the number of locations where

[2] U.S. Environmental Protection Agency, *Costs of Additional Requirements for Monitoring of Gross Alpha, Combined Radiums and Uranium (1976 versus 1999)*, provided by Wynne Miller, EPA/OGWDW, April 29, 1999.

monitoring is required. The largest annual per-site cost increase results from the new monitoring requirements for uranium.

Exhibit 4-1

UNIT COSTS: CHANGES IN MONITORING REQUIREMENTS

Regulatory Option	Cost Increase Per Year Per Site
Eliminate monitoring loopholes, no changes to MCLs	
Gross alpha at 15 pCi/L	\$11 - \$252
Combined radium at 5 pCi/L	\$26 - \$360
Changes to MCLs	
Radium-228 at 3 pCi/L	(\$17) - \$0
Gross alpha at 10 pCi/L, net of radium-226	\$11 - \$252
Uranium at 20, 40, or 80 pCi/L (ground and surface water)	\$37 - \$512

Notes:
1. Gross alpha estimates assume analysis is required within 48 hours to address radium-224.
2. Actual costs will vary within these ranges depending on influent concentrations.
3. Numbers in parentheses indicate savings in comparison to current requirements.

Source:
U.S. Environmental Protection Agency, *Costs of Additional Requirements for Monitoring of Gross Alpha, Combined Radium and Uranium (1976 versus 1999)*, provided by Wynne Miller, Office of Groundwater and Drinking Water, April 29, 1999.

Treatment Costs

Systems that detect radionuclide concentrations in excess of the MCLs have a number of treatment options for reducing these concentrations. As discussed in the background documents for this Notice of Data Availability (NODA), the following technologies can be used for the effective removal of gross alpha, radium, and/or uranium from drinking water: activated alumina, coagulation/filtration, greensand filtration, ion exchange, lime softening, reverse osmosis, and point-of-use devices.[3] For small systems, some of these technologies are more appropriate and affordable than others, as also discussed in the background documents.[4]

The cost of installing these treatment technologies will vary depending on the initial (influent) level of contamination as well as the quantity of water treated. To determine the costs of each of these treatments, EPA considers the capital costs for installing the treatment, the operations and maintenance costs associated with operating the technology, and the residuals handling and disposal costs. Capital costs consist of process, construction, and engineering costs, which in turn incorporate the following cost elements:

- Process costs include manufactured equipment, concrete, steel, electrical and instrumentation, pipes and valves, and housing costs.
- Construction costs include sitework and excavation, subsurface considerations, standby power, land, contingencies, and interest during construction.
- Engineering costs include general contractor overhead and profit, engineering fees, and legal, fiscal, and administrative fees (including permitting).

Operations and maintenance costs include the annual costs for materials, chemicals, power, and labor.

In addition, total treatment costs include the capital and operations and maintenance costs associated with options for residuals handling and disposal. Operation of many of the treatment technologies generates solid or liquid residuals that contain elevated radionuclides levels and must be disposed in a manner that complies with relevant laws and regulations.[5]

To estimate capital and operations and maintenance costs, EPA developed a set of unit cost curves which calculate costs as a function of design or average flow. These costs vary depending

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[3] International Consultants, Incorporated, *Technologies and Costs for the Removal of Radionuclides from Potable Water Supplies (Draft)*, prepared for the U.S. Environmental Protection Agency, April 1999.

[4] International Consultants, Incorporated, *Small System Compliance Technology List for the Radionuclides Rule (Final Draft Report*), prepared for the U.S. Environmental Protection Agency, April 1999.

[5] U.S. Environmental Protection Agency, *Large Water System Byproducts Treatment and Disposal Costs*, April 1993, and U.S. Environmental Protection Agency, *Small Water System Byproducts Treatment and Disposal Costs*, April 1993.

on influent and effluent concentrations, i.e., the removal rate needed. Capital costs are a function of the facility's design flow, while operations and maintenance costs are a function of average flow. EPA estimated mean design and average flow rates based on the average population served for systems in each size class.[6] These flow estimates are combined with the cost curve equations to predict costs for systems in each size class requiring different removal rates.

In Exhibit 4-2, we provide the range of treatment production costs (in dollars per thousand gallons treated) applied for each treatment option considered for gross alpha, combined radium, and uranium at 30 and 80 percent removal efficiencies. We also provide information on the cost of point-of-use (e.g., residential) removal technologies for small systems. The options in this chart include those that are likely to used most frequently by water systems, given their costs and other factors. For gross alpha and combined radium, we consider only ground water systems because we expect radionuclide concentrations to be below levels of concern in surface water (see discussion in Chapter 2). For uranium, we present production costs for both ground water and surface water systems.

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[6] Data on flow rates and population served are from International Consultants, Incorporated, *Drinking Water Baseline Handbook: First Edition (Draft)*, prepared for the U.S. Environmental Protection Agency, March 2, 1999.

Exhibit 4-2

UNIT COSTS FOR TREATMENT
(central tendency estimates of production costs per thousand gallons treated)

CENTRALIZED TREATMENT	30 Percent Removal Efficiency		80 Percent Removal Efficiency	
	Small Systems (25 - 500 persons served)	**Large Systems (501 - 1 million persons served)**	**Small Systems (25 - 500 persons served)**	**Large Systems (501 - 1 million persons served)**
Removal of Gross Alpha and Radium from Ground Water				
Water Softening/Iron Removal	$0.77 - $1.78	$0.21 - $1.11	$1.71 - $2.69	$0.54 - $1.68
Greensand Filtration	$0.96 - $2.91	$0.43 - $0.60	NA	NA
Removal of Uranium from Ground Water				
Water Softening/Iron Removal	$0.77 - $1.78	$0.21 - $1.11	$1.71 - $2.69	$0.54 - $1.68
Removal of Uranium from Surface Water				
Water Softening/Iron Removal	$0.63 - $1.47	$0.24 - $0.84	$1.37 - $2.22	$0.66 - $1.29
Enhanced Coagulation/ Filtration	$1.23 - $5.24	$0.18 - $0.61	$1.23 - $5.24	$0.18 - $0.61
POINT-OF-USE TREATMENT DEVICES (systems serving 25 - 500 persons)				
Point-of-Use Reverse Osmosis	$2.26 - $2.63			
Point-of-Use Ion Exchange/ Activated Alumina	$2.26 - $2.63			

Notes:
1. Water softening/iron removal includes treatment technologies such as ion exchange, oxidation/filtration, reverse osmosis, and lime softening.
2. NA means "not applicable."
Source:
Estimates provided by William Labiosa, EPA/OGWDW, November 22 and 23, 1999.

As indicated in the exhibit, production costs range from $0.18 to $5.24 per 1,000 gallons treated, depending on system size, treatment technology, and influent contamination levels. The upper bounds in the exhibit indicate treatment production costs for the smaller systems within each of the two system size categories, while the lower bounds reflect costs for larger systems, indicating economies of scale. Production costs are also driven by the number of sites per system; systems with one site will have lower production costs than those with multiple sites. Enhanced coagulation/ filtration for removal of uranium from surface water systems yields the highest production costs, while the lowest costs are generally attributable to water softening/iron removal treatments (e.g., ion exchange, oxidation/filtration, reverse osmosis, or lime softening). Production costs for point-of-use devices are relatively high compared to costs of other treatment options for small systems (i.e., those serving 25-500 persons); however, these devices may be simpler for small systems to implement than centralized treatment.

Costs of Alternative Compliance Actions

In some cases, a system may achieve compliance by changing the water source used or by adjusting its current operations. For example, a system may purchase water from a neighboring system (i.e., regionalization) or it may change its own water sources (e.g., closing certain wells or switching from ground water to surface water). Alternatively, it may increase the blending of water from uncontaminated sources or adjust the operations of its existing treatment systems. For this preliminary analysis, EPA considers two primary options: connecting with a neighboring system (including blending with uncontaminated water), or developing a new source.[7]

Under the first option, the costs include constructing new mains to transport water from the neighboring system to the existing local distribution system. Because the costs of purchasing the water from a neighboring system (which achieves the MCLs) are counterbalanced by the savings from no longer purchasing water from the local source, these charges are not considered in this analysis. For this preliminary analysis, EPA assumes that the costs of blending (combining water from uncontaminated and contaminated sources) will be similar to the costs of connecting with a neighboring system. The alternate source scenario involves developing a new well in an area with radionuclide concentrations below the MCLs.

Although in some cases these options may cost as much as or more as treatment, in other cases they can be much less expensive and are often chosen as compliance options. For this preliminary analysis, we assume that these options, on average, cost half as much as the cheapest treatment option (i.e., water softening/iron removal). EPA plans to explore the uncertainty in these compliance actions and cost estimates in more detail in the near future.

[7] The alternative source option and associated costs are discussed in: The Cadmus Group, *Regional Variation of the Cost of Drinking Water Wells for Public Water Supplies (Draft),* prepared for the U.S. Environmental Protection Agency, October 1999.

Per System, Per Household, and National Cost Estimates

The estimates described above are used in EPA's cost model to determine the per system, per household, and national costs of each of the regulatory options. This modeling includes five steps: (1) determine the number of systems out of compliance by system size class and removal rate needed; (2) estimate treatment or other compliance costs for each system out of compliance; (3) estimate monitoring costs for each system; (4) calculate per household costs; and (5) determine total national costs. In a sixth and final step, we then adjust the estimates from the modeling to eliminate double-counting of systems out-of-compliance with more than one option. We discuss each of these steps below.

The starting point for the modeling is the occurrence estimates described in Chapter 2, which predict the number of systems likely to be out of compliance under each of the regulatory options. The occurrence analysis both identifies the percentage of systems out of compliance by size class (i.e., by population served using the EPA system size classes reported in Exhibit 2-1) and by removal rate category. The removal rate categories considered are less than 30 percent, 30 to 50 percent, 50 to 80 percent, and a maximum removal of 95 percent. The proportion of systems in each of these categories is determined by comparing initial concentration levels to the MCL to determine the percent removal needed.

The second step, estimating treatment or other compliance costs, includes consideration of the number of entry points, or sites, within each system where treatment may be needed. Because each water system may include multiple sites, it may be necessary for a system to install more than one treatment technology -- resulting in higher capital, operations and maintenance, and monitoring costs. The cost model is therefore designed to estimate the number of sites per system and assign both treatment and monitoring costs at the site level.

EPA assumes that most ground water systems serving populations less than 3,300 persons will have only one treatment site, but that a few of these systems may have as many as nine sites. The percentage of systems likely to have more than one site generally rises as system size increases; larger ground water systems serving populations between 50,001 and one million persons may have as many as 37 sites per system. In general, surface water systems have fewer treatment sites; most of these systems are likely to have only one site, and the maximum estimated for larger systems is six sites.[8] For systems with multiple sites, radionuclide concentrations are likely vary from site to site; i.e., each site within a system may treat at a different removal rate. For this preliminary

[8] Sites per system estimates are based on data from International Consultants, Incorporated, *Drinking Water Baseline Handbook: First Edition (Draft)*, prepared for the U.S. Environmental Protection Agency, March 2, 1999.

analysis, the cost model does not reflect this intra-system variability. However, EPA plans to explore this issue in more detail in the near future.

To estimate the costs of treatment or other compliance options (such as changing water sources), EPA developed a series of decision trees that predict the compliance technologies likely to be used by system size and removal rate for each group of radionuclides. In general, EPA assumes that a system will install the least expensive alternative. If more than one alternative has the same costs, EPA assumes that the alternatives are implemented in the same proportions. In considering these costs, EPA takes into account the capital, operation and maintenance, and waste disposal costs described earlier.

In Exhibit 4-3, we summarize the assumptions regarding the frequency with which each treatment may be applied in ground water systems, which varies by system size and influent concentration.[9] More detailed information on these assumptions, as well as information on the assumptions used for surface water systems, is provided in Appendix D.

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[9] Decision trees provided by William Labiosa, EPA/OGWDW, November 22 and 23, 1999.

Exhibit 4-3

COMPLIANCE OPTIONS FOR REMOVAL OF GROSS ALPHA, RADIUM, AND URANIUM

Compliance Option	System Size (population served)	Frequency of Use (ground water systems only)	
		Gross Alpha and Radium	Uranium
Water Softening/ Iron Removal	25 - 500 persons	46 - 56 percent	56 percent
	501 - 1 million persons	36 - 66 percent	66 percent
MnO_2 (Greensand) Adsorption/Filtration	25 - 500 persons	0 - 10 percent	NA
	501 - 1 million persons	0 - 20 percent	NA
Enhanced Coagulation/ Filtration	25 - 500 persons	NA	0 percent
	501 - 1 million persons	NA	0 percent
Point-of-Use Reverse Osmosis	25 - 500 persons	5 percent	5 percent
	501 - 1 million persons	0 - 5 percent	0 percent
Point-of-Use Ion Exchange/ Activated Alumina	25 - 500 persons	5 percent	5 percent
	501 - 1 million persons	0 - 5 percent	0 percent
Regionalization/Blending/ Other	25 - 500 persons	17 percent	17 percent
	501 - 1 million persons	17 percent	17 percent
Alternative Source	25 - 500 persons	17 percent	17 percent
	501 - 1 million persons	17 percent	17 percent

Notes (See Appendix D for more detailed information):
1. NA indicates that compliance option is "not applicable."
2. Percentages indicate the fraction of systems likely to use each compliance approach.
3. Estimates vary within ranges depending on system size and influent concentrations.
4 Water softening/iron removal includes treatment technologies such as ion exchange, oxidation/filtration, reverse osmosis, and lime softening.

Source:
Based on information provided by William Labiosa, EPA/OGWDW, November 22 and 23, 1999.

For removal of gross alpha, radium, and uranium, most ground water systems exceeding an MCL are likely to use a water softening/iron removal technology, which may include ion exchange, oxidation/filtration, reverse osmosis, or lime softening. A small portion of systems (0 - 20 percent) will likely chose greensand filtration for removal of gross alpha and radium, while an even smaller portion of primarily small systems (0 - 5 percent) will implement point-of-use devices for radionuclide removal. Approximately 35 percent of all systems will likely employ a compliance option other than treatment (i.e., regionalization, blending, or alternative source).

For surface water systems requiring uranium removal, the treatment technology assumptions are largely the same as those for ground water systems. The principal difference is that a smaller portion of systems are expected to use water softening/iron removal technologies, and more systems, particularly larger ones, will use enhanced coagulation/filtration. Appendix D presents the detailed gross alpha, radium, and uranium decision trees for both ground and surface water systems.

Using the decision trees to determine the percentage of systems installing each type of treatment given the removal rates needed, EPA estimates the capital and operations and maintenance costs for each regulatory option. The cost estimates for each treatment technology are developed on a per-site basis and then weighted by the percentage of sites that are likely to install the treatment according to the decision trees.

For example, if systems in a particular size class account for a total of 14,000 treatment sites and the occurrence data lead us to predict that 0.1 percent of the systems will require 80 percent removal to comply with an MCL option, the model will estimate that 14 sites (14,000 * 0.001) will need to install treatment. If the decision trees indicate that 45 percent of the sites in this size and removal rate category will install water softening/iron removal, then the model assumes that approximately 6.3 sites (14 * 0.45) will apply this treatment. The model then multiplies the annual capital and operations and maintenance costs (derived from the cost curves for this size class, removal efficiency, and treatment technology) by the number of sites to generate an annual cost estimate.

The third step in the cost analysis involves calculating monitoring costs for each system. All systems will incur these costs regardless of whether they are out of compliance with a particular regulatory option. Because these costs vary depending on radionuclide concentrations, EPA estimates the percent of systems with concentrations within each of the following intervals: (1) less than the detection level; (2) between the detection level and one-half the MCL; (3) between one-half the MCL and the MCL; and (4) above the MCL. The percent of systems (by size class) within each interval is predicted by assuming that concentrations are distributed lognormally based on the NIRS data discussed in Chapter 2.

In the fourth step, EPA then estimates the change in per household water costs attributable to the costs of the compliance actions. This calculation assumes that all of these costs are passed onto the consumer and that the cost increases do not lead to changes in the quantity of water consumed. Monitoring costs are not included in this calculation because they are too small to have a noticeable impact on per household costs. The per household costs are determined by multiplying the average annual compliance costs per thousand gallons for systems in each size class by the average annual per household water consumption (83,000 gallons per year).

In the fifth step, EPA adds the treatment and other compliance costs to the monitoring costs for all systems across system size classes to determine the total national costs of each regulatory option. The resulting cost estimates are reported in the following section.

Finally, we adjust the estimate for double-counting. While EPA has developed separate cost estimates for each regulatory option, simply summing these costs will overstate the total costs of implementing all of the options simultaneously. Some systems may use a single type of treatment or other strategy to comply with more than one option. This concern is particularly important for gross alpha and combined radium, because several systems are affected by the options for both of these groups of radionuclides. Estimates of the overlap between systems affected by each regulatory option are provided in Chapter 2. To determine the costs associated with joint implementation, we multiply the occurrence estimates for each size category (from Chapter 2), eliminating double-counting, by a weighted average of the per system compliance costs.

FINDINGS

In this section, we present the results of the cost analysis. The initial section discusses the results for community water systems for gross alpha and combined radium; we then describe the findings for uranium. Next we summarize the findings for community water systems. The final section of this chapter summarizes the implications of the limitations in the analysis.

Community Water Systems: Gross Alpha and Combined Radium

We assess the costs of complying with the regulatory changes under consideration for gross alpha and combined radium in two incremental steps: first, we consider the costs associated with closing the existing monitoring loopholes; then, we assess the additional costs attributable to changing the MCLs.

Closing the Monitoring Loopholes

Exhibit 4-4 presents the cost increases attributable to closing loopholes in the existing monitoring requirements for gross alpha and combined radium.[10] These costs include: (1) the

[10] This chapter does not address cost increases associated with full compliance with the existing regulations (i.e., with the elimination of illegal noncompliance) because these increases are not attributable to the regulatory changes EPA is now considering.

increase in monitoring costs for all systems, and (2) the treatment or other costs associated with achieving compliance with the existing MCL for those systems currently out of compliance. The costs are assessed for ground water systems only because we do not expect these radionuclides to occur above levels of concern in surface water. Appendix E presents detailed results for each system size category.

Exhibit 4-4

ANNUAL COST INCREASES: CLOSING THE MONITORING LOOPHOLES
(community water systems)

Regulatory Option	System Size Class (population served)	Number of Systems Affected	Total National Cost Increase	Number of Systems Affected	Total National Cost Increase
		Directly Proportional		Lognormally Distributed	
Eliminate gross alpha loophole <u>only</u> (MCL = 15 pCi/L)	25 - 500 persons	210 systems	$2.0 million	170 systems	$1.7 million
	501 - 1 million persons	none	$0.5 million	80 systems	$32.8 million
	Total	**210 systems**	**$2.5 million**	**250 systems**	**$34.5 million**
Eliminate combined radium loophole <u>only</u> (MCL = 5 pCi/L)	25 - 500 persons	210 systems	$1.5 million	240 systems	$1.8 million
	501 - 1 million persons	60 systems	$20.1 million	70 systems	$37.0 million
	Total	**270 systems**	**$21.6 million**	**320 systems**	**$38.8 million**
Eliminate <u>both</u> loopholes simultaneously	25 - 500 persons	250 systems	$2.1 million	250 systems	$2.1 million
	501 - 1 million persons	60 systems	$20.1 million	150 systems	$69.8 million
	Total	**310 systems**	**$22.2 million**	**400 systems**	**$71.9 million**

<u>Notes:</u>
1. Detail may not add to total due to rounding.
2. Costs are based on full compliance with existing regulations, i.e., assume elimination of illegal noncompliance prior to changing the monitoring requirements.
3. The costs of eliminating both loopholes simultaneously are estimated by multiplying the unduplicated count of affected systems (from Chapter 2) by the weighted average costs per system affected.
<u>Source:</u>
Cost estimates provided by William Labiosa, EPA/OGWDW, November 22 and 23, 1999.

We estimate that less than one percent of all systems are in legal noncompliance status. However, these estimates vary depending on the approach used to estimate occurrence, as discussed previously in Chapter 2. For gross alpha, once the monitoring loophole is closed, the annual cost of achieving compliance with the existing MCL will total $2.5 million under the direct proportions approach, and $34.5 million under the lognormal approach. On average, costs range from approximately $12,000 per system ($2.5 million divided by 210 systems) to almost $140,000 per system ($34.5 million divided by 250 systems).

The large variance in costs reflects significant differences in the number of systems predicted to be out of compliance in the larger size classes (zero versus approximately 80) under the alternative approaches; larger systems tend to have more treatment sites and greater compliance costs. The lognormal approach also generally leads to higher predicted baseline occurrence levels, requiring more costly technologies to achieve the removal rates needed to reach the MCL.

For combined radium, the predicted annual compliance costs total $21.6 million under the direct proportions approach, and $38.8 million under the lognormal approach, or an average of about $80,000 to $122,000 per system. For both of the regulatory options, most of the cost increase is borne by large systems.

Because many systems are legally out of compliance with both MCLs, the total costs of jointly implementing changes to the gross alpha and combined radium monitoring requirements will be less than the sum of the costs reported in Exhibit 4-4 (i.e., less than $24.1 million under the direct proportions approach, and less than $73.3 million under the lognormal approach). Gross alpha and combined radium can be removed effectively by the same treatment technologies (or by using an alternative water source), so systems can implement a single compliance action to achieve both MCLs. The analysis in Chapter 2 suggests that most (about 80 percent) of the systems legally out of compliance with the gross alpha MCL are also out of compliance with the combined radium MCL under the direct proportions approach. To estimate the costs of implementing both regulatory requirements simultaneously, we multiply the number of systems affected in each size category (based on occurrence data from Chapter 2) by the weighted average costs per system. We find that the costs of implementing both options range from $22.2 million to $71.9 million depending on the approach used to estimate occurrence.

Revising the MCLs

Once the monitoring loopholes are closed and all systems comply with the current MCLs, the next step in the analysis considers the incremental effects of changes to the MCLs. Exhibit 4-5 reports the cost increases attributable to these changes.

Exhibit 4-5

ANNUAL COST INCREASES:
CHANGING THE GROSS ALPHA AND COMBINED RADIUM MCLS
(community water systems)

Regulatory Option	System Size Class (population served)	Number of Systems Affected	Total National Cost Increase	Number of Systems Affected	Total National Cost Increase
		Directly Proportional		Lognormally Distributed	
Implement gross alpha MCL at 10 pCi/L, net of radium-226, only	25 - 500 persons	420 systems	$2.5 million	330 systems	$2.1 million
	501 - 1 million persons	180 systems	$60.2 million	170 systems	$69.5 million
	Total	**610 systems**	**$62.7 million**	**500 systems**	**$71.6 million**
Limit radium-228 at 3 pCi/L, within combined radium MCL of 5 pCi/L, only	25 - 500 persons	80 systems	$0.5 million	130 systems	$0.8 million
	501 - 1 million persons	120 systems	$40.1 million	90 systems	$37.1 million
	Total	**210 systems**	**$40.7 million**	**210 systems**	**$37.9 million**
Implement both MCL changes simultaneously	25 - 500 persons	420 systems	$2.5 million	370 systems	$2.4 million
	501 - 1 million persons	250 systems	$80.0 million	200 systems	$81.3 million
	Total	**670 systems**	**$82.5 million**	**570 systems**	**$83.7 million**

Notes:
1. Detail may not add to total due to rounding.
2. Costs assume elimination of both illegal and legal noncompliance prior to changing the MCLs.
3. The costs of changing both MCLs simultaneously are estimated by multiplying the unduplicated count of affected systems (from Chapter 2) by the weighted average costs per system affected.

Source:
Cost estimates provided by William Labiosa, EPA/OGWDW, November 22 and 23, 1999.

As discussed in Chapter 2, the number of systems affected by the gross alpha MCL is slightly lower under the lognormal approach than under the direct proportions approach for estimating occurrence. The cost increase that results from requiring systems to achieve the revised gross alpha MCL ranges from $62.7 million to $71.6 million, or an average of about $103,000 to $143,000 per system. For the limit on radium-228, the difference between the lognormal and direct proportions results is smaller. The cost increase ranges from $40.7 million to $37.9 million, or an average of about $197,000 to $179,000 per system. A significant proportion of these costs are attributable to large systems out of compliance with the gross alpha MCL.

Because many systems will need to take action to comply with both revised MCLs, the total costs of compliance will be less than the sum of the costs reported in Exhibit 4-5 (i.e., less than $103.4 million under the direct proportions approach, and less than $109.5 million under the lognormal approach). The analysis in Chapter 2 suggests that most (about 70 percent) of the systems out of compliance with the revised combined radium MCL are also out of compliance with the revised gross alpha MCL under the direct proportions approach. To estimate the costs of implementing both regulatory requirements simultaneously, we multiply the unduplicated count of the number of systems affected (based on the analysis in Chapter 2) by the weighted average per system costs for each system size category. We find that changing both MCLs simultaneously may lead to annual national costs of $82.5 million to $83.7 million.

Community Water Systems: Uranium

As indicated in Exhibit 4-6, establishing an MCL for uranium would lead to an annual cost increase of approximately $5 million to $157 million nationally, depending on the MCL selected and the approach used to estimate occurrence.[11] Average costs per system under an MCL of 20 pCi/L range from approximately $38,000 to $162,000; under an MCL of 80 pCi/L, average costs range from $119,000 to $175,000 per system. Most of these costs would be incurred by large systems relying on ground water. Costs attributable to regulatory options for which no systems are out of compliance are due to new monitoring requirements.

[11] We do not assess potential double-counting for systems that are required to comply with a new MCL for uranium as well as the regulatory options for gross alpha and combined radium because uranium rarely occurs at levels of concern in systems affected by the other regulatory options (see Chapter 2) and may require different treatment for effective removal.

Exhibit 4-6

ANNUAL NATIONAL COST INCREASES: SETTING AN URANIUM MCL
(community water systems)

Regulatory Option	System Size Class (population served)	Ground Water Systems	Surface Water Systems	All Systems	Ground Water Systems	Surface Water Systems	All Systems
		Directly Proportional			Lognormally Distributed		
Uranium MCL = 20 pCi/L (20 μg/L)	25 - 500 persons	$7.1 million (760 systems)	$1.3 million (<10 systems)	$8.4 million (760 systems)	$6.5 million (670 systems)	$1.5 million (20 systems)	$8.0 million (680 systems)
	501 - 1 million persons	$22.1 million (60 systems)	$1.1 million (none)	$23.2 million (60 systems)	$141.4 million (250 systems)	$7.6 million (30 systems)	$149.0 million (290 systems)
	Total	**$29.2 million (820 systems)**	**$2.4 million (<10 systems)**	**$31.6 million (830 systems)**	**$148.0 million (920 systems)**	**$9.1 million (50 systems)**	**$157.0 million (970 systems)**
Uranium MCL = 40 pCi/L (40 μg/L)	25 - 500 persons	$3.2 million (300 systems)	$1.2 million (none)	$4.5 million (300 systems)	$3.6 million (300 systems)	$1.3 million (10 systems)	$4.9 million (310 systems)
	501 - 1 million persons	$1.1 million (none)	$1.1 million (none)	$2.2 million (none)	$59.6 million (110 systems)	$3.4 million (10 systems)	$63.1 million (120 systems)
	Total	**$4.4 million (300 systems)**	**$2.3 million (none)**	**$6.7 million (300 systems)**	**$63.3 million (410 systems)**	**$4.7 million (20 systems)**	**$68.0 million (430 systems)**
Uranium MCL =80 pCi/L (80 μg/L)	25 - 500 persons	$1.5 million (40 systems)	$1.2 million (none)	$2.8 million (40 systems)	$2.2 million (120 systems)	$1.3 million (<10 systems)	$3.5 million (130 systems)
	501 - 1 million persons	$1.1 million (none)	$1.1 million (none)	$2.2 million (none)	$24.6 million (40 systems)	$1.9 million (<10 systems)	$26.4 million (40 systems)
	Total	**$2.7 million (40 systems)**	**$2.3 million (none)**	**$5.0 million (40 systems)**	**$26.8 million (160 systems)**	**$3.1 million (10 systems)**	**$29.9 million (170 systems)**

Notes:
1. Detail may not add to total due to rounding.
2. Costs accrue even when no systems are out of compliance due to changes in the monitoring requirements.

Source:
Cost estimates provided by William Labiosa, EPA/OGWDW, November 22 and 23, 1999.

Community Water Systems: Summary of Results

In Exhibit 4-7 below, we summarize the results of the cost analysis for community water systems, based on the data presented in the previous exhibits. These results suggest uncertainty regarding the actual costs of some options because the direct proportions and lognormal approaches often lead to very different occurrence estimates. As noted earlier, EPA plan to conduct further research on occurrence to reduce the uncertainty in these estimates.

Exhibit 4-7

SUMMARY OF ANNUAL COST INCREASES ASSOCIATED WITH EACH OPTION

Regulatory Option	Total National Cost Increase	
	Directly Proportional	**Lognormally Distributed**
Compliance with existing MCLS after closing monitoring loopholes (combined radium = 5 pCi/L, gross alpha = 15 pCi/L):[1]		
Eliminate gross alpha loophole only	$2.5 million	$34.5 million
Eliminate combined radium loophole only	$21.6 million	$38.8 million
Eliminate both loopholes simultaneously[2]	$22.2 million	$71.9 million
Compliance with revised MCL options:[3]		
Revise gross alpha MCL to 10 pCi/L, net of radium-226 only	$62.7 million	$71.6 million
Limit radium-228 at 3 pCi/L within combined radium MCL of 5 pCi/L only	$40.7 million	$37.9 million
Revise both MCLs simultaneously[2]	$82.5 million	$83.7 million
Compliance with new MCL options:		
Establish uranium at 20 pCi/L (20 μg/L)	$31.6 million	$157.0 million
Establish uranium at 40 pCi/L (40 μg/L)	$6.7 million	$68.0 million
Establish uranium at 80 pCi/L (80 μg/L)	$5.0 million	$29.9 million

Notes:
1. Closure of loopholes is based on a full compliance baseline (i.e., occurrence data are adjusted to eliminate illegal noncompliance).
2. Eliminates double-counting of systems affected by both options.
3. MCL changes are based on a revised baseline that eliminates monitoring loopholes (i.e., occurrence data are adjusted to eliminate both illegal and legal noncompliance).

As indicated by the exhibit, the costs associated with closing the individual monitoring loopholes range from \$2.5 million to \$38.8 million, depending on the loophole and the approach used to estimate occurrence. Closing both loopholes leads to estimated costs ranging from \$22.2 million to \$71.9 million, once we eliminate double-counting of systems legally out of compliance with both MCLs.

The costs associated with changing the existing MCLs range from \$37.9 million to \$71.6 million, depending on the MCL and the approach for estimating occurrence. Changing both the gross alpha and combined radium MCLs simultaneously leads to estimated costs ranging from \$82.7 million to \$83.7 million, once we remove double-counting of systems out of compliance with both MCLs. The range of estimates is narrower for the MCL changes than for closing the loopholes, because the direct proportions and lognormal approaches lead to relatively similar estimates of the number of systems out of compliance.

For uranium, annual national compliance costs range from \$5.0 million to \$157.0 million, depending on the MCL and approach for estimating occurrence. The lognormal approach leads to significantly higher estimates in this case.

Exhibits 4-8 and 4-9 indicate the contribution of capital costs, operation and maintenance costs, and monitoring costs to the total costs summarized above. The first exhibit provides the results under the direct proportions approach; the second provides the results under the lognormal approach. These exhibits assume that each option is implemented independently; the estimates are not adjusted for double-counting of systems out of compliance with more than one option.

As shown in the exhibits, the highest costs are generally attributable to annual operations and maintenance expenses. The exhibits also provide the capital and operation and maintenance costs on a per-household basis, indicating a cost increase from close to \$0 to \$225 per household annually. Detailed results by system size category are presented in Appendix E.

Exhibit 4-8

BREAKDOWN OF TREATMENT AND MONITORING COSTS: DIRECT PROPORTIONS APPROACH (community water systems)

Regulatory Option		Total Capital Costs	Total Annualized Capital Costs	Annual Operations & Maintenance Costs	Annual Monitoring Costs	Total Annual Costs	Annual Capital and O&M Costs per Household
Gross alpha loophole (MCL = 15 pCi/L)		$ 4,719,403	$ 443,624	$ 882,192	$ 1,157,132	$ 2,482,948	$ 0 - $ 126
Combined radium loophole (MCL = 5 pCi/L)		$ 96,220,123	$ 9,044,692	$ 12,376,331	$ 166,333	$ 21,587,356	$ 6 - $ 126
Gross alpha MCL = 10 pCi/L, net of radium-226		$ 282,442,846	$ 26,549,628	$ 36,170,183	---	$ 62,719,810	$ 6 - $ 121
Radium-228 limited at 3 pCi/L, within combined radium MCL of 5 pCi/L		$ 184,478,821	$ 17,341,009	$ 23,316,669	---	$ 40,657,678	$ 6 - $ 128
Uranium MCL = 20 pCi/L (20 μg/L)	Ground Water	$ 117,508,834	$ 11,045,830	$ 15,305,144	$2,886,203	$ 29,237,178	$ 13 - $ 135
	Surface Water	$ 112,204	$ 10,547	$ 21,950	$ 2,333,064	$ 2,365,561	$ 0 - $ 123
Uranium MCL = 40 pCi/L (40 μg/L)	Ground Water	$ 6,836,583	$ 642,639	$ 1,144,406	$2,582,384	$ 4,369,429	$ 0 - $ 121
	Surface Water	---	---	---	$ 2,309,238	$ 2,309,238	$ 0 - $ 0
Uranium MCL = 80 pCi/L (80 μg/L)	Ground Water	$ 800,952	$ 75,290	$ 149,470	$ 2,446,495	$ 2,671,254	$ 0 - $ 113
	Surface Water	---	---	---	$ 2,308,316	$ 2,308,316	$ 0 - $ 0

Notes:
1. Detail may not add to total due to rounding; estimates are not adjusted for double-counting of systems out of compliance with more than one option..
Source:
Based on data provided by William Labiosa, EPA/OGWDW, November 22 and 23, 1999.

Exhibit 4-9

BREAKDOWN OF TREATMENT AND MONITORING COSTS: LOGNORMAL DISTRIBUTION APPROACH
(community water systems)

Regulatory Option		Total Capital Costs	Total Annualized Capital Costs	Annual Operations & Maintenance Costs	Annual Monitoring Costs	Total Annual Costs	Annual Capital and O&M Costs per Household
Eliminate gross alpha loophole (MCL = 15 pCi/L)		$ 145,985,859	$ 13,722,671	$ 19,607,649	$ 1,182,966	$ 34,513,286	$ 7 - $ 126
Eliminate combined radium loophole (MCL = 5 pCi/L)		$ 166,152,722	$ 15,618,356	$ 23,024,706	$ 166,333	$ 38,809,396	$ 9 - $ 127
Gross alpha MCL = 10 pCi/L, net of radium-226		$ 314,887,220	$ 29,599,399	$ 42,026,495	---	$ 71,625,893	$ 7 - $ 126
Radium-228 limited to 3 pCi/L within combined radium MCL of 5 pCi/L		$ 165,581,412	$ 15,564,653	$ 22,299,598	---	$ 37,864,251	$ 7 - $ 125
Uranium MCL = 20 pCi/L (20 μg/L)	Ground Water	$ 608,783,775	$ 57,225,675	$ 87,711,493	$ 3,015,334	$ 147,952,502	$ 23 - $ 225
	Surface Water	$ 16,249,589	$ 1,527,461	$ 5,084,334	$ 2,463,608	$ 9,075,403	$ 11 - $ 124
Uranium MCL = 40 pCi/L (40 μg/L)	Ground Water	$ 254,674,397	$ 23,939,393	$ 36,634,017	$ 2,684,158	$ 63,257,568	$ 22 - $ 217
	Surface Water	$ 5,851,895	$ 550,078	$ 1,826,124	$ 2,367,156	$ 4,743,358	$ 11 - $ 123
Uranium MCL = 80 pCi/L (80 μg/L)	Ground Water	$ 101,457,305	$ 9,536,987	$ 14,736,962	$ 2,527,514	$ 26,801,462	$ 22 - $ 211
	Surface Water	$ 1,951,483	$ 183,439	$ 611,888	$ 2,328,288	$ 3,123,615	$ 11 - $ 125

Notes:
1. Detail may not add to total due to rounding.
Source:
Based on data provided by William Labiosa, EPA/OGWDW November 22 and 23, 1999.

IMPLICATIONS OF LIMITATIONS IN THE ANALYSIS

In this section, we discuss the major limitations of our methodology and the degree to which they may lead us to under- or overstate the actual cost increases associated with each regulatory option. First, we discuss the uncertainties associated with predictions of compliance actions. Next, we discuss potential market impacts. Finally, we describe other limitations of the analysis in qualitative terms. The limitations in the occurrence estimates (discussed in Chapter 2) will also affect the cost analysis.

Compliance Actions

EPA recently reviewed the actions that water systems have taken to come into compliance with the MCLs for combined radium, nitrate and nitrite, and atrazine. These comprehensive analyses indicate that most water systems choose compliance options other than treatment. The most common of these options include modifications and/or additions to the present treatment system, blending with less contaminated water (i.e., water below the MCL), adding new wells for blending or replacement of contaminated wells, purchasing water from other water systems, and discontinuing the use of contaminated wells when they are not necessary to meet water demand. Exhibit 4-10 presents the frequency of these alternative compliance actions, based on a preliminary analysis of the analytic results.

Exhibit 4-10

ACTUAL COMPLIANCE ACTIONS

Contaminant	**Number of Systems**	**Compliance Action and Frequency of Use (percent of systems)**					
		Installed Treatment	**Modified Existing Operations**	**Blended**	**Added Well(s)**	**Purchased Water**	**Discontinued Contaminated Well Use**
Nitrate/ nitrite/ atrazine	208	23.9 percent	18.2 percent	13.6 percent	27.8 percent	13.6 percent	2.8 percent
Radium	76	27.6 percent	none	3.9 percent	10.5 percent	51.3 percent	6.6 percent

Note:
In the case of radium, these actions were not necessarily taken for the purpose of complying with the MCL; however, they brought the system into compliance.
Sources:
Data provided by William Labiosa, EPA/OGWDW, December 3, 1999.
1. Results for the States of OH, SD, FL, MO, CT, CA, WI, MN, NY, MD, OR, PA, and IN are from an unpublished survey conducted by the Association of State Drinking Water Administrators, September 1999.
2. Radium results are for the State of Illinois, submitted by U. S. Environmental Protection Agency, Region 5.

These results suggest that the decision trees (provided in Appendix D) may overstate the extent to which systems will choose to install treatment to comply with the regulatory options for radionuclides. To address this limitation, EPA plans to further assess the effects that compliance decisions may have on national costs, using Monte Carlo analysis to estimate the effects of weighting options other than treatment more heavily in the decision trees. This analysis will be based on probability distributions that reflect the likelihood that a system will choose a compliance option other than treatment, and the likely costs of these alternative compliance options.

Based on preliminary investigation of this issue, we expect that the average costs of compliance options other than treatment will be considerably lower than average treatment costs, and hence may reduce the total national costs of compliance considerably.[12] Therefore, EPA's current emphasis on the use of treatment for compliance in national costing models is likely to result in overestimates of national costs.

[12] Abt Associates, Incorporated, "Case Study Memorandum, Assessing the Cost of Compliance: A Drinking Water Retrospective (draft)," prepared for the U.S. Environmental Protection Agency, November 17, 1998; and International Consultants, Incorporated, *Actual Cost for Compliance with the Safe Drinking Water Act Standard for Radium 226 and 228 - Final Report,* prepared for the U.S. Environmental Protection Agency, July 1998.

Market Impacts

The analysis in the previous sections does not address the market effects of changes to the regulations for radionuclides. Economic theory suggests that analysis of the impacts of regulations on social welfare should take these types of effects into account. However, we expect that the costs of implementing the regulations will have a relatively small impact on the supply and demand for public water supplies, and hence do not quantify these effects. Examples of market impacts include changes in water price (if the system passes the costs fully or partially on to its customers) and changes in water consumption as a result of these price changes (e.g., reduced lawn watering in response to price increases).[13] Such impacts may mean that systems will reduce the amount of water they produce, and consumers may decrease the amount of water they consume, if the regulations lead to significant increases in costs.

Other Sources Of Uncertainty

In addition to the uncertainties in the occurrence estimates and in predicting compliance actions discussed previously, several other factors affect the estimates of compliance costs. In combination, these limitations lead us to believe that the analysis is likely to overstate the costs of complying with the regulatory options under consideration for community water systems.

Factors with indeterminate effects: The analysis does not assess the impacts of the regulatory options on other programs, e.g., the use of the uranium MCL as a target level for clean-up of ground or surface water at contaminated sites.

Factors that may lead us to overstate cost increases: There are a number of uncertainties in the unit cost estimates and in the decision trees used in this analysis that are discussed in the background documents. While some of these uncertainties may be counterbalancing, EPA believes that addressing these uncertainties (particularly in the capital cost estimates) is likely to decrease the national costs reported above. Furthermore, recent research suggests that cost estimates generated in these types of studies tend to overstate actual compliance costs, because they do not account for

[13] Economists generally refer the relationship between price and quantity demanded as "elasticity." Available studies suggest that elasticities for annual average residential water demand in the United States generally range from -0.3 to -0.7 with only a few exceptions. A 1984 U.S. Army Corps of Engineers review of 50 such studies concluded that it was most likely that average elasticities were at the low end of the range, i.e., between -0.2 and -0.4. In other words, water demand would decrease by 0.2 to 0.4 percent if prices increase by one percent. See: U.S. Army Corps of Engineers, *Influence of Price and Rate Structures on Municipal and Industrial Water Use*, June 1984.

cost savings resulting from future technological innovation, cost reductions achieved during the regulatory review and public comment periods, and other factors.[14]

Factors that may lead us to understate cost increases: This analysis does not include the costs associated with changes to the requirements for systems serving populations greater than one million; research conducted to-date suggests that few (if any) of these systems are likely to be affected by the regulatory options under consideration. It also does not address the effects of the regulatory options on Federal, state or local costs for program administration and enforcement.

[14] Winston Harrington, Richard D. Morgenstern, and Peter Nelson, *On the Accuracy of Regulatory Cost Estimates*, Resources for the Future, January 1999.

NON-TRANSIENT NON-COMMUNITY WATER SYSTEMS CHAPTER FIVE

The prior chapters discuss the impact of the regulatory options on community water systems, which are subject to the existing MCLs for radionuclides. EPA is also considering whether to extend the regulations to cover non-transient non-community systems which are not currently subject to these requirements. In this chapter, we provide information on the prevalence and concentrations of radionuclides in water supplied by non-transient non-community water systems. The information presented in this chapter is relatively general, and we are now conducting further research on this topic to better estimate regulatory impacts. Below, we describe our approach to the analysis, present our findings, and discuss the implications and limitations of the analysis.

The existing regulations (at 40 CFR 141.2) define a community water system as "a public water system which serves at least 15 service connections used by year-round residents or regularly serves at least 25 year-round residents." A non-transient, non-community water system is defined as "a public water system that is not a community water system and that regularly serves at least 25 of the same persons over 6 months per year." The majority of non-transient non-community water systems serve churches or schools. The remaining non-transient non-community water systems serve a variety of facilities ranging from manufacturing to prisons to airports.[1]

ANALYTIC APPROACH

No source of national data currently exists that describes radionuclide occurrence in water provided by non-transient non-community systems.[2] Therefore, to provide insights into the potential impacts of the regulatory options on these systems (which are not currently subject to the radionuclides regulations), we review available data on the extent to which these systems are located

[1] Science Applications International Corporation, *Geometries and Characteristics of Public Water Systems*, prepared for the U.S. Environmental Protection Agency, May 14, 1999.

[2] The NIRS sample used to estimate occurrence for the community water systems does not include non-transient non-community water systems.

in areas where radionuclide occurrence may exceed the regulatory standards being considered by EPA. These data address raw, not finished, water and are regional ranges rather than values for individual systems; hence, they are not sufficient to allow us to estimate the costs and risk reductions associated with the regulatory options for these systems. We are currently examining other data sources and developing estimates of the potential range of risk reductions and costs for these systems, and will provide the resulting analysis as an Addendum to this report.

Data Sources

To determine the extent to which non-transient non-community water systems are located in areas with potentially elevated radionuclide concentrations, we searched the literature for relevant data. We found that available data sources provide information on radionuclide occurrence in raw (unfinished) water in various geographic regions, rather than on occurrence in drinking water supplied by these systems.[3] These data do not provide estimates of the extent to which individual systems are likely to exceed the radionuclide MCLs, because concentrations will vary within the regions addressed and some non-transient non-community systems may treat their water before use to comply with other regulatory requirements.[4]

We identified three hydrologic studies of ground water and surface water throughout the United States that indicate the prevalence of radionuclides on a state-by-state base.[5] The first study was completed in 1987 by Research Planning Institute (RPI). The researchers collected data from a variety of different sources, including scientific publications, municipalities, and state agencies, then used this information in combination with information regarding the geology of regional ground water aquifers to quantitatively extrapolate radium-226 concentrations for every county in

[3] We focus on untreated water because non-transient non-community systems are subject to only a subset of the existing MCLs and are not currently required to comply with the MCLs for radionuclides. Most data on finished water supplies are for community water systems, which are subject to substantially more regulatory requirements.

[4] The extent to which these systems treat their water to address state or local water quality requirements or concerns in the absence of Federal requirements is uncertain. Non-transient non-community systems are subject to selected Federal MCLs, including those for certain organic and inorganic chemicals. In some cases, treatment installed to comply with these MCLs may also reduce radionuclide occurrence levels.

[5] Data on the number of non-transient non-community systems in each state as of December 1997 (from SDWIS) are provided in Appendix A.

the United States.[6] The RPI study assigns each county to one of four categories based on the range of radium-226 concentrations likely to occur in ground water in that county: less than 1 pCi/L, 1 to 5 pCi/L, 5 to 10 pCi/L, and greater than 10 pCi/L. We use these data to characterize the occurrence of radium-226 in each state.

A second report by RPI, completed in 1984, uses previous studies of three major hydrogeological provinces to identify types of aquifers that tend to have low or elevated activities of radium-228.[7] The report qualitatively classifies the radium-228 activity in each county across the United States as low, medium, or high, depending on the type of bedrock and the location of aquifers in that area. While the RPI study uses three categories for this classification, activity levels are reported only for the "elevated" and "low" categories. The report notes that relatively low activity levels include mean radium-228 concentrations ranging from 0.3 pCi/L to 0.7 pCi/L; elevated activity levels include mean values from 1.4 pCi/L to 2.4 pCi/L, but may range as high as 23 pCi/L. We assume that aquifers classified as "medium" have mean concentrations of 0.8 pCi/L to 1.3 pCi/L; however, because this range is not explicitly noted in the report, it is possible that there is some overlap between the ranges RPI actually used for each category. The RPI report then estimates the occurrence of radium-228 in each county, based on regional geology. We use these data to estimate the range of radium-228 activity levels found in each state.[8]

The third data source we use is a study of uranium completed by Oak Ridge National Laboratory (ORNL) in 1981.[9] The ORNL study provides concentration ranges for uranium that are based extensively on National Uranium Resource Evaluation (NURE) data collected in the late 1970s. These ranges are based on actual water samples rather than estimated from hydrogeologic

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[6] Research Planning Institute, *Creation of Generalized Maps of National Occurrence of Uranium, Radium-226, and Radon in Groundwater based on Geological Considerations,* February 1987(a).

[7] Research Planning Institute, *Aquifer Classification by Relative Risk of Ra-228 Occurrence,* September 1984. A later publication of the analysis included concentration ranges for eight states not included in the 1984 version. See: Michel, J. and M.J. Jordana, "Nationwide Distribution of Radium-228, Radium-226, Radon-222 and Uranium in Ground Water," *Radon, Radium, and Other Radioactivity in Ground Water: Hydrogeologic Impact and Application to Indoor Airborne Contamination,* (B. Graves, ed.), Lewis Publishers: Chelsea, Michigan, 1987(b), pp. 227 - 240.

[8] The 1984 RPI report also presents information on uranium in a similar format. Because the Oak Ridge study described below provides more detailed uranium data, we use the latter study in our analysis.

[9] Oak Ridge National Laboratory, *Uranium in U.S. Surface, Ground, and Domestic Waters, Volume 1,* prepared for the U.S. Environmental Protection Agency, April 1981.

data. In states where NURE data were not available, ORNL relied on raw water samples of surface and ground water collected by municipal and state agencies. These data are often much older than the NURE data; however the report states that, for places where both NURE and more recent data are available, correlation between the older and newer samples is high.

Approach

We use the three reports described above to estimate the number of non-transient non-community systems that are located in states with levels of radionuclide occurrence that may exceed the regulatory levels being considered by EPA. Data on the number of non-transient non-community systems in each state as of 1997 is taken from SDWIS and is summarized in Appendix A. To determine whether non-transient non-community systems are located in states where concentrations may exceed either the existing MCLs or the MCL options considered in this report, we applied the following decision rules.

Gross Alpha: None of the data sources reviewed provide estimates of gross alpha levels in raw water sources. We therefore estimate these levels by reviewing the available data on radium-226 and radium-228. We consider only non-transient non-community systems that rely on ground water sources because (as discussed in Chapter 2) we expect that gross alpha rarely occurs at levels of concern in surface water.

To determine the extent to which such systems are located in states that may be affected by application of the current MCL (15 pCi/L), we assume that total gross alpha is approximately equal to the radium-226 value plus radium-228 multiplied by three. The "radium-228 value times three" is used to estimate the concentration of radium-224 and its daughter products, based on recent research (discussed in Chapter 2) on co-occurrence of these radionuclides.. This approach assumes that the existing loophole in the monitoring requirements (which allows community water systems to avoid measuring radium-224 levels) will be eliminated before applying the MCL to non-transient non-community systems. When assessing a gross alpha MCL of 10 pCi/L (net of radium-226), we rely solely on the estimates of radium-224 extrapolated from the available data on radium-228.

To determine whether systems are located in states with radionuclide occurrence potentially above the current gross alpha MCL of 15 pCi/L, we apply the following decision rules.

- If the state has radium-226 levels equal to or less than 5 pCi/L (in RPI 1987) and radium-228 levels classified as "low" or "medium" (mean value less than 1.4 pCi/L in RPI 1984), we assume that systems located in the state are not likely to exceed the current MCL.[10]

- If the state has radium-226 levels between 5 and 10 pCi/L (in RPI 1987) and radium-228 levels are classified as "low" (mean value less than 0.8 pCi/L in RPI 1984), we also assume that systems located in the state are not likely to exceed the current MCL.

- The remaining states may have occurrence levels potentially exceeding the MCL.

To determine whether systems are located in states with radionuclide occurrence potentially above the proposed gross alpha MCL of 10 pCi/L, net of radium-226, we apply the following decision rules.

- If the state has radium-228 levels classified as "low" or "medium" (mean value less than 1.4 pCi/L in RPI 1984), we assume that systems located in the state are not likely to exceed the proposed MCL.

- The remaining states may have occurrence levels potentially exceeding the MCL.

Combined radium: For combined radium, we assess the likelihood that systems are located in states where occurrence may exceed the current MCL of 5 pCi/L. (EPA is also interested in determining the likelihood that systems will exceed an option that maintains a combined radium MCL of 5 pCi/L but limits the contribution of radium-228 to 3 pCi/L. However, the data are not specific enough to allow us to differentiate between these two options.[11]) We focus on systems that rely on ground water sources because (as discussed in Chapter 2) radium rarely occurs at levels of concern in surface water. Again, we assume that the monitoring loopholes are addressed prior to implementation of the MCL for these systems, so that they must fully comply with the standards.

To determine whether systems are located in states with occurrence levels potentially above the current combined radium MCL of 5 pCi/L, we apply the following decision rules.

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[10] We use values that total less then 15 pCi/L because the RPI (1984) values are means, not maximums, and some systems in each category are likely to exceed these means.

[11] Based on the available data, the decision rules used to determine the number of systems out of compliance with a combined radium MCL of 5 pCi/L that limits the contribution of radium-228 to 3 pCi/L would be identical to the decision rules for the current combined radium MCL.

- If the state has radium-226 levels less than 1 pCi/L (in RPI 1987) and radium-228 levels are classified as "low" or "medium" (mean value less than 1.4 pCi/L in RPI 1984), we assume that systems located in the state are not likely to exceed the current MCL.

- If the state has radium-226 levels less than 5 pCi/L (in RPI 1987) and radium-228 levels are classified as "low" (mean value less than 0.8 pCi/L in RPI 1984), we also assume that systems located in the state are not likely to exceed the current MCL.

- The remaining states may have occurrence levels potentially exceeding the MCL.

Uranium: The ORNL report includes ranges from samples taken in each state. To determine whether systems in a state are likely to exceed the uranium MCL options, we compare the high end of the reported concentration range to the MCL. We conduct this analysis separately for surface and ground water systems, and assume a one-to-one mass to activity ratio. The MCL options considered are 20 pCi/L (20 μg/L), 40 pCi/L (40 μg/L), and 80 pCi/L (80 μg/L).

FINDINGS

To assess radionuclide occurrence in non-transient non-community systems, we reviewed data on the extent to which these systems are located in areas where radionuclide levels may potentially exceed the regulatory standards being considered by EPA. In Exhibit 5-1, we report the number of non-transient non-community systems located in states with gross alpha or combined radium levels that could potentially exceed the current or proposed MCLs. (As discussed earlier, the data do not allow us to distinguish between the current combined radium MCL (5 pCi/L) and the alternative of limiting radium-228 to 3 pCi/L within this total; therefore, the later option is not included in the exhibit.) Note that most of the systems located in the listed states are likely to have radionuclide concentrations below levels of concern, both because the decision rules we apply are conservative (i.e., may include states where concentrations are largely below levels of concern) and because of the location and characteristics of individual systems, as discussed below.

Exhibit 5-1

NON-TRANSIENT NON-COMMUNITY SYSTEMS LOCATED IN STATES WITH POTENTIALLY ELEVATED GROSS ALPHA AND COMBINED RADIUM LEVELS (ground water systems only)

Regulatory Option	**States with Areas Potentially Exceeding MCL[1]**				**NTNC Systems in Listed States (percent of total)[2,3]**	
					Number of Systems	**Population Served**
Exceed gross alpha MCL of 15 pCi/L	Alabama Arkansas California Colorado Georgia Idaho Illinois	Iowa Maryland Michigan Minnesota Missouri Montana	New Mexico New York North Carolina North Dakota Oklahoma Pennsylvania	South Carolina South Dakota Texas Virginia Wisconsin Wyoming	11,157 (60%)	3,232,839 (62%)
Exceed gross alpha MCL of 10 pCi/L, net of Ra-226	Alabama Arkansas California Colorado Georgia Idaho Illinois	Iowa Maryland Michigan Minnesota Missouri Montana	New Mexico New York North Carolina North Dakota Oklahoma Pennsylvania	South Carolina South Dakota Texas Virginia Wisconsin Wyoming	11,157 (60%)	3,232,839 (62%)
Exceed combined radium MCL of 5 pCi/L	Alabama Arizona Arkansas California Colorado Connecticut Delaware Florida Georgia	Idaho Illinois Iowa Kansas Maine Maryland Michigan Minnesota Missouri	Montana New Jersey New Mexico New York North Carolina North Dakota Oklahoma Pennsylvania	South Carolina South Dakota Texas Utah Virginia Washington Wisconsin Wyoming	14,752 (79%)	4,200,139 (81%)

Notes:
(1) Based on data from RPI (1987a), RPI (1987b), and RPI (1984).
(2) Based on state-by-state 1997 SDWIS data.
(3) Exhibit does *not* indicate the number of systems out-of-compliance. Most of these systems are likely to have radionuclide concentrations below levels of concern.

Exhibit 5-2 provides similar data for systems located in states with potentially elevated levels of uranium. Roughly half the ground water systems and slightly more than one-quarter of the surface water systems are located in states that may have uranium levels in excess of the MCLs under consideration. Again, however, our approach may overstate the number of states with potentially affected systems, and concentration levels are likely to vary significantly within each state. Therefore, the exhibit may substantially overstate the number of systems potentially affected by each regulatory option.

Exhibit 5-2
NON-TRANSIENT NON-COMMUNITY SYSTEMS (NTNCS) LOCATED IN STATES WITH POTENTIALLY ELEVATED URANIUM LEVELS

Regulatory Option	Ground Water Systems[1,2]			Surface Water Systems[1,2,3]		
	States with Areas Potentially Exceeding MCL Options	NTNCS in Listed States (percent of total)[2,4]		States with Areas Potentially Exceeding MCL Options	NTNCS in Listed States (percent of total)[2,4]	
		Number of Systems	Population Served		Number of Systems	Population Served
Exceed MCL of 20 pCi/L (20 μg/L)	Arizona, California, Colorado, Connecticut, Georgia, Idaho, Kansas, Maine, Michigan, Minnesota, Missouri, Montana, Nebraska, Nevada, New Hampshire, New Mexico, North Carolina, Oklahoma, South Carolina, South Dakota, Texas, Utah, Virginia, Washington, Wisconsin, Wyoming	10,116 (54%)	2,660,194 (51%)	Colorado, Idaho, Kansas, Missouri, Montana, New Mexico, Texas, Utah, Wyoming	165 (29%)	147,010 (21%)
Exceed MCL of 40 pCi/L (40 μg/L)	Arizona, California, Colorado, Georgia, Idaho, Kansas, Maine, Michigan, Minnesota, Missouri, Montana, Nebraska, Nevada, New Hampshire, New Mexico, North Carolina, Oklahoma, South Carolina, South Dakota, Texas, Utah, Virginia, Wisconsin, Wyoming	9,387 (51%)	2,489,058 (48%)	Colorado, Idaho, Kansas, Montana, New Mexico, Texas, Utah, Wyoming	159 (28%)	145,065 (21%)
Exceed MCL of 80 pCi/L (80 μg/L)	Arizona, California, Colorado, Georgia, Kansas, Maine, Montana, Nevada, New Mexico, North Carolina, Oklahoma, South Dakota, Texas, Utah, Virginia, Wyoming	4,849 (26%)	1,568,551 (30%)	Colorado, Kansas, Montana, New Mexico, Texas, Utah, Wyoming	150 (26%)	143,495 (21%)

Sources:
(1) Based on occurrence data from ORNL (1981).
(2) Based on state-by-state 1997 SDWIS data.
(3) No surface water data were available for Delaware, Florida, Hawaii, North Dakota, or West Virginia. These states are not included in the uranium analysis.
(4) Exhibit does *not* indicate the number of systems out-of-compliance. Most of these systems are likely to have radionuclide concentrations below levels of concern.

IMPLICATIONS AND LIMITATIONS OF THE ANALYSIS

In this section, we discuss the major limitations of our methodology. We are currently researching the affects of the regulatory options on non-transient non-community systems in more detail, and plan to report the results in an Addendum to this document.

Factors that may lead us to overstate occurrence: The data reported in this chapter are not sufficient to estimate the number of non-transient non-community water systems that may be affected by the regulatory options under consideration. Instead, they provide an upper bound estimate of the number of states with potentially elevated levels.[12] Radionuclide concentrations vary significantly between locations within each state and many systems may rely on water sources that do not exceed the MCLs. In addition, some systems may have installed treatments that reduce radionuclide concentrations below levels of concern, either in response to regulations for other contaminants or concerns about exposure to radiation. Therefore, the data presented in the exhibits may substantially overstate the number of systems potentially affected by each regulatory option.

The available data suggest that most systems in the listed states may not exceed the MCLs. For example:

- Review of the NIRs data (in Chapter 2) indicates that the total number of community ground water systems in illegal or legal noncompliance status with the gross alpha and/or combined radium MCLs is less than three percent of all systems nationally.[13] For uranium, the rate of noncompliance is two percent or less of all (surface and ground water) systems nationally, depending on the regulatory option assessed.[14] While the absence of regulation of non-transient non-community systems suggests that noncompliance rates may be higher than

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[12] There is also significant uncertainty associated with the studies which are the basis for analysis in this chapter. Radionuclide concentrations are extrapolated based on limited geologic data or water samples, and are not always expressed in quantitative terms.

[13] Analysis conducted by EPA suggests that the number of systems located in each EPA region is relatively similar for small (serving populations of 25 - 3,300) community ground water systems and non-transient non-community systems. To the extent that areas of elevated radionuclide concentrations correspond with regional boundaries, these data suggest that concentrations in water sources used by community and non-transient non-community systems may be similar. (Personal communication with William Labiosa, EPA/OGWDW, December 1999.)

[14] Uranium is not regulated for either community or non-community systems; however, community systems may have lower occurrence levels if treatments installed to remove other contaminants remove uranium as well.

those reported for community systems, these data suggest that the percentages in Exhibits 5-1 and 5-2 may substantially overstate the rate of noncompliance.[15]

- Data provided by individual states indicates that only a fraction of the systems are likely to be out of compliance due to the variance in radionuclide concentrations within state boundaries. For example, in Illinois (which has relatively high radionuclide concentrations), data presented in Chapter 2 suggests that less than ten percent of the community ground water systems are not complying with the existing regulations. Illinois state staff roughly estimate that perhaps 14 percent of the non-transient non-community systems in the state may exceed the combined radium MCL of 5 pCi/L.[16] For Wisconsin, state staff roughly estimate that less than eight percent of the systems may exceed this MCL.[17]

These data suggest that perhaps between two or three percent and 15 percent of the systems located in the states listed in the above exhibits may exceed the MCLs under consideration. We are now conducting additional research to gain further insights into these issues.

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[15] Analysis conducted by EPA indicates that, for regulated inorganic contaminants which have physical properties similar to radium, community water supplies have a greater probability of reported violations than non-transient community water systems, suggesting that non-transient systems could have lower occurrence levels than community systems. (Personal communication with William Labiosa, EPA/OGWDW, December 1999.)

[16] Information provided by Miguel Deltoral, EPA Region 5, to Amit Kapdia, EPA/OGWDW, August 26, 1998.

[17] Information provided by Judy Adams, Wisconsin Department of Natural Resources, to William Labiosa, EPA/OGWDW, June 22, 1998.

SUMMARY AND CONCLUSIONS CHAPTER SIX

This chapter summarizes the results of the preliminary assessment of the costs and benefits of the regulatory options EPA is considering for radionuclides in drinking water. It discusses the changes in risk which coincide with changes in the costs of complying with each option, and compares the resulting costs and benefits.

The chapter contains two sections. The first section examines the potential incremental effects of the regulatory options relative to baseline conditions, including closing the monitoring loopholes and establishing new or revised MCLs. The second section discusses the implications and key limitations of this analysis, including a description of the costs and benefits that have not been quantified.

COMPARISON OF COSTS AND BENEFITS

This section compares the quantified cost increases associated with compliance with each regulatory option to the resulting benefits for community water systems. These costs include the monitoring, capital costs, and operations and maintenance costs described in Chapter Four. The quantified benefits include the decreased incidence of fatal and nonfatal cancers, as described in Chapter Three. Other impacts, such as the effects of the regulatory options on non-transient, non-community water systems and systems serving populations greater than one million, the use of MCLs as clean-up standards, and the effects of treatment on other contaminants present and resulting risk reductions, are not quantified in this preliminary analysis.

As discussed in Chapter One, some community water systems may legally exceed the current MCLs for gross alpha and combined radium, because the existing regulations include loopholes in the monitoring requirements that allow systems to avoid analyzing for the presence of certain radionuclides. EPA is now considering whether to close these monitoring loopholes, which would result in the costs and benefits summarized in Exhibits 6-1, 6-2, and 6-3 on the following pages. These impacts include the incremental costs of the new requirements for sampling and analysis. In addition, once the monitoring requirements are changed, some systems will find that they are out of compliance with the existing MCLs. Hence, for these systems, the impacts of the options for closing the loopholes include the costs and risk reductions associated with achieving the existing MCLs.

EPA is also considering whether to revise the MCLs for gross alpha and combined radium, as well as whether to establish a new MCL for uranium (which is not currently regulated). The costs and benefits of the alternative MCLs are also summarized in the exhibits. Exhibit 6-1 provides the estimates of the number of systems out of compliance using the direct proportions and lognormal approaches for estimating occurrence (as described in Chapter 2). Exhibits 6-2 and 6-3 provide the cost and risk results using the direct proportions and lognormal distribution approaches. More information on the risk and cost results is provided in Chapters Three and Four.

Exhibit 6-1
NUMBER OF COMMUNITY WATER SYSTEMS EXCEEDING STANDARDS

Option	Number of Systems
Illegally out of compliance with existing MCLs (combined radium = 5 pCi/L, gross alpha = 15 pCi/L) [1]	
Illegal noncompliance: gross alpha	400 systems
Illegal noncompliance: combined radium	420 systems
Total number of systems in illegal noncompliance (adjusts for overlap)	670 systems
Legally out of compliance with existing MCLs (due to monitoring loopholes)[2]	
Legal noncompliance (due to monitoring loopholes): gross alpha	210 - 250 systems
Legal noncompliance (due to monitoring loopholes): combined radium	270 - 320 systems
Total number of systems in legal noncompliance (adjusts for overlap)	310 - 400 systems
Out of compliance with options for revising MCLs [3]	
Gross alpha at 10 pCi/L net of radium 226	500 - 610 systems
Combined radium at 5 pCi/L with radium-228 limit at 3 pCi/L	210 systems
Total number of systems out of compliance with revised radium or gross alpha MCL (adjusts for overlap)	570 - 670 systems
Out of compliance with options for uranium MCL	
Uranium at 20 pCi/L (20 μg/L)	830 - 970 systems
Uranium at 40 pCi/L (40 μg/L)	300 - 430 systems
Uranium at 80 pCi/L (80 μg/L)	40 - 170 systems

Notes:
Ranges based on directly proportional versus lognormal distribution approach. Combined radium and gross alpha analyses include ground water systems only; uranium analysis includes both ground water and surface water systems.
1. Costs and risk reductions associated with complying with existing requirements for these systems are not assessed because these impacts are not attributable to the changes in requirements now under consideration.
2. Compared to initial baseline (i.e., occurrence data are adjusted to eliminate illegal noncompliance).
3. Compared to revised baseline (i.e., occurrence data are adjusted to eliminate legal noncompliance with both gross alpha and combined radium MCLs).

As indicated by the exhibit, about 670 systems were illegally out of compliance when the NIRS data were originally collected, if we adjust for double-counting. More recent data suggest that illegal noncompliance may have decreased somewhat since that time. Once we adjust the data to eliminate this illegal noncompliance, we find that between about 310 and 400 systems will be in legal noncompliance status with one or both of the existing MCLs, depending on whether we use the direct proportions or lognormal approach to estimate radionuclide concentrations. After the monitoring loopholes are closed, a total of 570 to 670 systems may be out of compliance with one or both of the MCL options for gross alpha and combined radium. In addition, the MCL options for uranium may affect from about 40 to almost 1,000 systems, depending on the option selected and the approach used to estimate noncompliance. In general, the estimates of the number of systems out of compliance are higher under the lognormal approach than under the direct proportions approach.

The costs and benefits associated with complying with the regulatory options are summarized on the following pages. We first report the results for the direct proportions approach and then report the results for the lognormal approach.

Exhibit 6-2
SUMMARY OF QUANTIFIED ANNUAL COSTS AND BENEFITS:
DIRECT PROPORTIONS APPROACH
(community water systems)

	Total Cancer Cases Avoided (fatal cases)	**Value of Avoided Cases (range)**	**Total Change in Compliance Costs**
Compliance with existing MCLs after closing monitoring loopholes (combined radium = 5 pCi/L, gross alpha = 15 pCi/L)[1]			
Eliminate gross alpha monitoring loophole only	0.04 cases total (0.03 fatal)	$0.2 million ($<0.1 - $0.3 million)	$2.5 million
Eliminate combined radium monitoring loophole only	0.31 cases total (0.21 fatal)	$1.2 million ($0.3 - $2.4 million)	$21.6 million
Eliminate both loopholes[2]	0.32 cases total (0.22 fatal)	$1.3 million ($0.3 - $2.5 million	$22.2 million
Compliance with revised MCL options [3]			
Revise gross alpha MCL to 10 pCi/L net of radium-226 only	0.53 cases total (0.35 fatal)	$2.1 million ($0.5 - $4.0 million)	$62.7 million
Limit radium-228 at 3 pCi/L within combined radium MCL of 5 pCi/L only	0.50 cases total (0.34 fatal)	$2.0 million ($0.5 - $3.9 million)	$40.7 million
Revise both gross alpha and radium MCLs[2]	0.78 cases total (0.52 fatal)	$3.1 million ($0.8 - $6.0 million)	$82.5 million
Compliance with new uranium MCL options			
Establish uranium MCL at 20 pCi/L (20 μg/L)	0.15 cases total (0.10 fatal)	$0.6 million ($0.2 - $1.2 million)	$31.6 million
Establish uranium MCL at 40 pCi/L (40 μg/L)	0.04 cases total (0.02 fatal)	$0.1 million ($<0.1 - $0.2 million)	$6.7 million
Establish uranium MCL at 80 pCi/L (80 μg/L)	0.01 cases total (<0.01 fatal)	$<0.1 million	$5.0 million

Notes:
See text for discussion of non-quantified impacts and limitations in the analysis.
Gross alpha and combined radium risk estimates include risk reductions due to incidental treatment; e.g., the removal of gross alpha by treatments installed to address combined radium and vice-versa.
1. Compared to full compliance baseline (i.e., occurrence data are adjusted to eliminate illegal noncompliance).
2. Removes double-counting of systems affected by both options.
3. Compared to revised baseline (i.e., occurrence data are adjusted to eliminate legal noncompliance).

Exhibit 6-3
SUMMARY OF QUANTIFIED ANNUAL COSTS AND BENEFITS: LOGNORMAL DISTRIBUTION APPROACH
(community water systems)

	Total Cancer Cases Avoided (fatal cases)	**Value of Avoided Cases (range)**	**Total Change in Compliance Costs**
Compliance with existing MCLs after closing monitoring loopholes (combined radium = 5 pCi/L, gross alpha = 15 pCi/L)[1]			
Eliminate gross alpha monitoring loophole only	0.35 cases total (0.22 fatal)	$1.3 million ($0.3 - $2.6 million)	$34.5 million
Eliminate combined radium monitoring loophole only	0.54 cases total (0.37 fatal)	$2.2 million ($0.6 - $4.3 million)	$38.8 million
Eliminate both loopholes[2]	0.86 cases total (0.57 fatal)	$3.4 million ($0.9 - $6.6 million)	$71.9 million
Compliance with revised MCL options[3]			
Revise gross alpha MCL to 10 pCi/L net of radium-226 only	0.70 cases total (0.45 fatal)	$2.7 million ($0.7 - $5.2 million)	$71.6 million
Limit radium-228 at 3 pCi/L within combined radium MCL of 5 pCi/L only	0.63 cases total (0.43 fatal)	$2.6 million ($0.7 - $5.0 million)	$37.9 million
Revise both gross alpha and radium MCLs[2]	1.08 cases total (0.72 fatal)	$4.3 million ($1.1 - $8.3 million)	$83.7 million
Compliance with new uranium MCL options			
Establish uranium MCL at 20 pCi/L (20 μg/L)	2.12 cases total (1.37 fatal)	$8.2 million ($2.1-$15.8 million)	$157.0 million
Establish uranium MCL at 40 pCi/L (40 μg/L)	1.54 cases total (1.00fatal)	$6.0 million ($1.5 - $11.6 million)	$68.0 million
Establish uranium MCL at 80 pCi/L (80 μg/L)	1.03 cases total (0.67 fatal)	$4.0 million ($1.0 - $7.7 million)	$29.9 million

Notes:
See text for discussion of non-quantified impacts and limitations in the analysis.
Gross alpha and combined radium risk estimates include risk reductions due to incidental treatment; e.g., the removal of gross alpha by treatments installed to address combined radium and vice-versa.
1. Compared to full compliance baseline (i.e., occurrence data are adjusted to eliminate illegal noncompliance).
2. Removes double-counting of systems affected by both options.
3. Compared to revised baseline (i.e., occurrence data are adjusted to eliminate legal noncompliance).

Under the direct proportions approach, Exhibit 6-2 indicates that risk reductions total less than one statistical cancer case annually for each option, and that compliance costs range from $2.5 million to $82.5 million depending on the options considered. Under the lognormal approach, Exhibit 6-3 indicates that risk reductions range from less than one to slightly more than two statistical cancer cases annually, and that compliance costs range from $34.5 million to $157.0 million depending on the options selected.

These exhibits show that the alternative approaches for estimating occurrence lead to substantially different estimates of risk reductions and compliance costs for some of the regulatory options. However, under both approaches, costs exceed the value of the risk reductions by a substantial amount.

As indicated by the exhibits, most of the regulatory options would change the statistical risks of incurring fatal or nonfatal cancers by less than two cases per year; in general, fatal cases are roughly two-thirds of the total cases avoided. The mean estimate of the value of these risk reductions ranges from less than $0.1 million to slightly over $8.0 million annually, depending on the regulatory option considered and the approach used to estimate occurrence. Sensitivity analysis of the values assigned to these avoided risks indicates that the highest total value may be about $16.0 million under the lognormal approach, if an MCL of 20 pCi/L is developed for uranium. The lowest risk reduction values accrue for closure of the gross alpha loophole and the less stringent uranium options under the direct proportions approach.

The value of the risk reductions is often less than the estimated compliance costs by an order of magnitude or more. Compliance costs range from $2.5 million to over $150 million annually. The options with the lowest and highest costs vary depending on the approach used for estimating occurrence. In most cases, the lognormal approach leads to higher costs and larger risk reductions. Use of the lognormal tends to increase the estimates of the number of systems out of compliance in the larger size categories and to lead to higher estimates of baseline concentrations. However, in a few cases the lognormal estimates are lower because data on which the distributions are based are tightly clustered near zero with only a few higher observations, which generally lowers the occurrence estimates.

The quantified costs and benefits can also be considered in terms of costs per cancer case avoided (compliance costs divided by cases avoided) or as net benefits (the value of risk reductions minus compliance costs) as illustrated in Exhibit 6-4 below. This exhibit suggests that the cost per cancer case avoided exceeds $30 million for each option considered, and is greater than $60 million in most cases. In contrast, the mean estimate of the value of avoiding fatal risks is about $5.8 million per statistical case (as discussed in Chapter 3), suggesting that the costs of achieving the MCLs may be greater than individuals' willingness to pay for these risk reductions. The estimated dollar value of the risk reductions offsets the compliance costs to a small extent, with negative net benefits in all cases. These calculations should be viewed with caution, however, because compliance costs may be overstated, not all benefits are quantified, and the value of the risk reductions is uncertain, as discussed elsewhere in this report.

Exhibit 6-4

COMPARISON OF QUANTIFIED ANNUAL COSTS AND BENEFITS
(community water systems)

Regulatory Option	Directly Proportional		Lognormal Distribution	
	Cost per Cancer Case Avoided [3]	Net Benefits [4]	Cost per Cancer Case Avoided [3]	Net Benefits [4]
Compliance with existing MCLs after closing monitoring loopholes (combined radium = 5 pCi/L, gross alpha = 15 pCi/L)[1]				
Eliminate gross alpha monitoring loophole only	$62.5 million	($2.3 million)	$98.6 million	($33.2 million)
Eliminate combined radium monitoring loophole only	$69.7 million	($20.4 million)	$71.9 million	($36.6 million)
Eliminate both loopholes [2]	$69.4 million	($20.9 million)	$83.6 million	($68.5 million)
Compliance with revised MCL options[2]				
Revise gross alpha MCL to 10 pCi/L net of radium-226 only	$118.3 million	($60.6 million)	$102.3 million	($68.9 million)
Limit radium-228 at 3 pCi/L within combined radium MCL of 5 pCi/L only	$81.4 million	($38.7 million)	$60.2 million	($35.3 million)
Revise both gross alpha and radium MCLs [2]	$105.8 million	($79.4 million)	$77.5 million	($79.4 million)
Compliance with new uranium MCL options				
Establish uranium MCL at 20 pCi/L (20 μg/L)	$210.7 million	($31.0 million)	$74.1 million	($148.8 million)
Establish uranium MCL at 40 pCi/L (40 μg/L)	$167.5 million	($6.6 million)	$44.2 million	($62.0 million)
Establish uranium MCL at 80 pCi/L (80 μg/L)	$500.0 million	($5.0 million)	$29.0 million	($25.9 million)

Notes:
See text for discussion of non-quantified impacts and limitations in the analysis.
1. Compared to full compliance baseline (i.e., occurrence data are adjusted to eliminate illegal noncompliance).
2. Compared to revised baseline (i.e., occurrence data are adjusted to eliminate legal noncompliance).
3. Cost estimates divided by total number of cases avoided from Exhibits 6-2 and 6-3.
4. Best estimates of value of avoided cases minus cost estimate from Exhibits 6-2 and 6-3; parentheses indicate negative numbers.

IMPLICATIONS AND KEY LIMITATIONS

These results are preliminary and subject to uncertainties that are discussed in detail in the preceding chapters, as are EPA's plans for conducting additional research to address related concerns. When all of the sources of uncertainty are taken into account, EPA believes that costs may exceed benefits by a smaller amount than indicated by the above exhibits, and in some cases actual costs and benefits may be relatively equal.

The discussion of uncertainty in Chapter Four suggests that the costs may be overstated. The cost estimates summarized in the above exhibits assume that systems will often install treatment to comply with the MCLs, while recent research suggests that they will generally select less costly options such as blending water from contaminated and uncontaminated sources. The benefits associated with risk reductions may be understated because the analysis does not consider the effects of treatment on other contaminants present nor does it include the effects of uranium on the kidneys. In addition, the risk coefficients used in the analysis are highly uncertain. This report also does not consider benefits other than human health risk reductions, such as improvements (if any) in the aesthetic qualities of the water (taste, odor, color) or reduced materials damages that may be associated with the strategies used to comply with the revised regulations.

The analysis also does not include consideration of other impacts that will have more uncertain effects on the relationship between costs and benefits. The exhibits do not include estimates of costs and risk reductions for systems serving populations more than one million or on non-transient non-community systems. This report also does not consider the impact of the regulations on other programs, such as the use of MCLs in site clean-up decisions.

Finally, the preliminary analysis does not quantify the impacts of the regulatory options on certain groups of concern. It does not address health risks posed to children, members of low income or minority groups, or sensitive sub-populations. It also does not address unfunded mandates or options for further minimizing costs for small systems. All of these factors are of interest to decision-makers and will be taken into account in the final selection of the regulatory options to be implemented.

Appendix A

NUMBER OF WATER SYSTEMS AND POPULATION SERVED
(Community and Non-Transient Non-Community Water Systems)

Appendix A

DATA ON WATER SYSTEMS AND POPULATIONS SERVED

The following pages provide the detailed data on the water system characteristics used in the preliminary economic analysis. These exhibits are based on validated 1997 data from EPA's Safe Drinking Water Information System (SDWIS) provided in February 1999.[1] We exclude systems classified as "other" ownership from these exhibits because the validation effort indicated that these systems are most likely inactive. We also exclude systems serving fewer than 25 people because they do not meet the definition of public water systems subject to the regulations. Community water systems serving more than one million persons are assessed separately in this analysis, and hence are also excluded from the exhibits (no non-transient non-community systems serve populations greater than one million). Because the data on population served includes only retail populations, we include systems relying on purchased water to avoid leaving out the portion of the population that depends on these systems.

1. Exhibits A-1 and A-2 provide data on community water systems organized by water source and system size class, including the number of systems and the average population served.

2. Exhibits A-3 and A-4 provide the same data for non-transient, non-community water systems.

3. Exhibit A-5 provides data on non-transient, non-community systems organized by state, number of ground water systems, number of surface water systems, and population served by each type.

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[1] International Consultants, Incorporated, *Drinking Water Baseline Handbook: First Edition (Draft)*, prepared for the U.S. Environmental Protection Agency, March 3, 1999, Exhibits B4.1.1(a), B4.1.2(a), B4.2.1(a), and B4.2.1(b).

Exhibit A-1

COMMUNITY WATER SYSTEMS: NUMBER OF SYSTEMS (1997 SDWIS data)

	Population Categories								
System Type	**25-100**	**101-500**	**501-1,000**	**1,001-3,300**	**3,301-10,000**	**10,001-50,000**	**50,001-100,000**	**100,001-1,000,000**	**Total**
Ground Water	13,848	14,654	4,645	5,674	2,472	1,279	139	70	42,781
Public	1,202	4,104	2,574	3,792	1,916	997	113	52	14,750
Private	12,361	9,776	1,705	1,531	459	243	24	14	26,113
Purchased-public	114	427	265	272	84	36	1	4	1,203
Purchased-private	171	347	101	79	13	3	1	0	715
Surface Water	942	1,967	1,167	2,435	1,821	1,528	268	247	10,375
Public	151	385	331	928	882	810	146	161	3,794
Private	307	389	111	211	107	113	33	39	1,310
Purchased-public	185	687	511	1,015	720	560	86	40	3,804
Purchased-private	299	506	214	281	112	45	3	7	1,467
TOTAL	**14,790**	**16,621**	**5,812**	**8,109**	**4,293**	**2,769**	**403**	**317**	**53,156**

Exhibit A-2

COMMUNITY WATER SYSTEMS: AVERAGE NUMBER OF PERSONS SERVED (1997 SDWIS data)

	Population Categories							
System Type	**25-100**	**101-500**	**501-1,000**	**1,001-3,300**	**3,301-10,000**	**10,001-50,000**	**50,001-100,000**	**100,001-1,000,000**
Ground Water	61	249	737	1,858	5,739	21,168	67,661	225,473
Public	65	290	745	1,885	5,758	20,875	67,543	213,794
Private	60	230	721	1,805	5,669	22,562	67,670	297,449
Purchased-public	71	282	741	1,809	5,609	20,076	96,000	125,381
Purchased-private	64	271	772	1,775	6,317	18,654	52,500	0
Surface Water	62	283	751	1,982	5,964	22,656	68,441	247,380
Public	55	300	769	2,064	6,012	23,080	69,224	257,483
Private	59	259	770	1,975	6,182	25,438	67,985	277,442
Purchased-public	71	297	745	1,935	5,928	21,712	67,082	193,330
Purchased-private	64	270	722	1,879	5,603	19,776	74,293	156,384

Exhibit A-3

NON-TRANSIENT NON-COMMUNITY WATER SYSTEMS: NUMBER OF SYSTEMS (1997 SDWIS data)

	Population Categories								
System Type	**25-100**	**101-500**	**501-1,000**	**1,001-3,300**	**3,301-10,000**	**10,001-50,000**	**50,001-100,000**	**100,001-1,000,000**	**Total**
Ground Water	9,169	6,873	1,912	675	59	11	0	0	18,699
Public	1,704	3,109	1,145	327	21	5	0	0	6,311
Private	7,432	3,731	752	342	33	2	0	0	12,292
Purchased-public	11	16	8	6	5	3	0	0	49
Purchased-private	22	17	7	0	0	1	0	0	47
Surface Water	209	223	77	67	16	4	1	1	598
Public	48	34	11	17	1	0	0	0	111
Private	78	119	47	33	8	0	0	0	285
Purchased-public	14	27	7	6	3	3	1	1	62
Purchased-private	69	43	12	11	4	1	0	0	140
TOTAL	**9,378**	**7,096**	**1,989**	**742**	**75**	**15**	**1**	**1**	**19,297**

Exhibit A-4

NON-TRANSIENT NON-COMMUNITY WATER SYSTEMS: AVERAGE NUMBER OF PERSONS SERVED
(1997 SDWIS data)

	Population Categories							
System Type	**25-100**	**101-500**	**501-1,000**	**1,001-3,300**	**3,301-10,000**	**10,001-50,000**	**50,001-100,000**	**100,001-1,000,000**
Ground Water	53	257	720	1,626	5,125	18,348	0	0
Public	55	281	705	1,517	6,000	15,525	0	0
Private	53	238	741	1,717	4,563	15,200	0	0
Purchased-public	59	274	835	2,418	5,160	26,267	0	0
Purchased-private	34	221	705	0	0	15,000	0	0
Surface Water	48	264	787	1,845	5,256	29,500	93,204	0
Public	45	258	801	2,125	4,860	0	0	0
Private	56	261	785	1,673	5,342	0	0	0
Purchased-public	47	248	750	2,080	5,160	33,333	93,204	152,079
Purchased-private	43	285	800	1,803	0	18,000	0	0

Exhibit A-5

NON-TRANSIENT NON-COMMUNITY WATER SYSTEMS BY STATE (1997 SDWIS data)

	Number of Systems		Total Population Served	
State	**Ground Water**	**Surface Water**	**Ground Water**	**Surface Water**
Alabama	46	8	21,182	11,102
Alaska	0	0	0	0
Arizona	214	9	100,287	6,652
Arkansas	57	60	13,528	3,869
California	1,017	52	359,033	112,956
Colorado	133	26	34,884	16,557
Connecticut	444	0	101,172	0
Delaware	76	1	23,915	1,300
Florida	1,115	1	285,998	250
Georgia	291	9	80,240	5,367
Hawaii	14	2	7,437	930
Idaho	265	9	68,195	1,570
Illinois	445	11	142,645	9,816
Indiana	692	4	158,048	1,569
Iowa	133	2	35,715	2,000
Kansas	66	2	23,002	637
Kentucky	80	26	21,620	11,394
Louisiana	234	12	88,070	11,036
Maine	344	3	67,436	1,370
Maryland	495	2	142,171	572
Massachusetts	227	4	67,647	735
Michigan	1,718	0	344,654	0
Minnesota	429	6	43,394	2,159

Exhibit A-5

NON-TRANSIENT NON-COMMUNITY WATER SYSTEMS BY STATE (1997 SDWIS data)

	Number of Systems		Total Population Served	
State	**Ground Water**	**Surface Water**	**Ground Water**	**Surface Water**
Mississippi	124	0	88,119	0
Missouri	227	6	76,360	1,945
Montana	213	5	38,382	620
Nebraska	189	0	26,219	0
Nevada	91	8	28,497	11,420
New Hampshire	414	0	75,905	0
New Jersey	999	3	274,557	3,139
New Mexico	149	7	38,101	1,452
New York	693	32	248,223	19,429
North Carolina	655	11	198,136	9,506
North Dakota	22	10	2,349	2,096
Ohio	1,116	15	276,441	10,004
Oklahoma	123	9	20,419	1,461
Oregon	332	9	67,531	4,868
Pennsylvania	1,249	25	480,283	15,854
Rhode Island	69	0	25,121	0
South Carolina	247	11	71,219	13,926
South Dakota	25	4	3,072	375
Tennessee	58	10	11,010	16,358
Texas	747	81	253,447	96,945
Utah	52	10	20,969	21,571
Vermont	0	0	0	0
Virginia	649	15	288,913	74,318

Exhibit A-5

NON-TRANSIENT NON-COMMUNITY WATER SYSTEMS BY STATE (1997 SDWIS data)

	Number of Systems		**Total Population Served**	
State	**Ground Water**	**Surface Water**	**Ground Water**	**Surface Water**
Washington	285	17	69,964	170,466
West Virginia	178	19	38,774	15,483
Wisconsin	1,049	0	214,561	0
Wyoming	80	19	13,733	5,713
Total	**18,570**	**575**	**5,180,578**	**698,790**

Notes:
Excludes systems serving less than 25 people; includes systems relying primarily on purchased water.
Surface water systems include those using ground water under the influence of surface water.
The Drinking Water Baseline Handbook, which contain state and national summaries of the SDWIS system and population counts, is currently undergoing revision. The totals in this table may not match the national totals in Exhibits A-3 and A-4.
Source:
International Consultants, Incorporated, *Drinking Water Baseline Handbook: First Edition (Draft)*, prepared for the U.S. Environmental Protection Agency, March 3, 1999.

Appendix B

HISTOGRAMS OF OCCURRENCE DATA

Appendix B

HISTOGRAMS OF OCCURRENCE DATA

The following pages provide graphs of the frequency distributions of the National Inorganics and Radionuclides Survey (NIRS) data used in the occurrence analysis (as described in Chapter Two). For drinking water systems serving 25-500 persons and 501-3,300 persons, we include three histograms for both combined radium and gross alpha: the original NIRS data, the initial baseline data (adjusted to eliminate illegal noncompliance), and the revised baseline (adjusted to eliminate legal noncompliance). For uranium, we provide histograms of the original NIRS data only; because uranium is not currently regulated in drinking water systems, there are no adjustments for illegal or legal noncompliance.

We do not include graphs of the occurrence data for systems serving more than 3,300 persons because the sample sizes for the two largest size categories in NIRS are not large enough to be representative at the national level. We also exclude graphs of uranium occurrence in surface water, because NIRS reports data for ground water systems only. However, because we assume that uranium levels in surface water are one-third the levels of uranium in groundwater (as described in Chapter Two), the histograms for surface water would have the same shape as the graphs for uranium in groundwater, but would be centered around a lower activity level; i.e., the whole graph would shift to the left.

The graphs in this Appendix do not include censored data points, i.e., those reported in NIRS as less than the Minimum Reporting Limit (MRL) for all radionuclides included in the calculation of activity levels. If included in the histograms, these data points would be clustered at the left side of the distributions. For each graph, we indicate the number of censored systems and the percentage of total systems that the censored data points represent.

It should be noted that the graphs in this Appendix are scaled differently in order to fit them on a page. This change in scale means that care must be taken when comparing the graphs. For example, when compared on the same scale, the initial baseline and revised baseline distributions for a given radionuclide and system size category have shorter right-hand tails than the distribution of the original NIRS data.

The remainder of this Appendix includes the following.

1. Exhibit B-1(a) presents the original NIRS, initial baseline, and revised baseline occurrence distributions for combined radium in systems serving populations of 25-500 persons. Exhibit B-1(b) provides the same graphs for systems serving populations of 501 to 3,300 persons.

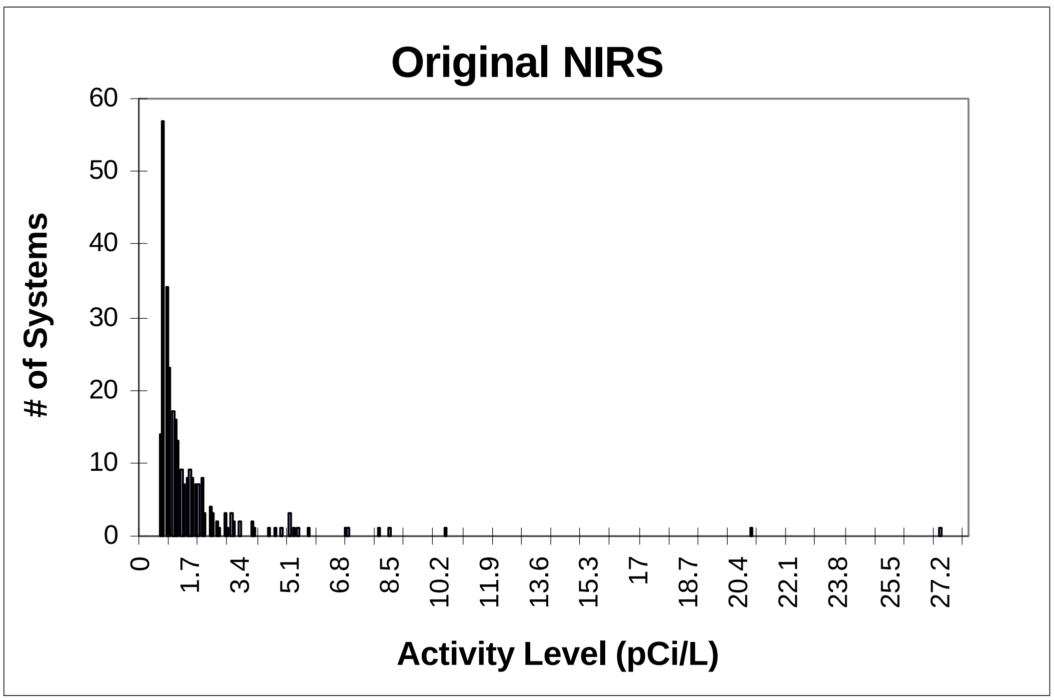
2. Exhibits B-2(a) and B-2(b) include the analogous histograms for gross alpha.

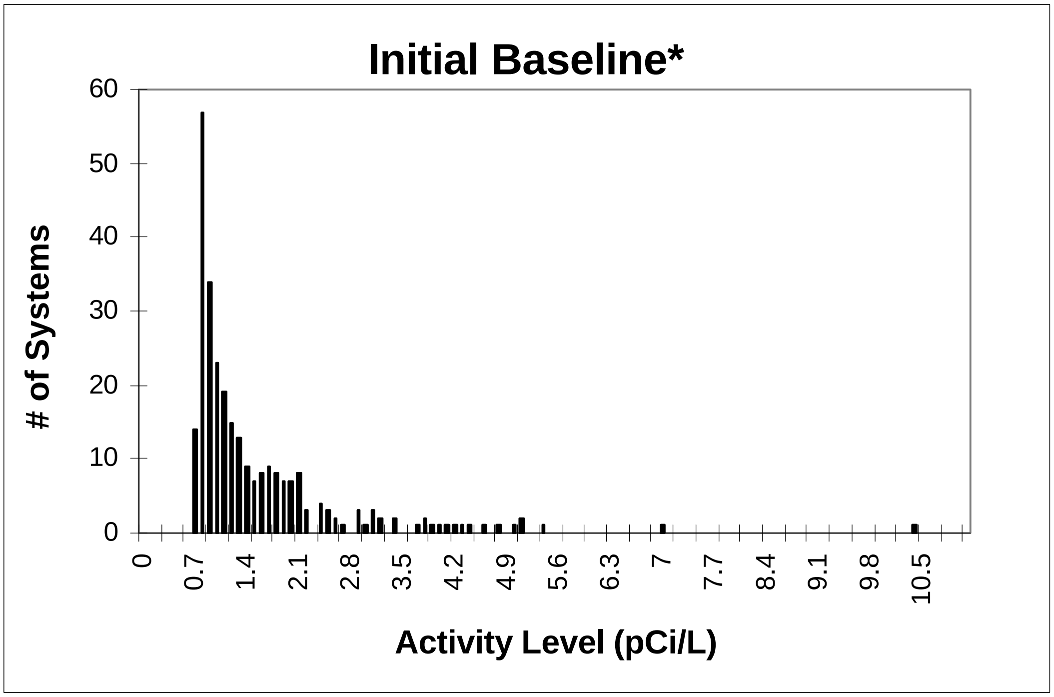
3. Exhibit B-3 provides histograms of the original NIRS data for uranium.

Exhibit B-1(a)

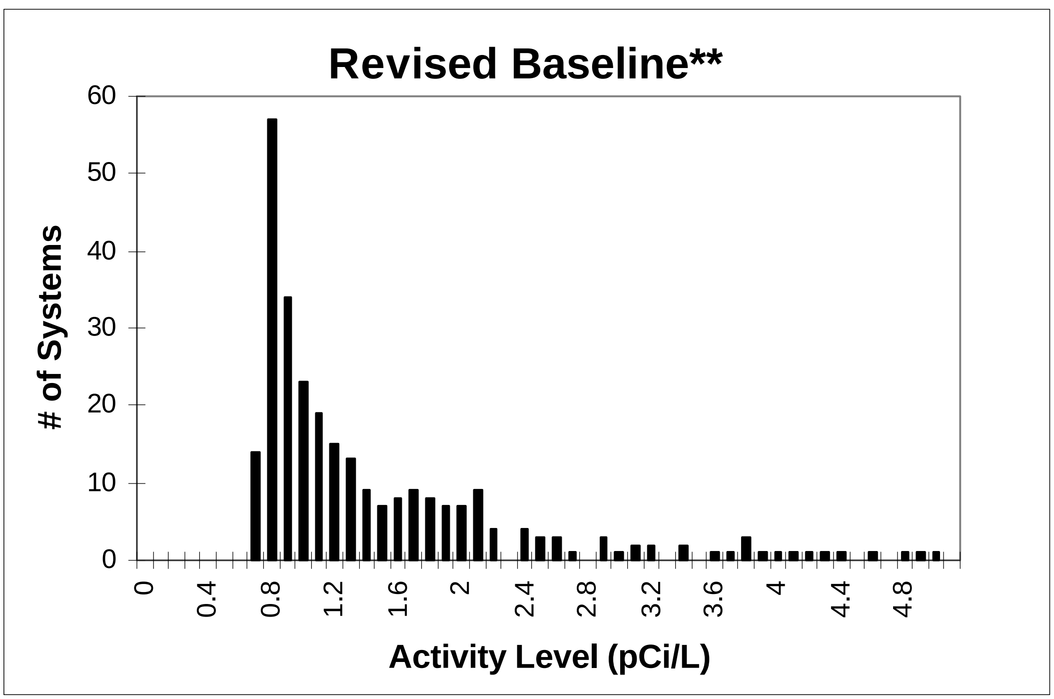
DISTRIBUTION OF COMBINED RADIUM ACTIVITY LEVELS IN NIRS
(population <=500)

Note: Censored data points (i.e., those reported in NIRS as less than the Minimum Reporting Limit (MRL) for both radium-226 and radium-228) are not depicted in these graphs. For combined radium, the values of these censored data range from zero to 1.18 (the sum of the MRLs for radium-226 and radium-228). Of the 671 data points for NIRS systems serving a population of less than or equal to 500 people, 390 (58.1 percent) are censored. Note that these graphs are scaled differently.





* Adjusted to eliminate illegal noncompliance.

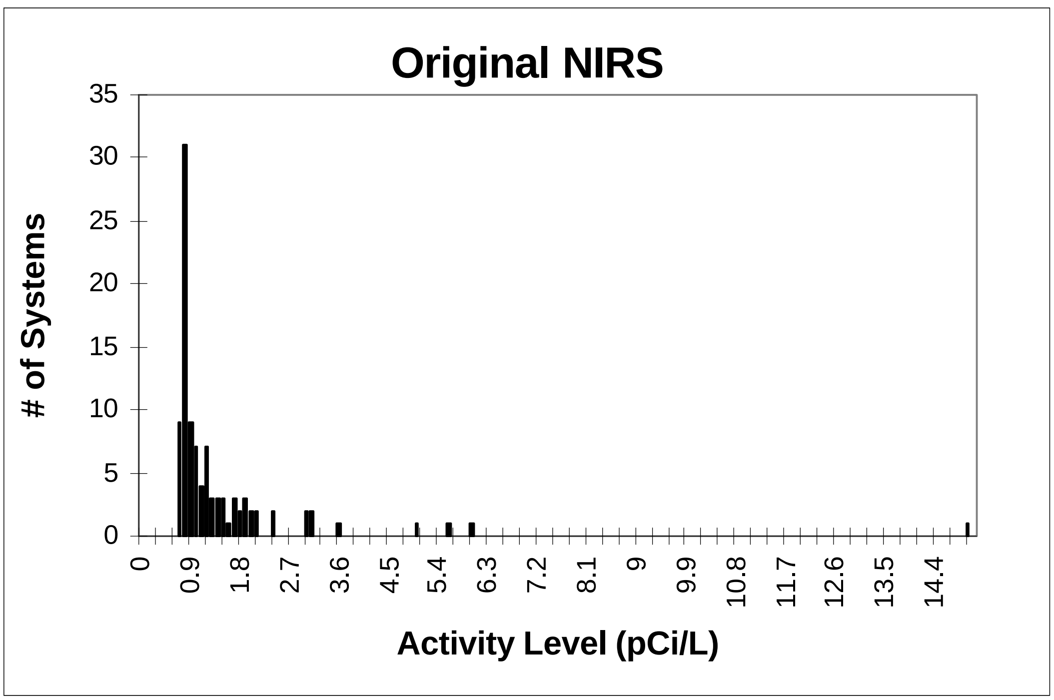


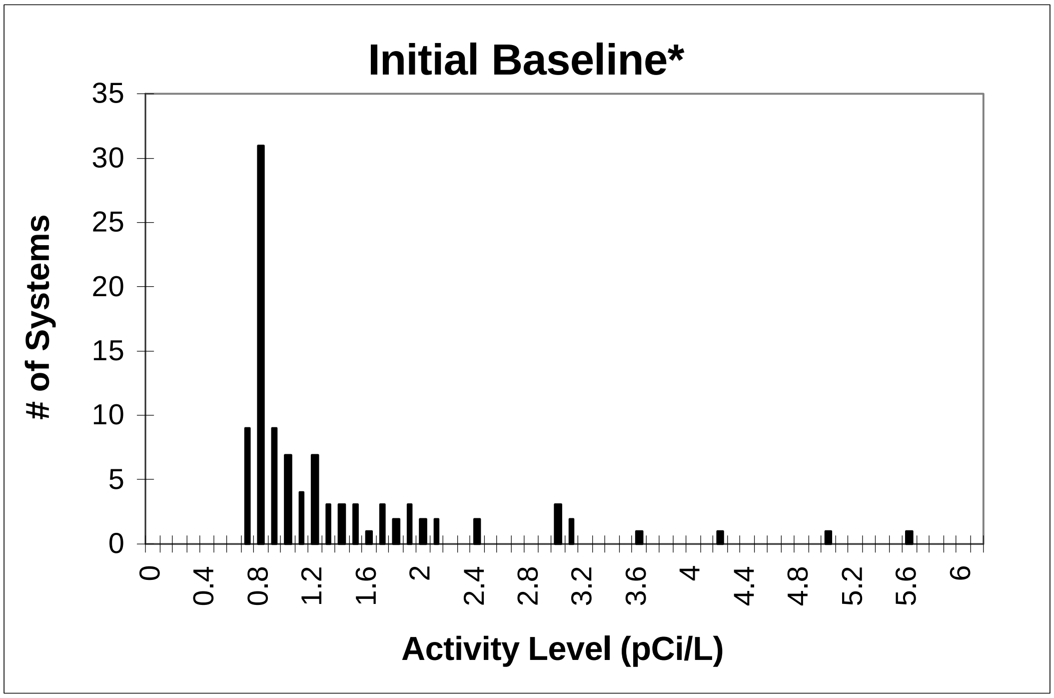
**Adjusted to eliminate legal noncompliance.

Exhibit B-1(b)

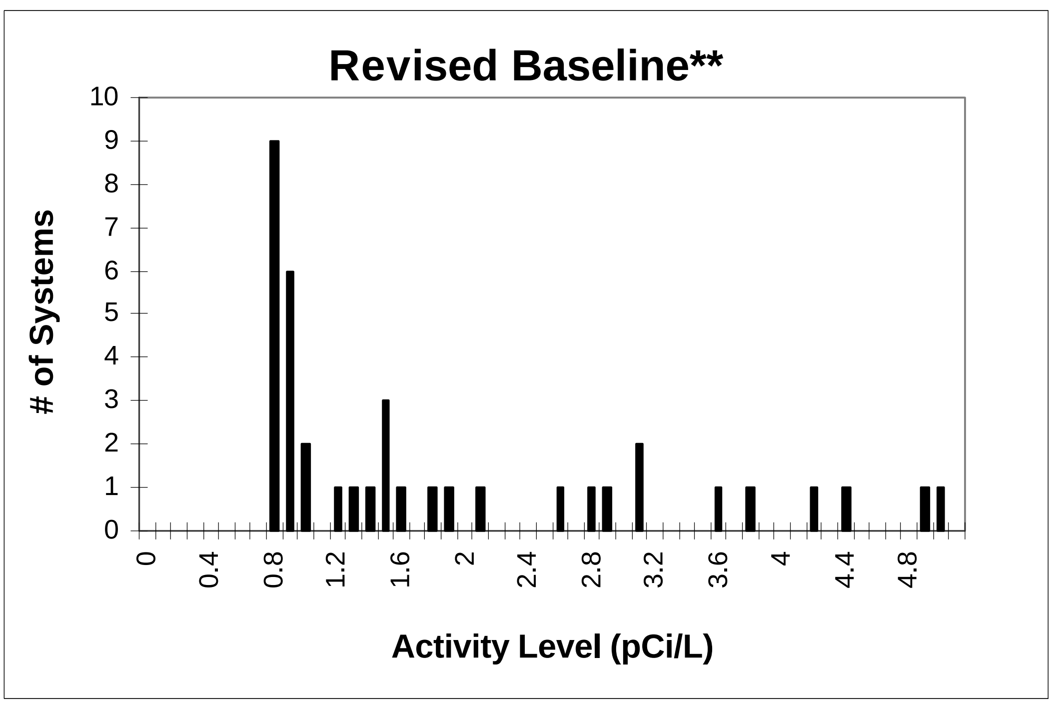
DISTRIBUTION OF COMBINED RADIUM ACTIVITY LEVELS IN NIRS
(population 501-3,300)

Note: Censored data points (i.e., those reported in NIRS as less than the Minimum Reporting Limit (MRL) for both radium-226 and radium-228) are not depicted in these graphs. For combined radium, the values of these censored data range from zero to 1.18 (the sum of the MRLs for radium-226 and radium-228). Of the 231 data points for NIRS systems serving a population of 501 - 3,300 people, 130 (56.3 percent) are censored. Note that these graphs are scaled differently.





* Adjusted to eliminate illegal noncompliance.

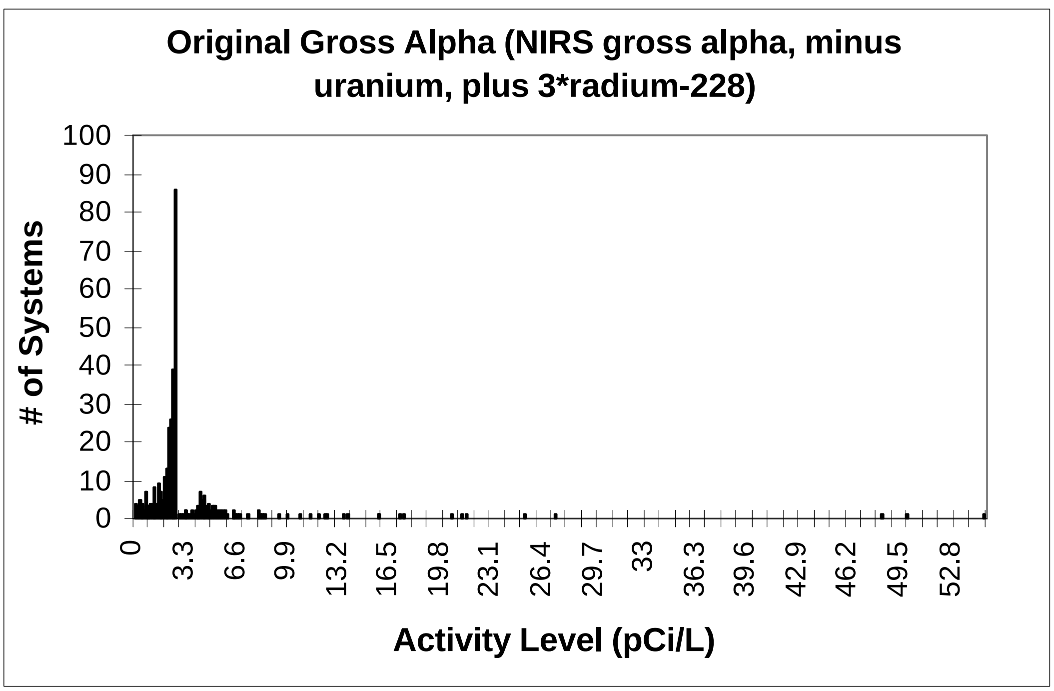


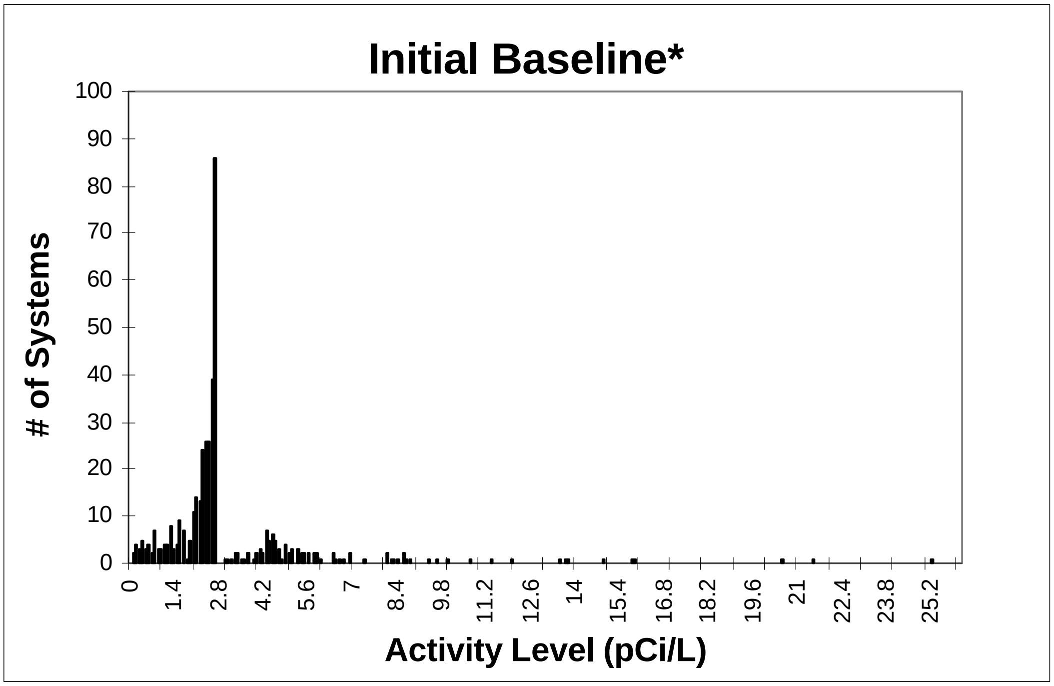
**Adjusted to eliminate legal noncompliance.

Exhibit B-2(a)

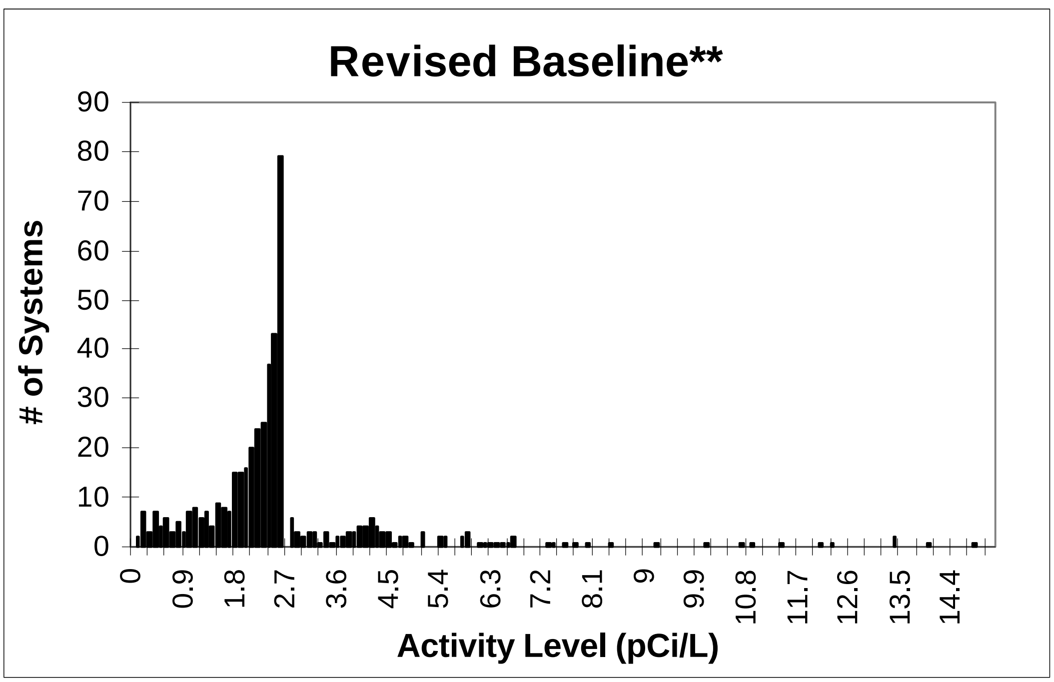
DISTRIBUTION OF GROSS ALPHA ACTIVITY LEVELS IN NIRS
(population <=500)

Note: To adjust the gross alpha values reported for a system in NIRS to meet the regulatory definitions used in this analysis, we subtract the NIRS uranium value from the gross alpha value and add three times the radium-228 value (to estimate the occurrence of radium-224 and its daughter products). To calculate net gross alpha for the revised baseline, we then subtract radium-226. Censored data points (i.e., those reported in NIRS as less than the Minimum Reporting Limit (MRL) for all of the radionuclide components of gross alpha) are not depicted in these graphs. For gross alpha, the values of these censored data points fall below 5.6 pCi/L. Of the 660 original gross alpha and initial baseline data points for NIRS systems serving a population of less than or equal to 500 people, 227 (34.4 percent) are censored. Of the 659 revised baseline data points for NIRS systems in this population size category, 182 (27.6 percent) are censored. Note that these graphs are scaled differently.





* Adjusted to eliminate illegal noncompliance.

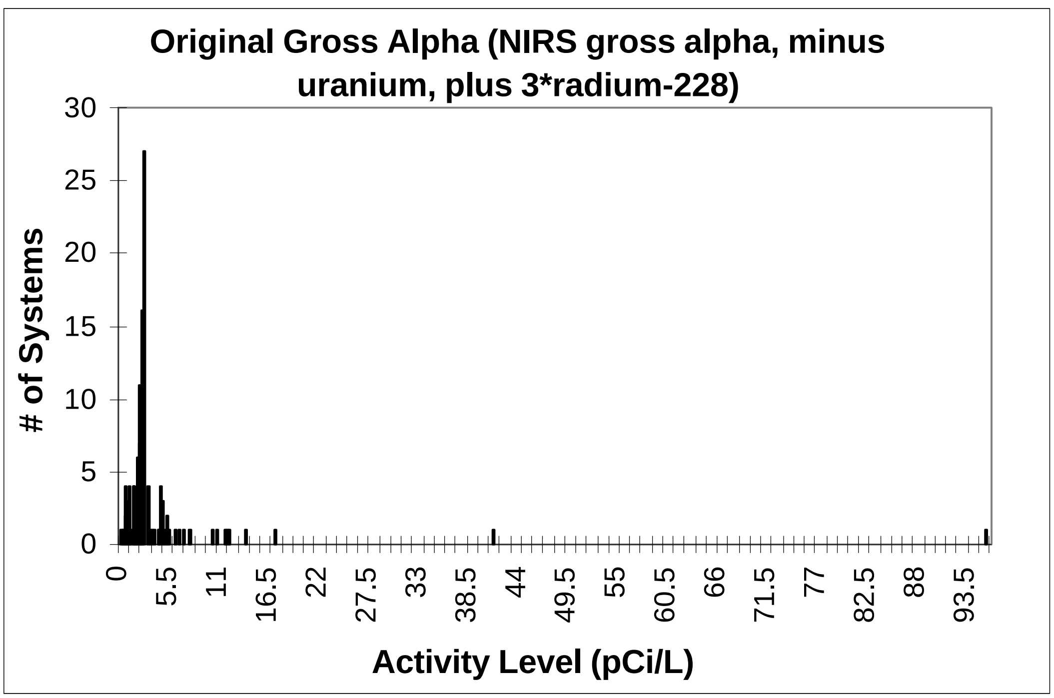


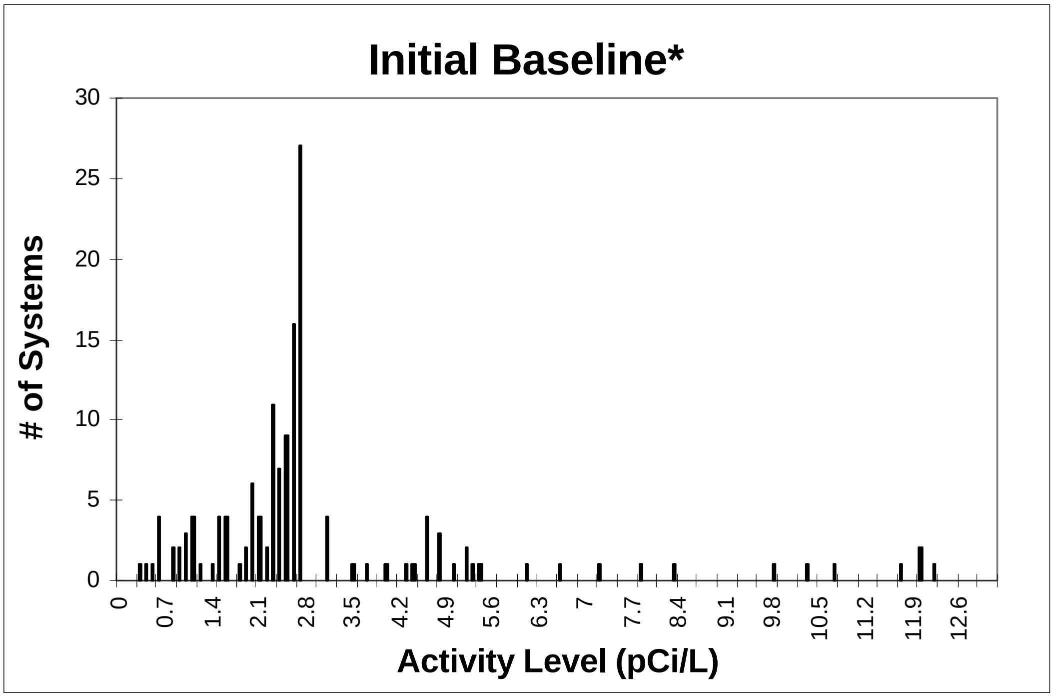
**Adjusted to eliminate legal noncompliance. Excludes radium-226.

Exhibit B-2(b)

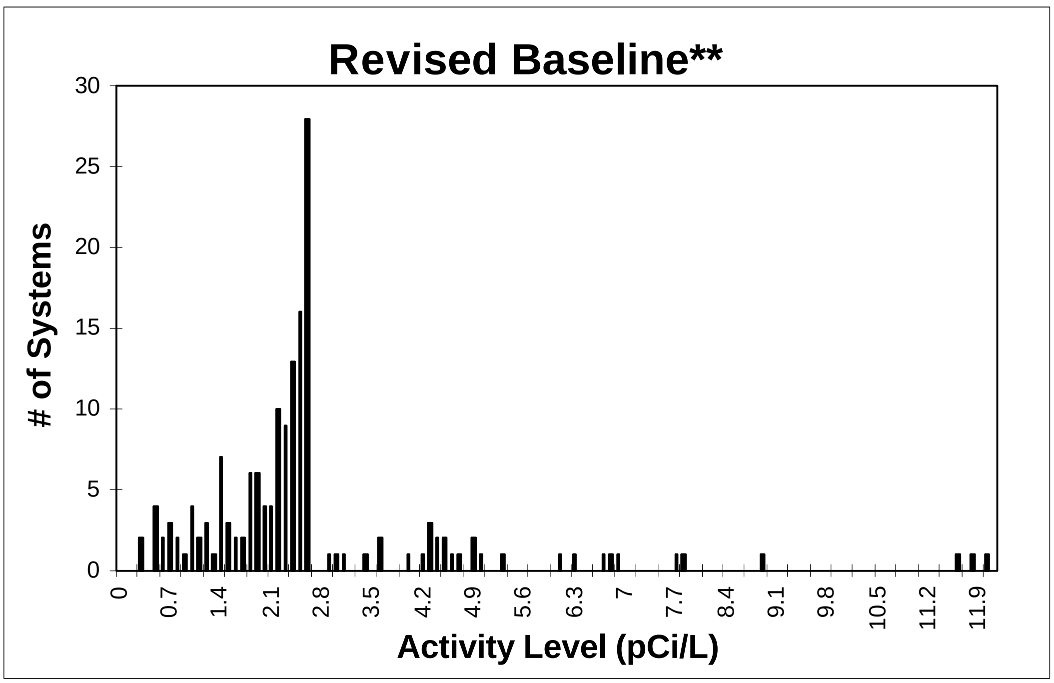
DISTRIBUTION OF GROSS ALPHA ACTIVITY LEVELS IN NIRS
(population 501-3,300)

Note: To adjust the gross alpha values reported for a system in NIRS to meet the regulatory definitions used in this analysis, we subtract the NIRS uranium value from the gross alpha value and add three times the radium-228 value (to estimate the occurrence of radium-224 and its daughter products). To calculate net gross alpha for the revised baseline, we then subtract radium-226. Censored data points (i.e., those reported in NIRS as less than the Minimum Reporting Limit (MRL) for all of the radionuclide components of gross alpha) are not depicted in these graphs. For gross alpha, the values of these censored data points fall below 5.6 pCi/L. Of the 229 original gross alpha and initial baseline data points for NIRS systems serving a population of 501 to 3,300 people, 78 (34.1 percent) are censored. Of the 229 revised baseline data points for NIRS systems in this population size category, 61 (26.6 percent) are censored. Note that these graphs are scaled differently.





* Adjusted to eliminate illegal noncompliance.



**Adjusted to eliminate legal noncompliance. Excludes radium-226.

Exhibit B-3
DISTRIBUTION OF URANIUM ACTIVITY LEVELS IN NIRS

Note: Censored data points (i.e., those reported in NIRS as less than the Minimum Reporting Limit (MRL)) are not depicted in these graphs. For uranium, the values of these censored data range from zero to 0.08 (the MRL for uranium). Of the 662 data points for NIRS systems serving a population of less than or equal to 500 people, 185 (27.9 percent) are censored. Of the 232 data points for NIRS systems serving a population of 501 - 3,300 people, 69 (29.7 percent) are censored. Note that these graphs are scaled differently.

Exhibit B-3(a): Population <=500

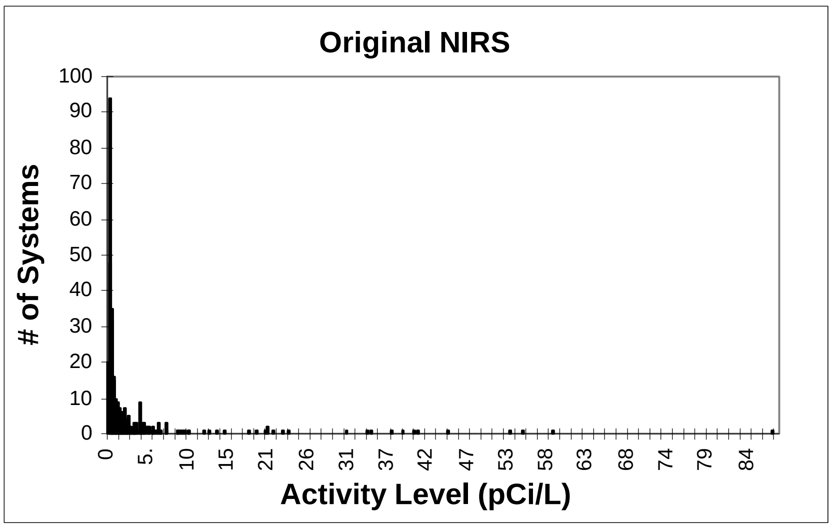
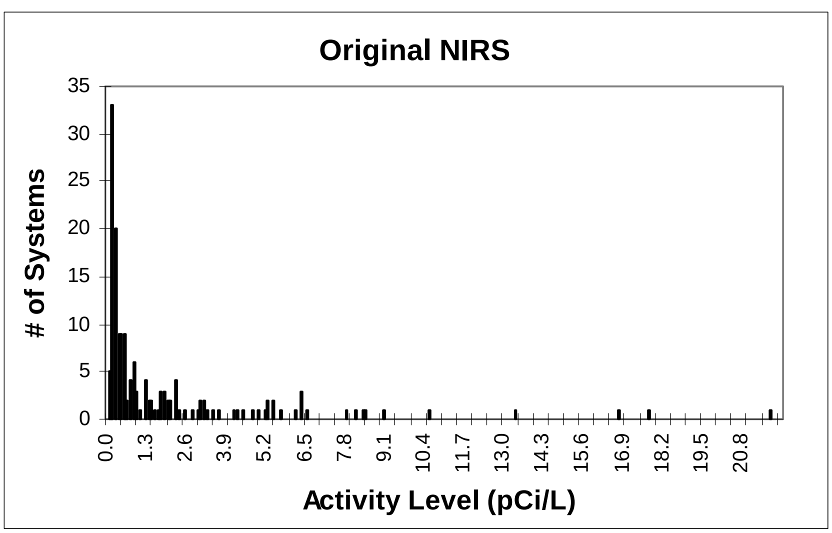


Exhibit B-3(b): Population 501-3,300



Appendix C

DETAILED RISK RESULTS FOR COMMUNITY WATER SYSTEMS

Appendix C

DETAILED RISK RESULTS FOR COMMUNITY WATER SYSTEMS

Appendix C presents the risk results for community water systems by cancer type (nonfatal, fatal, or total) and system size and type. Note that the tables indicate the risk reductions due solely to treatment of the radionuclide directly addressed by the regulatory option; they do not consider the incidental treatment of other radionuclides present.

Exhibit C-1 presents estimates of the cancer risk reductions that result from closing the monitoring loopholes; Exhibits C-2 through C-5 present anticipated cancer risk reductions from changes to the MCLs. The tables presenting the risk results for the uranium MCLs provide separate estimates for surface water and ground water systems (only ground water systems were considered for the other regulatory options). The total number of cases avoided including the effects of incidental treatment are provided in Chapter 3 of this report.

Exhibit C-1

ANNUAL CANCER RISKS AVOIDED: CLOSING THE MONITORING LOOPHOLES
(Community Ground Water Systems)

System Size Class	Cancer Type	Directly Proportional (statistical cases)		Lognormal Distribution (statistical cases)	
		Radium Loophole	Gross Alpha Loophole	Radium Loophole	Gross Alpha Loophole
25-100	Fatal Cancer	0.005	0.002	0.006	0.002
	Nonfatal Cancer	0.002	0.001	0.002	0.001
	Total Cancer	0.008	0.004	0.008	0.004
101-500	Fatal Cancer	0.023	0.010	0.025	0.010
	Nonfatal Cancer	0.010	0.006	0.010	0.006
	Total Cancer	0.033	0.017	0.035	0.016
501-1,000	Fatal Cancer	0.006	0	0.013	0.008
	Nonfatal Cancer	0.002	0	0.005	0.005
	Total Cancer	0.009	0	0.018	0.013
1,001-3,300	Fatal Cancer	0.019	0	0.040	0.025
	Nonfatal Cancer	0.008	0	0.016	0.015
	Total Cancer	0.026	0	0.056	0.040
3,301-10,000	Fatal Cancer	0.025	0	0.053	0.034
	Nonfatal Cancer	0.010	0	0.022	0.021
	Total Cancer	0.035	0	0.075	0.054
10,001-50,000	Fatal Cancer	0.048	0	0.102	0.065
	Nonfatal Cancer	0.020	0	0.042	0.039
	Total Cancer	0.067	0	0.144	0.104
50,001-100,000	Fatal Cancer	0.017	0	0.035	0.022
	Nonfatal Cancer	0.007	0	0.015	0.014
	Total Cancer	0.023	0	0.050	0.036
100,001-1,000,000	Fatal Cancer	0.028	0	0.059	0.038
	Nonfatal Cancer	0.011	0	0.025	0.023
	Total Cancer	0.039	0	0.084	0.061
All Systems	Fatal Cancer	0.170	0.013	0.334	0.204
	Nonfatal Cancer	0.070	0.007	0.138	0.124
	Total Cancer	0.240	0.020	0.471	0.329

Notes:
1. Numbers in table represent the direct effects of closing a particular loophole (e.g., the column pertaining to closure of the radium loophole refers to risk reductions from reduced Ra-226 and -228 only). Removal of other radionuclides present (i.e., gross alpha in the case of the radium loophole) results in additional incremental risk reductions, ranging from 0.02 cases to 0.07 cases nationally depending on the combination of regulatory options implemented.
2. Detail may not sum to total due to rounding.

Exhibit C-2

ANNUAL CANCER RISKS AVOIDED: ADJUSTING THE MCLs
(Community Ground Water Systems)

System Size Class	Cancer Type	Directly Proportional (statistical cases)		Lognormal Distribution (statistical cases)	
		Radium-228 at 3 pCi/L	**Gross Alpha at 10 pCi/L**	**Radium-228 at 3 pCi/L**	**Gross Alpha at 10 pCi/L**
25-100	Fatal Cancer	0.001	0.002	0.002	0.003
	Nonfatal Cancer	0.001	0.001	0.001	0.002
	Total Cancer	0.002	0.003	0.003	0.004
101-500	Fatal Cancer	0.006	0.009	0.008	0.011
	Nonfatal Cancer	0.002	0.006	0.003	0.007
	Total Cancer	0.008	0.015	0.012	0.019
501-1,000	Fatal Cancer	0.009	0.006	0.013	0.011
	Nonfatal Cancer	0.004	0.004	0.005	0.007
	Total Cancer	0.013	0.011	0.019	0.018
1,001-3,300	Fatal Cancer	0.029	0.020	0.041	0.033
	Nonfatal Cancer	0.012	0.013	0.017	0.021
	Total Cancer	0.041	0.033	0.058	0.055
3,301-10,000	Fatal Cancer	0.039	0.027	0.055	0.045
	Nonfatal Cancer	0.016	0.017	0.022	0.029
	Total Cancer	0.055	0.044	0.077	0.074
10,001-50,000	Fatal Cancer	0.074	0.051	0.105	0.086
	Nonfatal Cancer	0.030	0.033	0.043	0.055
	Total Cancer	0.105	0.084	0.148	0.140
50,001-100,000	Fatal Cancer	0.026	0.018	0.037	0.030
	Nonfatal Cancer	0.010	0.011	0.015	0.019
	Total Cancer	0.036	0.029	0.051	0.049
100,001-1,000,000	Fatal Cancer	0.043	0.030	0.061	0.050
	Nonfatal Cancer	0.018	0.019	0.025	0.032
	Total Cancer	0.061	0.049	0.086	0.082
All Systems	Fatal Cancer	0.228	0.163	0.323	0.268
	Nonfatal Cancer	0.093	0.105	0.131	0.172
	Total Cancer	0.321	0.267	0.453	0.440

Notes:
1. Numbers in table represent the direct effects of adjusting a particular MCL (i.e., the effect of changing the gross alpha MCL on risks from gross alpha only). Adjusting these MCLs results in additional incremental risk reductions, ranging from 0.18 cases to 0.26 cases annually, depending on the combination of regulatory options implemented.
2. Detail may not sum to total due to rounding.

Exhibit C-3

ANNUAL CANCER RISKS AVOIDED: LIMITING URANIUM TO 20 pCi/L and 20 μg/L (Community Water Systems)

System Size Class	Cancer Type	Directly Proportional (statistical cases)		Lognormal Distribution (statistical cases)	
		Ground Water	Surface Water	Ground Water	Surface Water
25-100	Fatal Cancer	0.010	0	0.015	0.000
	Nonfatal Cancer	0.005	0	0.008	0.000
	Total Cancer	0.015	0	0.023	0.000
101-500	Fatal Cancer	0.044	0	0.064	0.002
	Nonfatal Cancer	0.024	0	0.035	0.001
	Total Cancer	0.067	0	0.098	0.003
501-1,000	Fatal Cancer	0.002	0	0.041	0.002
	Nonfatal Cancer	0.001	0	0.022	0.001
	Total Cancer	0.003	0	0.064	0.003
1,001-3,300	Fatal Cancer	0.006	0	0.128	0.012
	Nonfatal Cancer	0.003	0	0.069	0.006
	Total Cancer	0.009	0	0.197	0.018
3,301-10,000	Fatal Cancer	0.008	0	0.172	0.027
	Nonfatal Cancer	0.004	0	0.093	0.014
	Total Cancer	0.012	0	0.265	0.041
10,001-50,000	Fatal Cancer	0.015	0	0.328	0.085
	Nonfatal Cancer	0.008	0	0.178	0.046
	Total Cancer	0.023	0	0.506	0.130
50,001-100,000	Fatal Cancer	0.005	0	0.114	0.045
	Nonfatal Cancer	0.003	0	0.062	0.024
	Total Cancer	0.008	0	0.176	0.069
100,001-1,000,000	Fatal Cancer	0.009	0	0.191	0.149
	Nonfatal Cancer	0.005	0	0.104	0.081
	Total Cancer	0.013	0	0.295	0.230
All Systems	Fatal Cancer	0.098	0	1.053	0.322
	Nonfatal Cancer	0.053	0	0.570	0.174
	Total Cancer	0.151	0	1.623	0.496

Note: Detail may not sum to total due to rounding.

Exhibit C-4

ANNUAL CANCER RISKS AVOIDED: LIMITING URANIUM TO 40 pCi/L and 40μg/L (Community Water Systems)

System Size Class	Cancer Type	Directly Proportional (statistical cases)		Lognormal Distribution (statistical cases)	
		Ground Water	Surface Water	Ground Water	Surface Water
25-100	Fatal Cancer	0.004	0	0.012	0.000
	Nonfatal Cancer	0.002	0	0.006	0.000
	Total Cancer	0.007	0	0.018	0.000
101-500	Fatal Cancer	0.019	0	0.052	0.002
	Nonfatal Cancer	0.010	0	0.028	0.001
	Total Cancer	0.029	0	0.080	0.002
501-1,000	Fatal Cancer	0	0	0.031	0.001
	Nonfatal Cancer	0	0	0.017	0.001
	Total Cancer	0	0	0.048	0.002
1,001-3,300	Fatal Cancer	0	0	0.096	0.008
	Nonfatal Cancer	0	0	0.052	0.004
	Total Cancer	0	0	0.148	0.012
3,301-10,000	Fatal Cancer	0	0	0.129	0.017
	Nonfatal Cancer	0	0	0.070	0.009
	Total Cancer	0	0	0.198	0.026
10,001-50,000	Fatal Cancer	0	0	0.246	0.055
	Nonfatal Cancer	0	0	0.133	0.030
	Total Cancer	0	0	0.379	0.084
50,001-100,000	Fatal Cancer	0	0	0.085	0.029
	Nonfatal Cancer	0	0	0.046	0.016
	Total Cancer	0	0	0.132	0.045
100,001-1,000,000	Fatal Cancer	0	0	0.143	0.096
	Nonfatal Cancer	0	0	0.078	0.052
	Total Cancer	0	0	0.221	0.148
All Systems	Fatal Cancer	0.023	0	0.793	0.208
	Nonfatal Cancer	0.013	0	0.430	0.112
	Total Cancer	0.036	0	1.223	0.320

Note: Detail may not sum to total due to rounding.

Exhibit C-5

ANNUAL CANCER RISKS AVOIDED: LIMITING URANIUM TO 80 pCi/L and 80 μg/L (Community Water Systems)

System Size Class	Cancer Type	Directly Proportional (statistical cases)		Lognormal Distribution (statistical cases)	
		Ground Water	**Surface Water**	**Ground Water**	**Surface Water**
25-100	Fatal Cancer	0.001	0	0.009	0.000
	Nonfatal Cancer	0.000	0	0.005	0.000
	Total Cancer	0.001	0	0.014	0.000
101-500	Fatal Cancer	0.003	0	0.039	0.001
	Nonfatal Cancer	0.001	0	0.021	0.001
	Total Cancer	0.004	0	0.059	0.002
501-1,000	Fatal Cancer	0	0	0.021	0.001
	Nonfatal Cancer	0	0	0.011	0.000
	Total Cancer	0	0	0.033	0.001
1,001-3,300	Fatal Cancer	0	0	0.065	0.004
	Nonfatal Cancer	0	0	0.035	0.002
	Total Cancer	0	0	0.101	0.007
3,301-10,000	Fatal Cancer	0	0	0.088	0.010
	Nonfatal Cancer	0	0	0.048	0.005
	Total Cancer	0	0	0.135	0.015
10,001-50,000	Fatal Cancer	0	0	0.167	0.032
	Nonfatal Cancer	0	0	0.091	0.017
	Total Cancer	0	0	0.258	0.049
50,001-100,000	Fatal Cancer	0	0	0.058	0.017
	Nonfatal Cancer	0	0	0.032	0.009
	Total Cancer	0	0	0.090	0.026
100,001-1,000,000	Fatal Cancer	0	0	0.098	0.056
	Nonfatal Cancer	0	0	0.053	0.031
	Total Cancer	0	0	0.150	0.087
All Systems	Fatal Cancer	0.003	0	0.545	0.122
	Nonfatal Cancer	0.002	0	0.295	0.066
	Total Cancer	0.005	0	0.840	0.188

Note: Detail may not sum to total due to rounding.

Appendix D

DECISION TREES FOR COMMUNITY WATER SYSTEMS

Appendix D

DECISION TREES FOR COMMUNITY WATER SYSTEMS

Appendix D presents the decision trees that are used in the cost model to estimate the probability that community water systems will undertake different types of compliance actions, provided by William Labiosa of EPA/OGWDW on November 22 and 23, 1999. Separate decision trees were developed for gross alpha and combined radium and for uranium, based on system size, and removal rate. Exhibit D-1 presents the decision tree for removal of gross alpha and combined radium in ground water systems; Exhibits D-2 and D-3 present the decision trees for removal of uranium in ground water and surface water systems, respectively. A description of how EPA used these decision trees in the cost analysis is provided in Chapter 4 of this report.

Exhibit D-1

DECISION TREE FOR COMBINED RADIUM AND GROSS ALPHA (Ground Water Systems)

Technology	**Water Softening/ Iron Removal (MAX)[1]**	**Enhanced Lime Softening (MAX)**	**Greensand Filtration (MAX)**	**Point-of-Use Reverse Osmosis**	**Point-of-Use Cation Exchange**	**Regionalization/ Blending/ Other**	**Alternative Source**	**Totals**
Decision Tree for Systems Requiring Max Removal								
Population Size Category								
1 (25-100)	56%	0%	0%	5%	5%	17%	17%	100%
2 (101-500)	56%	0%	0%	5%	5%	17%	17%	100%
3 (501-1,000)	66%	0%	0%	0%	0%	17%	17%	100%
4 (1,001-3,300)	66%	0%	0%	0%	0%	17%	17%	100%
5 (3,301-10,000)	66%	0%	0%	0%	0%	17%	17%	100%
6 (10,001-50,000)	66%	0%	0%	0%	0%	17%	17%	100%
7 (50,001-100,000)	66%	0%	0%	0%	0%	17%	17%	100%
8 (100,001- 1 million)	66%	0%	0%	0%	0%	17%	17%	100%
Decision Tree for Systems Requiring 80% Removal								
Technology	**WS/IR(80%)**	**ELS(80%)**	**GS(80%)**	**POU RO**	**POU CX**	**Regionalize/Blend**	**Alt. Source**	**Totals**
Population Size Category								
1 (25-100)	56%	0%	0%	5%	5%	17%	17%	100%
2 (101-500)	56%	0%	0%	5%	5%	17%	17%	100%
3 (501-1,000)	66%	0%	0%	0%	0%	17%	17%	100%
4 (1,001-3,300)	66%	0%	0%	0%	0%	17%	17%	100%
5 (3,301-10,000)	66%	0%	0%	0%	0%	17%	17%	100%
6 (10,001-50,000)	66%	0%	0%	0%	0%	17%	17%	100%
7 (50,001-100,000)	66%	0%	0%	0%	0%	17%	17%	100%
8 (100,001- 1 million)	66%	0%	0%	0%	0%	17%	17%	100%
Decision Tree for Systems Requiring 50% Removal								
Technology	**WS/IR(50%)**	**ELS(50%)**	**GS(50%)**	**POU RO**	**POU CX**	**Regionalize/Blend**	**Alt. Source**	**Totals**
Population Size Category								
1 (25-100)	46%	0%	10%	5%	5%	17%	17%	100%
2 (101-500)	46%	0%	10%	5%	5%	17%	17%	100%
3 (501-1,000)	46%	0%	10%	5%	5%	17%	17%	100%
4 (1,001-3,300)	46%	0%	10%	5%	5%	17%	17%	100%
5 (3,301-10,000)	66%	0%	0%	0%	0%	17%	17%	100%
6 (10,001-50,000)	66%	0%	0%	0%	0%	17%	17%	100%
7 (50,001-100,000)	66%	0%	0%	0%	0%	17%	17%	100%
8 (100,001- 1 million)	66%	0%	0%	0%	0%	17%	17%	100%
Decision Tree for Systems Requiring 30% Removal								
Technology	**WS/IR(30%)**	**ELS(30%)**	**GS(30%)**	**POU RO**	**POU CX**	**Regionalize/Blend**	**Alt Source**	**Totals**
Population Size Category								
1 (25-100)	46%	0%	10%	5%	5%	17%	17%	100%
2 (101-500)	46%	0%	10%	5%	5%	17%	17%	100%
3 (501-1,000)	36%	0%	20%	5%	5%	17%	17%	100%
4 (1,001-3,300)	36%	0%	20%	5%	5%	17%	17%	100%
5 (3,301-10,000)	66%	0%	0%	0%	0%	17%	17%	100%
6 (10,001-50,000)	66%	0%	0%	0%	0%	17%	17%	100%
7 (50,001-100,000)	66%	0%	0%	0%	0%	17%	17%	100%
8 (100,001- 1 million)	66%	0%	0%	0%	0%	17%	17%	100%

Notes:
[1] Water softening/iron removal includes treatment technologies such as ion exchange, oxidation/filtration, reverse osmosis, and lime softening.

Exhibit D-2

DECISION TREE FOR URANIUM (Ground Water Systems)

Decision Tree for Systems Requiring Max Removal								
Technology	**Water Softening/ Iron Removal (MAX)[1]**	**Activated Alumina (MAX)**	**Enhanced Coagulation/ Filtration (MAX)**	**Point-of-Use Reverse Osmosis**	**Point-of-Use Anion Exchange/ Activated Alumina**	**Regionalization/ Blending/ Other**	**Alternative Source**	**Totals**
Population Size Category								
1 (25-100)	56%	0%	0%	5%	5%	17%	17%	100%
2 (101-500)	56%	0%	0%	5%	5%	17%	17%	100%
3 (501-1,000)	66%	0%	0%	0%	0%	17%	17%	100%
4 (1,001-3,300)	66%	0%	0%	0%	0%	17%	17%	100%
5 (3,301-10,000)	66%	0%	0%	0%	0%	17%	17%	100%
6 (10,001-50,000)	66%	0%	0%	0%	0%	17%	17%	100%
7 (50,001-100,000)	66%	0%	0%	0%	0%	17%	17%	100%
8 (100,001- 1 million)	66%	0%	0%	0%	0%	17%	17%	100%
Decision Tree for Systems Requiring 80% Removal								
Technology	**WS/IR(80)**	**AA(80)**	**EC/F(80)**	**POU RO**	**POU AX/AA**	**Regionalize/Blend**	**Alt. Source**	**Totals**
Population Size Category								
1 (25-100)	56%	0%	0%	5%	5%	17%	17%	100%
2 (101-500)	56%	0%	0%	5%	5%	17%	17%	100%
3 (501-1,000)	66%	0%	0%	0%	0%	17%	17%	100%
4 (1,001-3,300)	66%	0%	0%	0%	0%	17%	17%	100%
5 (3,301-10,000)	66%	0%	0%	0%	0%	17%	17%	100%
6 (10,001-50,000)	66%	0%	0%	0%	0%	17%	17%	100%
7 (50,001-100,000)	66%	0%	0%	0%	0%	17%	17%	100%
8 (100,001- 1 million)	66%	0%	0%	0%	0%	17%	17%	100%
Decision Tree for Systems Requiring 50% Removal								
Technology	**WS/IR(50)**	**AA(50)**	**EC/F(50)**	**POU RO**	**POU AX/AA**	**Regionalize/Blend**	**Alt. Source**	**Totals**
Population Size Category								
1 (25-100)	56%	0%	0%	5%	5%	17%	17%	100%
2 (101-500)	56%	0%	0%	5%	5%	17%	17%	100%
3 (501-1,000)	66%	0%	0%	0%	0%	17%	17%	100%
4 (1,001-3,300)	66%	0%	0%	0%	0%	17%	17%	100%
5 (3,301-10,000)	66%	0%	0%	0%	0%	17%	17%	100%
6 (10,001-50,000)	66%	0%	0%	0%	0%	17%	17%	100%
7 (50,001-100,000)	66%	0%	0%	0%	0%	17%	17%	100%
8 (100,001- 1 million)	66%	0%	0%	0%	0%	17%	17%	100%
Decision Tree for Systems Requiring 30% Removal								
Technology	**WS/IR(30)**	**AA(30)**	**EC/F(30)**	**POU RO**	**POU AX/AA**	**Regionalize/Blend**	**Alt. Source**	**Totals**
Population Size Category								
1 (25-100)	56%	0%	0%	5%	5%	17%	17%	100%
2 (101-500)	56%	0%	0%	5%	5%	17%	17%	100%
3 (501-1,000)	66%	0%	0%	0%	0%	17%	17%	100%
4 (1,001-3,300)	66%	0%	0%	0%	0%	17%	17%	100%
5 (3,301-10,000)	66%	0%	0%	0%	0%	17%	17%	100%
6 (10,001-50,000)	66%	0%	0%	0%	0%	17%	17%	100%
7 (50,001-100,000)	66%	0%	0%	0%	0%	17%	17%	100%
8 (100,001- 1 million)	66%	0%	0%	0%	0%	17%	17%	100%

Notes:
[1] Water softening/iron removal includes treatment technologies such as ion exchange, oxidation/filtration, reverse osmosis, and lime softening.

Exhibit D-3

DECISION TREE FOR URANIUM (Surface Water Systems)

Decision Tree for Systems Requiring Max Removal								
Technology	**Water Softening/ Iron Removal (MAX)[1]**	**Activated Alumina (MAX)**	**Enhanced Coagulation/ Filtration (MAX)**	**Point-of-Use Reverse Osmosis**	**Point-of-Use Anion Exchange/ Activated Alumina**	**Regionalization/ Blending/ Other**	**Alternative Source**	**Totals**
Size Category								
1 (25-100)	51%	0%	5%	5%	5%	17%	17%	100%
2 (101-500)	51%	0%	5%	5%	5%	17%	17%	100%
3 (501-1,000)	16%	0%	50%	0%	0%	17%	17%	100%
4 (1,001-3,300)	10%	0%	56%	0%	0%	17%	17%	100%
5 (3,301-10,000)	10%	0%	56%	0%	0%	17%	17%	100%
6 (10,001-50,000)	0%	0%	66%	0%	0%	17%	17%	100%
7 (50,001-100,000)	0%	0%	66%	0%	0%	17%	17%	100%
8 (100,001- 1 million)	0%	0%	66%	0%	0%	17%	17%	100%
Decision Tree for Systems Requiring 80% Removal								
Technology	**WS/IR(80)**	**AA(80)**	**EC/F(80)**	**POU RO**	**POU AX/AA**	**Regionalize/Blend**	**Alt. Source**	**Totals**
Size Category								
1 (25-100)	51%	0%	5%	5%	5%	17%	17%	100%
2 (101-500)	51%	0%	5%	5%	5%	17%	17%	100%
3 (501-1,000)	16%	0%	50%	0%	0%	17%	17%	100%
4 (1,001-3,300)	10%	0%	56%	0%	0%	17%	17%	100%
5 (3,301-10,000)	10%	0%	56%	0%	0%	17%	17%	100%
6 (10,001-50,000)	0%	0%	66%	0%	0%	17%	17%	100%
7 (50,001-100,000)	0%	0%	66%	0%	0%	17%	17%	100%
8 (100,001- 1 million)	0%	0%	66%	0%	0%	17%	17%	100%
Decision Tree for Systems Requiring 50% Removal								
Technology	**WS/IR(50)**	**AA(50)**	**EC/F(50)**	**POU RO**	**POU AX/AA**	**Regionalize/Blend**	**Alt. Source**	**Totals**
Size Category								
1 (25-100)	51%	0%	5%	5%	5%	17%	17%	100%
2 (101-500)	51%	0%	5%	5%	5%	17%	17%	100%
3 (501-1,000)	16%	0%	50%	0%	0%	17%	17%	100%
4 (1,001-3,300)	10%	0%	56%	0%	0%	17%	17%	100%
5 (3,301-10,000)	10%	0%	56%	0%	0%	17%	17%	100%
6 (10,001-50,000)	0%	0%	66%	0%	0%	17%	17%	100%
7 (50,001-100,000)	0%	0%	66%	0%	0%	17%	17%	100%
8 (100,001- 1 million)	0%	0%	66%	0%	0%	17%	17%	100%
Decision Tree for Systems Requiring 30% Removal								
Technology	**WS/IR(30)**	**AA(30)**	**EC/F(30)**	**POU RO**	**POU AX/AA**	**Regionalize/Blend**	**Alt. Source**	**Totals**
Size Category								
1 (25-100)	51%	0%	5%	5%	5%	17%	17%	100%
2 (101-500)	51%	0%	5%	5%	5%	17%	17%	100%
3 (501-1,000)	16%	0%	50%	0%	0%	17%	17%	100%
4 (1,001-3,300)	10%	0%	56%	0%	0%	17%	17%	100%
5 (3,301-10,000)	10%	0%	56%	0%	0%	17%	17%	100%
6 (10,001-50,000)	0%	0%	66%	0%	0%	17%	17%	100%
7 (50,001-100,000)	0%	0%	66%	0%	0%	17%	17%	100%
8 (100,001- 1 million)	0%	0%	66%	0%	0%	17%	17%	100%

Notes:
[1] Water softening/iron removal includes treatment technologies such as ion exchange, oxidation/filtration, reverse osmosis, and lime softening.

Appendix E

DETAILED OCCURRENCE AND COST RESULTS FOR COMMUNITY WATER SYSTEMS

APPENDIX E

Appendix E presents the detailed occurrence and cost results for each system size category, which are summarized in Chapters 2 and 4 of this report. The appendix contains a separate table for each regulatory option. Each table indicates the total national annual operations and maintenance costs, annualized capital expenditures, annual monitoring costs, and total annual costs by system size category. The number of systems affected nationally by each regulatory option is also reported. In addition, the tables presenting the results for the uranium MCLs contain separate estimates for surface water and ground water systems. Each table presents the results obtained through both the direct proportion and lognormal distribution approaches.

Exhibit E-1 contains the estimates for closing the gross alpha monitoring loophole; Exhibit E-2 presents the estimates for closing the combined radium loophole; Exhibits E-3 and E-4 contain the estimates for changing the MCL for gross alpha and combined radium, respectively; and Exhibits E-5 through E-7 present the estimates for creating a new uranium MCL.

Exhibit E-1

NATIONAL COSTS DUE TO CLOSING MONITORING LOOPHOLE FOR GROSS ALPHA
(ground water systems only)

System Size Class	Directly Proportional					Lognormally Distributed				
	Number of Affected Systems	**Annual Capital Costs**	**Annual O&M Costs**	**Annual Monitoring Costs**	**Total Annual Costs**	**Number of Affected Systems**	**Annual Capital Costs**	**Annual O&M Costs**	**Annual Monitoring Costs**	**Total Annual Costs**
25-100	102	$ 115,817	$ 235,136	$ 299,850	$ 650,803	84	$ 96,593	$ 191,916	$ 295,072	$ 583,581
101-500	108	$ 327,806	$ 647,056	$ 342,500	$ 1,317,363	89	$ 277,667	$ 538,345	$ 337,044	$ 1,153,056
501-1,000	0	$ 0	$ 0	$ 117,165	$ 117,165	25	$ 404,049	$ 425,307	$ 125,374	$ 954,730
1,001-3,300	0	$ 0	$ 0	$ 171,699	$ 171,699	31	$ 1,080,659	$ 1,149,991	$ 183,729	$ 2,414,380
3,301-10,000	0	$ 0	$ 0	$ 101,934	$ 101,934	13	$ 1,559,203	$ 1,689,217	$ 109,075	$ 3,357,496
10,001-50,000	0	$ 0	$0	$ 90,538	$ 90,538	7	$ 3,986,067	$ 6,129,901	$ 96,881	$ 10,212,849
50,001-100,000	0	$ 0	$ 0	$ 22,217	$ 22,217	1	$ 2,336,806	$ 3,855,565	$ 23,774	$ 6,216,145
100,001-1,000,000	0	$ 0	$ 0	$ 11,229	$11,229	0*	$ 3,981,627	$ 5,627,407	$ 12,016	$ 9,621,050
TOTAL	211	$ 443,624	$ 882,192	$ 1,157,132	$2,482,948	250	$ 13,722,671	$ 19,607,649	$ 1,182,966	$ 34,513,286

* Model predicts an expected value of less than 0.5 systems affected nationally.
Notes:
1) Results are not adjusted for double-counting of systems out-of-compliance for both the combined radium and gross alpha loopholes.
2) Detail may not add to total due to rounding.

Exhibit E-2

NATIONAL COSTS DUE TO CLOSING MONITORING LOOPHOLE FOR COMBINED RADIUM
(ground water systems only)

System Size Class	Directly Proportional					Lognormally Distributed				
	Number of Affected Systems	Annual Capital Costs	Annual O&M Costs	Annual Monitoring Costs	Total Annual Costs	Number of Affected Systems	Annual Capital Costs	Annual O&M Costs	Annual Monitoring Costs	Total Annual Costs
25-100	103	$ 119,132	$ 232,254	$ 42,892	$ 394,278	118	$ 136,874	$ 269,135	$ 42,892	$ 448,900
101-500	109	$ 346,890	$ 664,221	$ 48,993	$ 1,060,104	125	$ 478,305	$ 817,129	$ 48,993	$ 1,344,426
501-1,000	20	$ 279,049	$ 283,106	$ 16,945	$ 579,100	24	$ 450,407	$ 489,490	$ 16,945	$ 956,842
1,001-3,300	24	$ 744,502	$ 755,544	$ 24,832	$ 1,524,878	30	$ 1,207,169	$ 1,338,526	$ 24,832	$ 2,570,527
3,301-10,000	11	$ 1,107,357	$ 1,116,554	$ 14,742	$ 2,238,653	13	$ 1,692,693	$ 1,953,577	$ 14,742	$ 3,661,011
10,001-50,000	5	$ 2,310,303	$ 3,249,553	$ 13,094	$ 5,572,951	7	$ 4,297,618	$ 6,931,454	$ 13,094	$ 11,242,165
50,001-100,000	1	$ 1,625,459	$ 2,516,964	$ 3,213	$ 4,145,636	1	$ 2,585,268	$ 4,498,729	$ 3,213	$ 7,087,211
100,001-1,000,000	0*	$ 2,511,998	$ 3,558,135	$ 1,624	$ 6,071,757	0*	$ 4,770,023	$ 6,726,667	$ 1,624	$ 11,498,313
TOTAL	272	$ 9,044,692	$ 12,376,331	$ 166,333	$ 21,587,356	317	$ 15,618,356	$ 23,024,706	$ 166,333	$ 38,809,396

* Model predicts an expected value of less than 0.5 systems affected nationally.
Notes:
1) Results are not adjusted for double-counting of systems out-of-compliance for both the combined radium and gross alpha loopholes.
2) Detail may not add to total due to rounding.

Exhibit E-3

NATIONAL COSTS DUE TO CHANGING THE GROSS ALPHA MCL
(ground water systems only)

System Size Class	Directly Proportional					Lognormally Distributed				
	Number of Affected Systems	**Annual Capital Costs**	**Annual O&M Costs**	**Annual Monitoring Costs**	**Total Annual Costs**	**Number of Affected Systems**	**Annual Capital Costs**	**Annual O&M Costs**	**Annual Monitoring Costs**	**Total Annual Costs**
25-100	205	$ 214,527	$ 460,811	$ 0	$ 675,338	161	$ 184,181	$ 366,908	$ 0	$ 551,089
101-500	217	$ 579,097	$ 1,243,043	$ 0	$ 1,822,139	170	$ 529,000	$ 1,028,114	$ 0	$ 1,557,114
501-1,000	60	$ 837,796	$ 849,979	$ 0	$ 1,687,775	56	$ 900,246	$ 947,348	$ 0	$ 1,847,594
1,001-3,300	73	$ 2,235,242	$ 2,268,394	$ 0	$ 4,503,636	68	$ 2,408,113	$ 2,561,929	$ 0	$ 4,970,042
3,301-10,000	32	$ 3,324,653	$ 3,352,263	$ 0	$ 6,676,916	30	$ 3,474,534	$ 3,764,390	$ 0	$ 7,238,924
10,001-50,000	16	$ 6,936,296	$ 9,756,235	$ 0	$ 16,692,531	15	$ 8,018,156	$ 12,216,672	$ 0	$ 20,234,828
50,001-100,000	2	$ 4,880,167	$ 7,556,758	$ 0	$ 12,436,925	2	$ 5,207,852	$ 8,594,268	$ 0	$ 13,802,120
100,001-1,000,000	1	$ 7,541,850	$ 10,682,700	$ 0	$ 18,224,550	1	$ 8,877,316	$ 12,546,866	$ 0	$ 21,424,181
TOTAL	606	$ 26,549,628	$ 36,170,183	$ 0	$ 62,719,810	502	$ 29,599,399	$ 42,026,495	$ 0	$ 71,625,893

Notes:
1) Results are based on full compliance with existing MCLs, after closure of the monitoring loopholes.
2) Results are not adjusted for double-counting of systems out-of-compliance with both the revised gross alpha and combined radium MCLs.
3) Detail may not add to total due to rounding.

Exhibit E-4

NATIONAL COSTS DUE TO CHANGING THE COMBINED RADIUM MCL
(ground water systems only)

System Size Class	Directly Proportional					Lognormally Distributed				
	Number of Affected Systems	Annual Capital Costs	Annual O&M Costs	Annual Monitoring Costs	Total Annual Costs	Number of Affected Systems	Annual Capital Costs	Annual O&M Costs	Annual Monitoring Costs	Total Annual Costs
25-100	41	$ 47,475	$ 94,705	$ 0	$ 142,180	61	$ 68,135	$ 138,785	$ 0	$ 206,920
101-500	43	$ 136,394	$ 262,389	$ 0	$ 398,783	65	$ 192,164	$ 384,233	$ 0	$ 576,397
501-1,000	40	$ 558,004	$ 566,117	$ 0	$ 1,124,121	28	$ 465,872	$ 494,913	$ 0	$ 960,785
1,001-3,300	49	$ 1,488,937	$ 1,511,032	$ 0	$ 2,999,969	34	$ 1,246,438	$ 1,342,505	$ 0	$ 2,588,942
3,301-10,000	21	$ 2,214,668	$ 2,233,126	$ 0	$ 4,447,794	15	$ 1,784,865	$ 1,963,659	$ 0	$ 3,748,524
10,001-50,000	11	$ 4,620,627	$ 6,499,124	$ 0	$ 11,119,750	8	$ 4,468,397	$ 6,925,236	$ 0	$ 11,393,633
50,001-100,000	1	$ 3,250,912	$ 5,033,911	$ 0	$ 8,284,823	1	$ 2,685,497	$ 4,481,476	$ 0	$ 7,166,973
100,001-1,000,000	1	$ 5,023,993	$ 7,116,265	$ 0	$ 12,140,258	0*	$ 4,653,286	$ 6,568,791	$ 0	$ 11,222,077
TOTAL	207	$ 17,341,009	$ 23,316,669	$ 0	$ 40,657,678	212	$ 15,564,653	$ 22,299,598	$ 0	$ 37,864,251

* Model predicts an expected value of less than 0.5 systems affected nationally.
Notes:
1) Results are based on full compliance with existing MCLs, after closure of the monitoring loopholes.
2) Results are not adjusted for double-counting of systems out-of-compliance with both the revised gross alpha and combined radium MCLs.
3) Detail may not add to total due to rounding.

Exhibit E-5

NATIONAL COSTS DUE TO ESTABLISHING URANIUM MCL AT 20 pCi/L

System Size Class	Directly Proportional					Lognormally Distributed				
	Number of Affected Systems	Annual Capital Costs	Annual O&M Costs	Annual Monitoring Costs	Total Annual Costs	Number of Affected Systems	Annual Capital Costs	Annual O&M Costs	Annual Monitoring Costs	Total Annual Costs
Ground Water Systems										
25-100	369	$ 511,761	$ 787,528	$ 793,578	$ 2,092,866	324	$ 457,562	$ 696,933	$ 770,307	$ 1,924,803
101-500	391	$ 1,588,823	$ 2,535,141	$ 906,457	$ 5,030,420	342	$ 1,441,744	$ 2,265,563	$ 879,877	$ 4,587,183
501-1,000	20	$ 372,326	$ 407,045	$ 269,974	$ 1,049,345	83	$ 1,948,004	$ 2,555,766	$ 310,710	$ 4,814,480
1,001-3,300	24	$ 960,535	$ 1,056,488	$ 395,632	$ 2,412,655	101	$ 5,175,360	$ 6,901,236	$ 455,328	$ 12,531,924
3,301-10,000	11	$ 1,107,558	$ 1,116,245	$ 234,877	$ 2,458,679	44	$ 6,294,165	$ 8,329,306	$ 270,317	$ 14,893,788
10,001-50,000	5	$ 2,311,986	$ 3,250,932	$ 208,618	$ 5,771,537	23	$ 12,927,409	$ 21,552,612	$ 240,097	$ 34,720,118
50,001-100,000	1	$ 1,624,413	$ 2,513,659	$ 51,194	$ 4,189,266	2	$ 9,785,965	$ 18,195,916	$ 58,918	$ 28,040,799
100,001-1,000,000	0*	$ 2,568,428	$ 3,638,107	$ 25,874	$ 6,232,409	1	$ 19,195,466	$ 27,214,162	$ 29,779	$ 46,439,407
TOTAL	821	$ 11,045,830	$ 15,305,144	$2,886,203	$ 29,237,178	921	$ 57,225,675	$ 87,711,493	$ 3,015,334	$ 147,952,502
Surface Water Systems										
25-100	1	$ 1,522	$ 3,426	$ 587,313	$ 592,261	6	$ 6,839	$ 14,676	$ 621,781	$ 643,296
101-500	3	$ 9,025	$ 18,524	$ 670,853	$ 698,402	12	$ 42,040	$ 81,976	$ 710,224	$ 834,240
501-1,000	0	$ 0	$ 0	$ 244,649	$ 244,649	5	$ 23,998	$ 61,513	$ 257,555	$ 343,066
1,001-3,300	0	$ 0	$ 0	$ 358,519	$ 358,519	10	$ 70,210	$ 204,155	$ 377,432	$ 651,797
3,301-10,000	0	$ 0	$ 0	$ 212,844	$ 212,844	8	$ 167,300	$ 418,145	$ 224,072	$ 809,517
10,001-50,000	0	$ 0	$ 0	$ 189,048	$ 189,048	7	$ 272,317	$ 931,440	$ 199,021	$ 1,402,778
50,001-100,000	0	$ 0	$ 0	$ 46,392	$ 46,392	1	$ 198,281	$ 767,609	$ 48,839	$ 1,014,729
100,001-1,000,000	0	$ 0	$ 0	$ 23,447	$ 23,447	1	$ 746,476	$ 2,604,819	$ 24,684	$ 3,375,979
TOTAL	4	$ 10,547	$ 21,950	$ 2,333,064	$ 2,365,561	50	$ 1,527,461	$ 5,084,334	$ 2,463,608	$ 9,075,403

* Model predicts an expected value of less than 0.5 systems affected nationally.
Notes:
1) Detail may not add to total due to rounding.

Exhibit E-6

NATIONAL COSTS DUE TO ESTABLISHING URANIUM MCL AT 40 pCi/L

System Size Class	Directly Proportional					Lognormally Distributed				
	Number of Affected Systems	Annual Capital Costs	Annual O&M Costs	Annual Monitoring Costs	Total Annual Costs	Number of Affected Systems	Annual Capital Costs	Annual O&M Costs	Annual Monitoring Costs	Total Annual Costs
Ground Water Systems										
25-100	144	$ 169,806	$ 284,584	$ 678,582	$ 1,132,971	146	$203,541	$ 312,671	$ 679,981	$ 1,196,193
101-500	152	$ 472,833	$ 859,822	$ 775,104	$ 2,107,759	155	$ 634,899	$ 1,009,588	$ 776,703	$ 2,421,190
501-1,000	0	$ 0	$ 0	$ 256,894	$ 256,894	35	$ 803,819	$ 1,022,947	$ 279,375	$ 2,106,140
1,001-3,300	0	$ 0	$ 0	$ 376,463	$ 376,463	42	$ 2,129,518	$ 2,759,639	$ 409,408	$ 5,298,565
3,301-10,000	0	$ 0	$ 0	$ 223,497	$ 223,497	19	$ 2,582,371	$ 3,328,392	$ 243,056	$ 6,153,819
10,001-50,000	0	$ 0	$ 0	$ 198,511	$ 198,511	10	$ 5,995,989	$ 10,091,830	$ 215,883	$ 16,303,702
50,001-100,000	0	$ 0	$ 0	$ 48,713	$ 48,713	1	$ 4,003,003	$ 7,341,777	$ 52,977	$ 11,397,757
100,001-1,000,000	0	$ 0	$ 0	$ 24,621	$ 24,621	1	$ 7,586,253	$ 10,767,174	$ 26,775	$ 18,380,202
TOTAL	296	$ 642,639	$ 1,144,406	$ 2,582,384	$ 4,369,429	408	$ 23,939,393	$ 36,634,017	$ 2,684,158	$ 63,257,568
Surface Water Systems										
25-100	0	$ 0	$ 0	$ 576,529	$ 576,529	2	$ 2,638	$ 5,732	$ 594,109	$ 602,480
101-500	0	$ 0	$ 0	$ 658,535	$ 658,535	5	$ 16,056	$ 31,741	$ 678,616	$ 726,413
501-1,000	0	$ 0	$ 0	$ 244,484	$ 244,484	2	$ 8,489	$ 22,023	$ 249,094	$ 279,606
1,001-3,300	0	$ 0	$ 0	$ 358,277	$ 358,277	4	$ 24,909	$ 73,383	$ 365,034	$ 463,325
3,301-10,000	0	$ 0	$ 0	$ 212,700	$ 212,700	3	$ 59,256	$ 150,221	$ 216,712	$ 426,189
10,001-50,000	0	$ 0	$ 0	$ 188,921	$ 188,921	2	$ 98,922	$ 338,246	$ 192,484	$ 629,651
50,001-100,000	0	$ 0	$ 0	$ 46,360	$ 46,360	0*	$ 71,001	$ 274,223	$ 47,235	$ 392,459
100,001-1,000,000	0	$ 0	$ 0	$ 23,431	$ 23,431	0*	$ 268,808	$ 930,555	$ 23,873	$ 1,223,236
TOTAL	0	$ 0	$ 0	$ 2,309,238	$ 2,309,238	19	$ 550,078	$ 1,826,124	$ 2,367,156	$ 4,743,358

* Model predicts an expected value of less than 0.5 systems affected nationally.
Notes:
1) Detail may not add to total due to rounding.

Exhibit E-7

NATIONAL COSTS DUE TO ESTABLISHING URANIUM MCL AT 80 pCi/L

System Size Class	Directly Proportional					Lognormally Distributed				
	Number of Affected Systems	Annual Capital Costs	Annual O&M Costs	Annual Monitoring Costs	Total Annual Costs	Number of Affected Systems	Annual Capital Costs	Annual O&M Costs	Annual Monitoring Costs	Total Annual Costs
Ground Water Systems										
25-100	21	$ 21,458	$ 38,563	$ 615,566	$ 675,587	60	$ 82,691	$ 128,132	$ 635,903	$ 846,726
101-500	22	$ 53,832	$ 110,907	$ 703,125	$ 867,863	64	$ 255,116	$ 410,792	$ 726,355	$ 1,392,262
501-1,000	0	$ 0	$ 0	$ 256,690	$ 256,690	13	$ 300,169	$ 372,414	$ 265,214	$ 937,796
1,001-3,300	0	$ 0	$ 0	$ 376,165	$ 376,165	16	$ 794,139	$ 1,004,150	$ 388,656	$ 2,186,945
3,301-10,000	0	$ 0	$ 0	$ 223,320	$ 223,320	7	$ 959,737	$ 1,208,058	$ 230,736	$ 2,398,530
10,001-50,000	0	$ 0	$ 0	$ 198,353	$ 198,353	4	$ 2,877,849	$ 4,985,354	$ 204,940	$ 8,068,142
50,001-100,000	0	$ 0	$ 0	$ 48,675	$ 48,675	0*	$ 1,481,967	$ 2,683,114	$ 50,291	$ 4,215,372
100,001-1,000,000	0	$ 0	$ 0	$ 24,601	$ 24,601	0*	$ 2,785,321	$ 3,944,950	$ 25,418	$ 6,755,689
TOTAL	42	$ 75,290	$ 149,470	$ 2,446,495	$ 2,671,254	165	$ 9,536,987	$ 14,736,962	$ 2,527,514	$ 26,801,462
Surface Water Systems										
25-100	0	$ 0	$ 0	$ 576,289	$ 576,289	1	$ 885	$ 1,994	$ 582,564	$ 585,443
101-500	0	$ 0	$ 0	$ 658,261	$ 658,261	2	$ 5,617	$ 11,224	$ 665,429	$ 682,269
501-1,000	0	$ 0	$ 0	$ 244,391	$ 244,391	1	$ 2,749	$ 7,195	$ 245,877	$ 255,821
1,001-3,300	0	$ 0	$ 0	$ 358,141	$ 358,141	1	$ 8,141	$ 24,182	$ 360,319	$ 392,642
3,301-10,000	0	$ 0	$ 0	$ 212,620	$ 212,620	1	$ 19,185	$ 49,095	$ 213,913	$ 282,193
10,001-50,000	0	$ 0	$ 0	$ 188,849	$ 188,849	1	$ 33,203	$ 113,335	$ 189,998	$ 336,535
50,001-100,000	0	$ 0	$ 0	$ 46,343	$ 46,343	0*	$ 23,049	$ 89,160	$ 46,624	$ 158,834
100,001-1,000,000	0	$ 0	$ 0	$ 23,423	$ 23,423	0*	$ 90,610	$ 315,702	$ 23,565	$ 429,877
TOTAL	0	$ 0	$ 0	$ 2,308,316	$ 2,308,316	6	$ 183,439	$ 611,888	$ 2,328,288	$ 3,123,615

* Model predicts an expected value of less than 0.5 systems affected nationally.

Notes:

1) Detail may not add to total due to rounding.

Appendix F

TRENDS IN COSTS AND RISK REDUCTIONS ASSOCIATED WITH ADDITIONAL RADIUM OPTIONS

Appendix F

TRENDS IN COSTS AND RISK REDUCTIONS ASSOCIATED WITH ADDITIONAL RADIUM OPTIONS

In the text of this report, we report the results of the analysis for a single MCL option for combined radium: limiting the contribution of radium-228 to 3 pCi/L within the total MCL of 5 pCi/L. Earlier analyses (conducted in June 1999) considered other options that placed more stringent limits on the contribution of radium-228, including limits of 1 pCi/L, 2 pCi/L, and 2.5 pCi/L, in addition to 3 pCi/L. In this Appendix, we present the results of those initial analyses and discuss the implications of the overall trend in the results. Note that these results are based on outdated assumptions and earlier versions of the cost and risk models, and hence should be approached with caution.

The results of these analyses show that as the limit on the contribution of radium-228 decreases from 3 pCi/L to 1 pCi/L, the compliance costs for community water systems increase more substantially than the value of avoided the cancer cases. The net benefits for all of the options are negative, with costs that exceed benefits in all cases.

These estimates are presented to provide insights into the pattern of the incremental changes across regulatory options. We have since made several major changes to the analytic approach to improve the accuracy of the resulting estimates. Therefore, the estimates in this Appendix for the MCL option limiting radium-228 to 3 pCi/L do not match the estimates presented in Chapters 2, 3, and 4 of this report.

Exhibit F-1 summarizes the costs and benefits of each option for community water systems. The annual value of avoided cancer cases and national compliance costs are presented graphically in Exhibit F-2 to highlight the overall trend in the results.

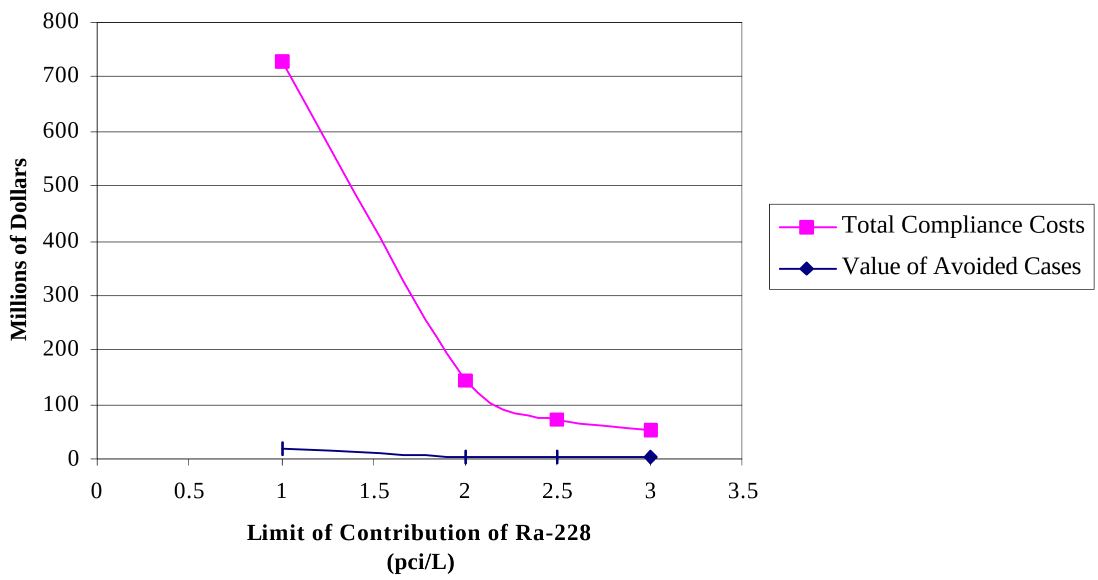
Exhibit F-1
PRELIMINARY ESTIMATES OF
ANNUAL COSTS AND RISK REDUCTIONS ASSOCIATED WITH COMBINED RADIUM MCL OPTIONS[1]

Options	Number of Systems Exceeding MCL	Total Cancer Cases Avoided (fatal cases)	Value of Avoided Cases (range)[2]	Total Compliance Costs	Net Benefits[3]	Cost per Case Avoided (fatal and nonfatal)
Radium-228 at 1 pCi/L	3,893 systems	4.57 cases total (3.26 fatal)	$19.0 million ($4.7 - $36.7 million)	$726.4 million	-$707.4 million	$158.9 million per case
Radium-228 at 2 pCi/L	581 systems	1.27 cases total (0.90 fatal)	$5.3 million ($1.3 - $10.1 million)	$142.2 million	- $136.9 million	$112.0 million per case
Radium-228 at 2.5 pCi/L	280 systems	0.56 cases total (0.40 fatal)	$2.3 million ($0.6 - $4.5 million)	$ 71.0 million	- $68.7 million	$126.8 million per case
Radium-228 at 3 pCi/L	199 systems	0.56 cases total (0.39 fatal)	$2.3 million ($0.6 - $4.4 million)	$52.7 million	- $48.1 million	$94.1 million per case

IMPORTANT CAVEAT:
These results reflect the data and assumptions used in a preliminary (June 1999) analysis. Significant changes have been made since that time which affect the absolute value of the estimates of costs and risks. These changes may have less of an effect, however, on the general relationship observed between costs and risk reductions across regulatory options.

Notes:
1. Costs and risk reductions are compared to a full compliance baseline (i.e., occurrence data are adjusted to eliminate illegal and legal noncompliance).
2. Best estimate (in 1997 dollars) is $5.8 million per fatal case and $ 0.099 million per nonfatal case; range is $1.4 million - $11.2 million per fatal case and $0.088 - $0.110 million per nonfatal case. Value for fatalities based on estimates of value of statistical life; value for nonfatal cases is estimate of average medical costs of illness.
3. Net benefits (best estimate of value of avoided cases minus compliance costs) are negative in all cases; i.e., costs exceed benefits.

Exhibit F-2
ANNUAL COSTS AND RISK REDUCTIONS ASSOCIATED WITH EACH COMBINED RADIUM MCL OPTION



Note:
1. See discussion regarding limitations in the analysis on previous pages.